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Agricultural Suppression: Lysenkoism versus Pesticides

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There is a difficult problem in studying suppression. On one hand, examples chosen for review need to be sufficiently historical. There must be some passage of time to allow the reviewer perspective so that certain questions can be answered: In what ways was the flow of information biased? Was the information biased accidentally, i.e., misinformation? Was the information biased deliberately, i.e., disinformation? Who were the major actors in producing and controlling the flow of information? What were the issues for disagreement? What were the motives of the different vested interests? And, in particular, what damage was done as a result of suppression?

On the other hand, if the study of suppression is to be most useful, it must be able to deal, not just with past problems (with the enormous advantage of hindsight), but with present problems. The analysis should suggest means for effective action to keep the flow of information honest and accurate, to ensure that all affected parties play appropriate roles in the decision process.

We have chosen two different case history collections. The first case history is the rise and fall of Lysenko. This episode is completely finished. There is reasonable agreement about many of the details and the damage. Nevertheless, the case history itself has been subjected to serious Western bias as a result of differences in political ideology. Nearly all Western writing on Lysenko stresses the differences between capitalist and socialist science. Here we show the many similarities. This case history is especially valuable in revealing suppression at a higher level of anaylysis, literally, 'the suppression of suppression'.

The second case history collection concerns the chemicalisation of agriculture. Here we have a more complex situation, of both valuable improvements and serious side-effects. Here too we have the problems of dealing with a current controversy. Fortunately, sufficient time has elapsed from the earlier warnings by dissident scientists, warnings from the 1960s, to be able to evaluate some of the dissenters' warnings. Sufficient time has also elapsed to allow some estimate of the amount of damage done by suppression.

The best known example of the adverse consequences of suppression of agricultural information is the Lysenko period in the U.S.S.R. Lysenko's rise to power began in the late 1930s. Total dominance was achieved by 1948 when Lysenko delivered his address *On the Situation in Biology* to the Lenin All-Union Academy of Agricultural Science—Lysenko's address having been personally annotated by Stalin. From 1948 to 1965 Lysenko reigned supreme—although contrary to the Western propagandistic picture there were some important dissenting challenges[1]—Lysenko's fall from power occurred when the damage was too obvious to hide or to excuse : the collapse of the virgin lands scheme, a massive agricultural debacle which also contributed to the decline and fall of Nikita Khrushchev and a change in the Soviet government.

There is an enormous literature on the Lysenko affair. Our own files include over two hundred references. Yet, we have been unable to find a satisfactory review which integrates all the important elements behind this affair and does it without ideological bias. Western writing about the Lysenko period is so suffused with smug satisfaction about the failures of Soviet communism as to be almost useless. The few Western Marxist writers either evade the topic completely or demonstrate their ignorance of both agriculture and the sociology of science. These writers fail to see the similarities between Lysenko and a number of Western elite scientists who have crept into positions of power. The two most useful references to the Lysenko period are the books by Zhores Medvedev[1] and David Joravsky[2]

The following points are made quickly in summarising the rise and fall of Trofim Denisovich Lysenko. We place relatively more emphasis on those aspects of the affair which have been given insufficient attention by Western writers.

Lysenko was more skilled in 'public relations' than in plant breeding of genetics. Even some of his critics acknowledged his ability to go to the farms and talk with (not talk down to) the peasants. At that time many Soviet scientists considered themselves part of the Soviet elite and rather above such egalitarian behaviour.

The U.S.S.R. has one of the most variable climates in the world. Before (and after) Lysenko it was typical for one harvest in three to be poor, or even a complete failure if the cold persisted too long. Famine was a regular occurrence before the 1918 Revolution. Famine occurred again with the liquidation of the kulaks during Stalin's regime, as well as with the catastrophic damage done by the German invasion during World War II. Accordingly, almost any charismatic figure who promised a solution that was in conformity to some extent with socialist practice stood a good chance of obtaining powerful political support. In that respect Lysenko was no different from any Western scientific 'operators' who have demonstrated their skill at wheedling large sums of money for research. Like Edward Teller (father of the hydrogen bomb and a leader in the lobbying for 'star wars'), Lysenko went right to the top, receiving the backing of first Stalin and then Khrushchev.

Lysenko also had another advantage. He was a Ukrainian, a representative of one of the largest persecuted minorities in the U.S.S.R. Thus, Lysenko had a special value for Stalin, to show thas the Supreme Soviet was not prejudiced against Ukrainians.

The common Western explanation for the rise of Lysenko is that his emphasis on the inheritance of acquired characters provided a scientific (or pseudoscientific) justification for the Marxist philosophical emphasis on the social perfectability of humans. It is, however, difficult to find evidence for this facile interpretation.

One should be fair in judging Lysenko. During the period of his rise, the inheritance of acquired characters was at least a minor paradigm among some Western plant breeders, e.g., Luther Burbank. Furthermore, besides the large amount of evidence for nuclear inheritance (which Lysenko ignored, targetting those who accepted such evidence as Mendelists and Morganists), there was also considerable evidence for cytoplasmic inheritance, especially in plants. Thus, the inheritance of a number of plant characteristics did not conform to the simple Mendelian ratios. Many Western scientists went too far the other way, denying the legitimacy of cytoplasmic inheritance until in the 1960s, when it became possible to characterise the DNA of chloroplasts and mitochondria. Oversimplified extremism in science is by no means restricted only to Lysenko and his followers.

Lysenko's well-known polemic antipathy to nuclear inheritance was matched by a less well-known dislike of statistics.[1] Lysenko and his followers were unwilling to submit their claims to true scientific testing. Claims for increased yields were not subjectcd to biometrical analysis. From just sloppiness in the collection and treatment of agricultural data, some of Lysenko's followers progressed to the practice of some quite outrageous frauds, such as those detailed by Zhores Medvedev.[1]

Here again, however, Lysenko and followers are not unique. Antipathy to statistical analysis of data is still fairly common among Western biologists. It is not difficult to find examples of eminent Western biologists making strong claims on the basis of data which are not analysed statistically—and which, when the data are statistically tested by someone else, the claims are refuted; this is all part of the phenomenon of *disciplinary dogmatism.*[3] Many Western scientists of some stature feel that they can make *ex cathedra* pronouncements, as part of *the cult of the expert*, without subjecting those claims to rigorous testing—and, what is worse, some of these scientists resent it strongly when someone else does the tests and disputes their claims.

Although Joravsky's[2] book on the Lysenko affair is one of the most widely cited Western references concerning this topic, we have never seen any of the citers refer to one of Joravsky's major observations : The Stalinist purges were not directed solely at the supporters of orthodox genetics *but* *included a number of Lysenko's supporters.* A major factor predisposing a researcher to being purged was association with foreign colleagues, especially British or American ones. Xenophobia was exacerbated by the 'Cold War' tensions and even before that period, the memories of British and American attempts to subvert the Russian Revolution.

A number of Soviet scientists publicly criticised Lysenko without suffering suppression or repression : this is "Prianishnikov Effect"[2] named for an eminent plant physiologist who repeatedly opposed Lysenko and kept his job as head of a major research institute. As Joravsky[2] points out, it was often the equivocators who aroused suspicion that were purged, not the outright open opponents. The case of Maria Yudina, a musician who publicly challenged Stalin and wrote a letter which colleagues called "suicidal", and whose career continued to prosper, also suggests that, at least at times, clear dissent was safer than equivocation.[4]

Why then didn't more Soviet scientists attempt to defend scientific standards in general and the science of genetics in particular ? Medvedev[1] gives a number of examples of where famous scientists toadied to Lysenko, especially after his election to academician status. Here too, however, we have a failing which is far from being restricted to Soviet science. Although there are occasional personal feuds, elite scientists are often very reluctant to criticise their peers. An interesting case is provided by William Broad and Nicholas Wade[5] in their book on fraudulent behaviour by Western scientists : W.D. McElroy was already a powerful figure in American science when he was exposed as having plagiarised a large portion of a less well-known colleague's review article on bioluminescence ; yet, McElroy's dominance was not dented and he continued as a major figure in the U.S. National Academy of Sciences and Director of the National Science Foundation. Sir Cyril Burt's career of fraudulence was not openly challenged by his eminent British colleagues—although he was not elected to the Royal Society.[6] The Burt example is particularly relevant to the Lysenko affair for two other reasons: Burt's scientific position on the 'nature-nurture' question was exactly the opposite of Lysenko ; Burt believed almost completely in the use of simple Mendelian patterns of genetics to explain complex behavioural phenomena, such as human intelligence and criminality; Lysenko believed largely in environmental determinism, taken to the extreme of the inheritance of acquired characters. Just as Lysenko's antipathy to genetics and statistics damaged Soviet agriculture and biological science, Sir Cyril Burt's fraudulence has had significant social effects on the British educational system.[6]

A key matter which has not been sufficiently explored by either Soviet or Western writers on the Lysenko affair is the interaction between Lysenko and N.I. Vavilov.

Vavilov is the Western writer's favourite example of the good Russian scientist who opposed Lysenko and thus died in a Siberian concentration camp. These facts are correct, but only part of a more complex situation.

Lysenko's rise was greatly facilitated by becoming Vavilov's protege. For several years Vavilov supported Lysenko—although Vavilov was generally regarded as a good enough scientist to see through the errors promulgated by Lysenko. (Vavilov is generally credited with formulating the concepts of centres of domestication and centres of diversification for crop plants. His research on plant breeding involved considerable study outside the U.S.S.R. and Vavilov had friendly relations with a number of eminent British scientists.)

Vavilov was an autocratic figure, and he cunningly operated to rise rapidly in the Soviet hierarchy, becoming the boss of over one hundred separate research laboratories. When Vavilov finally began to criticise Lysenko, it was too late. Vavilov was charged and convicted of spying for the British. Lysenko, ever the opportunist, took over Vavilov's position and soon became surrounded with the inevitable sycophants.

Ironically, it was the failure of the Russian Revolution to reform the intense hierarchical system of the universities and the research institutes that made it possible for Lysenko to take over. Soviet genetics had to hibernate for nearly twenty years. Before Lysenko the U.S.S.R. had risen to an enviable position in terms of the status of its research in genetics. After Lysenko's takeover some excellent genetic research continued in the U.S.S.R., but it was largely hidden in research institutes which did not include genetics in their title.[1] Within a year of the fall of Lysenko, the U.S.S.R. had three new genetics journals with many papers of a high standard.[7] Nevertheless, the damage was considerable, especially for agricultural science and its applications.

The Rise and Decline of Pesticides

The era of the heavy use of pesticides (including herbicides) is almost entirely from the late 1940s. There have been two main uses for pesticides: reduction of those human diseases carried by arthropod vectors, and reduction of pests(largely insects and some other arthropods) and weeds in crops. DDT is generally credited with having saved thousands of lives at the end of World War II as a result of itse effectiveness against lice and other insect vectors of human disease. At first, insecticides allowed the eradication of malaria in many parts of the world.

A few scientists issued warnings. Attention was drawn to the fact that some pests had already evolved resistance against some of the pre-World War II insecticides, e.g., some populations of codlin moth had become resistant to lead arsenate. Thus, it was predicted that these new wonder chemicals would soon lose their effectiveness, simply as the inevitable consequence of Darwin's (and Wallace's) theory of evolution by natural selection. It was also warned that the destruction of non-target organisms could remove useful predators and parasites, therby ultimately increasing pest problems for the future.

However, it was not until the early 1960s that a range of warnings started to reach the public. Although a number of researchers and writers should be given credit, the fact is that it was largely the efforts of Rachel Carson which were effective. The publication of her book *Silent Spring* in 1962 is usually considered the seminal event. Rachel Carson provided the public with a readable account of research giving the first indications of serious ecological damage by pesticides, notably cases of the build-up of pesticide residues in food chains, a type of bioaccumulation. where pesticide levels become hundreds or thousands-fold in their concentration. Thus, animals at the top of the food chain soon accumulate toxic levels of pesticides (or pesticide residues). Part of Rachel Carson's success is that she pointed out the obvious: a few years after heavy use of pesticides certain common species had almost disappeared, the 'silent spring' for many insect-eating birds.

The response to these criticisms of excessive and inappropriate pesticide use has been a level of suppression which, while not as physically vicious as that which accompanied Lysenkoism in the U.S.S.R., was at least as pervasive (and probably more effective).

The vested interests associated with the chemical industry were caught off guard by Rachel Carson's *Silent Spring*, but did mobilise for an effective counterattaek[8] Rachel Carson was a difficult target. She had no academic position from which she could be fired—and she was dying of cancer. Nevertheless, she was subjected to considerable personal abuse and to denigration of her scholarly qualifications. (Rachel Carson was sometimes described as a journalist, probably because of the fact that some of her books first appeared in the *New Yorker*: her qualifications in fisheries biology and ecology, including some scientific publications, are almost never mentioned.) There were even allegations of a Communist plot to sabotage American agriculture by undermining public confidence in pesticides.

Other conservationists and ecologists who took up the pesticide issue were more vulnerable. Richard Rudd wrote his excellent book *Pesticides and the Living Landscape* at around the same time as Rachel Carson wrote *Silent Spring*—but Rudd's book only appeared in print two years later, in 1964. A commercial publisher was scared off Rudd's manuscript despite backing from a major American conservation organisation. Rudd's book was eventually published by the University of Wisconsin Press—with the manuscript having been sent out to no less than 18 different scientists for "peer reviewing' as a result of repeated attempts by the pro-pesticide lobby to block publication on the grounds of alleged errors.[8] In reflecting on this totally unwarranted delay in publication, Richard Rudd provides a valuable insight :

> "The trouble with my own efforts is the same as with the upset following *Silent Spring*: Challenge to a basic, well-entrenched system—far more extensive and profound than most people comprehend—is simply not done. It is particularly inacceptable (*sic*) from someone 'inside'. I had worked on vertebrate pest control for five years and was a member of the state Agricultural Experiment Station. I was dismissed without notice or cause given from the Experiment Station in 1964."

Rudd also had his University job threatened and his promotion blocked.[8] The important point in explaining the reaction (or overreaction) is that Rudd had done an 'inside job'. The pro-pesticide lobby could attempt to discredit Rachel Carson as lacking expertise in pest control; but, Rudd was a professional in that very field. Although there is an element of randomness in the reaction of vested interests, in general the overreaction to criticism is most severe when the critic is both essentially correct and has professional qualifications that can not be easily dismissed.[9]

Perhaps the most revealing example of suppression concerning pesticides is that which befell Frank Egler. Egler was one of the first ecologists to research the use of herbicides, both for answering certain general questions in plant ecology and for roadside weed control—the latter having been correctly analysed as a waste of money, In two seminal review articles published in 1964 Egler provided more evidence in support of Rachel Carson.[10] Egler should also be given credit for providing the first general review of the significance of suppression in biasing the flow of information concerning a variety of ecological problems, a review published in the same year as Rachel Carson's *Silent Spring*.[11]

It is the response to the second of Egler's review articles on pesticides, published in the journal *BioScience*, which disproves the myth of value-free scientists fearlessly devoted to the search for truth. A major American entomological association voted to censure both Frank Egler for writing the 'offending' article and the journal *BioScience* for publishing it. But, the most damaging fact was revealed only later by an observer at the entomological society meeting where the vote of censure was passed.[12] *Most of the voters at that meeting could not possibly have seen the issue of BioScience with the 'offending' article—for, as a result of delays in sending out the subscription copies, most of the copies of that issue had not been received by subscribers at the time the censure vote was taken.* Many of those censuring entomologists received research money, salaries, or consulting fees from pesticide firms, from captured government bureaucracies, or from client academic departments.

This example of suppression proves what can otherwise only be reasonably suspected in other suppression cases: many academics and scientists are motivated largely by careerist pressures of self-aggrandizement. The entomologists who voted against Egler (and the journal *BioScience*) apparently felt that they did not need to bother themselves with actually reading Egler's 'offending' article. Nor did any of those entomologists publish a article (which would be the proper way to carry out a scientific argument openly). It was sufficient that those entomologists perceived that a scientist had criticised a convenient source of money. Joseph Haberer.[13] in his analysis of the behaviour of scientists also concludes that many scientists are motivated by selfish power seeking, "prudential acquiescence" : a willingness to bend their views to avoid conflict with, and to court favours from, vested interests.

The situation is especially bad in the applied sciences, such as agriculture. Not only are the different interest groups interacting more closely to control scientific and academic eommunity, but the subject itself is insulated to some extent from criticism from other scientific and academic specialists, such as ecologists, rural sociologists, and economists. Indeed, Andre Mayer and Jean Mayer, in their provocative review, define agriculture as "the island empire"[14] in recognition of that degree of isolation from dissenting criticism and the vulnerability to internal and external vested interests.

Bias in the flow of information concerning pesticides has been greatly intensified by the American (and Australian) intervention in Indochina. In the period 1962-1971 American war planes sprayed herbicides over much of Vietnam and parts of Cambodia and Laos. This included approximately 11,000,000 gallons of Agent Orange (an equal mixture of the phenoxy herbicides 2,4-D and 2,4, 5-T in the form of n-butyl esters), 5.2-5.6 million gallons of Agent White (80% trisisopropanololamine salt of 2,4-D and 20% picloram, a toxic and highly persistent herbicide of a class distinct from the phenoxy group); and, 1.1-2.1 million gallons of Agent Blue (sodium cacodylate, a methylated derivative of arsenic, toxic both to humans and to rice and other crop plants).[15]

There have been claims and counter-claims concerning the toxicity of these substances, both to the target Vietnamese population and to American and Australian servicemen. As the chemical names given above indicate, people were exposed to a variety of herbicides. Suppression began even at this most elementary level. Almost all media attention has been directed to Agent Orange, and to its constituent phenoxy herbicides, plus the so-called 'dioxin' contaminant (best referred to by the convenient abbreviation as TCDD). Nearly all of the reference samples from the Agent Orange sprayings were destroyed by the Americans—thus, there are no accurate data on the amount of TCDD, or the amount of other chlorinated dibenzodioxins or dibenzofurans. As the amount of TCDD varies greatly, depending upon the method of 2,4,5.-T manufacture (and, in particular, temperature changes during synthesis of the trichlorophenolate precursor), the actual amount of TCDD can vary by two or three orders of magnitude,

Furthermore, there has been almost no media attention directed to the exposure of humans to Agent Blue, Most of this herbicide was used against rice and other crop plants intended for Vietnamese consumption. The use of a toxic organo-arsenical has the potential for both conversion into other toxic arsenic compounds and some food chain passage. One can only guess that the almost complete suppression of discussion about Agent Blue is related to two factors: First, it was even more obviously being used as a form of chemical warfare against people, Second, while there is enough scientific information to allow one to argue about the degree of toxicity of phenoxy herbicides, few scientists, even those employed as spokesmen for the chemical industry, would wish to be seen by the public as saying that arsenic is not a toxic chemical.

Powerfur political forces in both the U.S.A. and Australia, forces thal supported the aggressive war against Vietnam, have joined the agribusiness lobby to claim that phenoxy herbicides are both innocuous and effective. Many examples of suppression are covered in two books on Agent Orange.[16] and we will not review those examples here. We will, however, review briefly a more recent example of bias in information flow, an example which is especially important.

In Australia, as in the U.S.A., there were many complaints about possible toxic effects to returned servicemen, toxic effects attributed to the use of Agent Orange. After a long delay and some occasional attempts at white-washing the Australian Federal government set up a Royal Commission to investigate the use and effects of chemical agents on Australian personnel in Vietnam. The Royal Commission was presided over by Justice Philip Evatt.

The Report of that Royal Commission is an imposing collection of nine volumes, one of which is a long list of the scientific literature on phenoxy herbicides, together with an assortment of other references. The Report decided that the herbicides did not harm the health of Australian servicemen—and then concluded with a virulent attack on environmentalists, such as Rachel Carson, who had dared to raise questions about the toxicity of herbicides and other chemicals.

However, the actions of that Royal Commission have not been without criticism :

1. Some witnesses, whose evidence and opinions questioned the safety of humans exposed to phenoxy herbicides (and the TCDD contaminants), complained of being unfairly treated.[17] In particular, the two eminent Swedish epidemiologists who had observed an increase in certain soft-tissue cancers in workers exposed to phenoxy herbicides had their work virulently, if uncritically, attacked.

2. Large parts of the Royal Commission's Final Report were simply plagiarised (word-for-word except for an occasional minor alteration) from the Monsanto Chemical Company's submission document, a document that clearly represented the vested interests of but one side in a very complex dispute. As Brian Martin concluded:[18] : "Of the many instances of plagiarism which I have studied, this is one of the more egregious cases".

3. The long and strong attack on environmentalists in the Royal Commission's Final Report is based extremely closely on a single literature source : Edith Efron's *The Apocalyptics*.[19] This is a wide-ranging and biased accounl; supported by the chemical industry lobby. While the book is cited by the Royal Commission, the reader of that Final Report is not warned how closely the opinions of the Royal Commision and Edith Efron coincide. This would appear to qualify as *idea plagiarism*. It may well be even more significant than the word-for-word plagiarism mentioned in the previous paragraph. There is no evidence that Edith Efron was brought before the Royal Commission and that the opposing parties in this dispute had any

opportunity to cross-examine her views which were to form such a major part of the conclusion to the Royal Commission's Final Report.

Despite the revelation about plagiarism and the unfair treatment of certain scientific witnesses, the Australian government has made no attempt to investigate the conduct of that Royal Commision publicly. Apparently, such behaviour is considered acceptable in Australia.

This example illustrates well the difficulty of evaluating the toxicity and efficacy of pesticides.

Having presented these examples of bias in the flow of information about various agricultural chemicals, with suppression operating at a number of different levels, we can now summarise quickly how the earlier critics of pesticides abuse have been shown to be essentially correct (and, thus, we provide evidence that the suppression of alternative views has caused significant damage). Four distinct sets of factors have contributed to the decline of favour for pesticides.

1. Loss of efficacy of pesticides : the evolution of pesticide resistance by pests.

If pesticides were really all that consistently successful, the post-World War II era of heavy pesticide use should have been characterised by a significant reduction in overall pest damage to crops. The Ehrlichs[20] provide a number of estimates of crop losses to pests, estimates provided by different authorities at different times. The era of high pesticide use does *not* have lower estimates of pest damage. Unfortunately, most estimates of pest damage in growing crops are guesses, and different individual experts will make differing estimates. Post-harvest losses are easier to assess accurately, but these too remain high.[21] Temporary gains for some crops in some places have been cancelled by worsening pest damage elsewhere, pest damage even in the presence of chemical 'control'.

It should also be emphasied that pesticides are not important for many crops. In fact, in the USA, a single crop, maize, receives most chemical input. Maize and cotton together account for approximately half of the insecticide consumed; maize and soybeans together account for almost 70% of all herbicide consumed in American agriculture [22].

There has been a slowly growing awareness that many pesticide programmes are not working well, It has simply been a matter that, however, effective the massive advertising budget and the suppression of dissenting views, an increasing number of farmers and insect control workers have seen with their own eyes examples of the failure of chemical control. An initial response to declining efficacy is to use either higher doses or other (often more expensive) pesticides; the annual loss from such declining efficacy has been estimated to cost about $ 130,000,000 per year in the U.S.A. alone in terms of extra chemical control.[23] Pesticide costs have escalated—with in many instances a parallel escalation in pest damage. Pesticide-resistant pests have delivered the economic coups de grace to a number of multi-million dollar development fiascos, e.g., the attempt to grow cotton in the Ord River Scheme in the northern Western Australia—where even the use of an organophosphate pesticide that had also been considered for use as a nerve gas ultimately failed to control cotton pests.[24]

The explanation for the inevitable failure of most chemical control programmes is simple straightforward Darwinian evolution, as the first eritics of over-dependence on pesticides had warned. Pest species often have high genetic variability. Monocultural agriculture provides a 'free lunch' for pests, allowing the build-up of large pest populations. This includes the survival of many mutants with sub-normal fitness. By chance alone, a few of these sub-normal fitness mutants have greater pesticide resistance than their fitter relations. (Frequently the pesticide resistance mutation will either keep pesticide away from some critical site or speed up the detoxication of the pesticide, usually by breaking the chemical down into less toxic products.)

Fitness, however, depends on a complex interaction between genes and the environment. When the environment includes pesticides sprayed by humans, the pesticide-resistant mutant survives to reproduce even though its pesticide-sensitive relations do not. Genetic recombination and additional mutations often quickly counteract any initial loss in fitness of the original pesticide-resistance mutation. There is a rapid flux of genetic variants, rising and falling in frequency, as better presticide-resistant mutations replace the poorer ones. The ultimate result is a fitter pest, now adapted to survive well against sprays.

Some mutations convey narrow specificity : resistance to only a single toxic chemical. But, many mutations convey some measure of *cross-resistance* : resistance to a number of different pesticides, usually confined to within one major pesticide class.

Thus, there is a common pattern in pest control; after several successful years of chemical control, there is a decline in efficacy. Higher doses are needed to countract resistance. Soon the farmer must change pesticides. Thanks to cross-resistance, the new pesticide often does not give as good control for as long a period as did the first pesticide. But, new pesticides are increasingly difficult to discover and increasingly expensive to develop.[23]

After 10-20 years, it is not uncommon to find the evolution of *superpests.* A combination of cross-resistance and multiple resistance results in a tougher pest, resistant to many of the different economically feasible pesticides. A recent review of pesticide resistance warns.[23]

> Arthropods' resistant illustrates how severe these problems can become when a unilateral approach—introducing one new pesticide after another—is followed. Some particularly resistance-prone species—house-flies, certain mosquitoes, cotton bollworms, cattle ticks, and spider mites, among them - have been able to overcome the toxic effects of virtually every pesticide to which they have been extensively exposed...... For agricultural pests, few farmers or pest-control managers have escaped

the impact of resistant pests......

The "unilateral approach" of reiterated chemical control has had far-reaching complications. Heavy pesticide use, applied to cash crop in Third World countries, has facilitated the evolution of pesticide resistance not only in crop pests but also in arthropod vectors of human and animal disease. Thus, pesticide resistance has become a serious problem to public health programmes as well.

The literature data suggest that the problem of pesticide resistance in pests is accelerating. In 1970 there were 98 pest species resistant to DDT. In 1980 there were 229 pest species resistant to DDT. But, there was even faster evolution against the newer pesticides used to overcome resistance to DDT and related organochlorines. For example, in 1970 only 3 pest species were resistant to carbamate pesticides—but by 1980 that number had in creased to 51 species.[23]

As the price of pest control with chemicals has escalated, and as the efficacy has declined, farmers are beginning to demand that governments place more emphasis on research into cheaper and more effective means of biological control. Even some pro-pesticide scientists have had to shift their position more in the direction of alternative pest control (or eradication) paradigms : integrated pest management,[25] sterile male techniques,[26] or improvements in biological control.[27]

2. Ecological damage from pesitcides.

The 1960s anti-pesticide dissenters emphasised the general ecological damage arising from the indiscriminate killing of non-target organisms by pesticides. Rachel Carson and other critics were widely rediculed as "eco-nuts" because of this ecological concern.

Ironically, some of the best evidence for the validity of their concern about damage to the ecological web, the interactions between predators and prey, between consuming organisms and decomposers *etc.*, come from the more thorough studies of pest problems in the context of agricultural eco-systems : notably "the pesticide treadmil" and the creation of secondary pests.

This is not to deny the original claims of widespread damage to more natural ecosystems. There is ample evidence suggesting that widespread pesticide contamination has altered the species composition of natural ecosystems, but there are complications from other human caused changes, such as general habitat destruction, overfishing, and pollution from non-pesticide chemicals, ranging from acid rain to substances which are similar to but distinct from pesticides, e.g., PCB's (polychlorinated biphenyls, widely used for a variety of industrtal purposes and resembling DDT and other organochlorine pesticides in their environmental persistence, food chain concentration, and general toxicological properties).

In contrast to "bird kills", whieh are often associated with particular spraying events, there are fewer dramatic acute incidents in ecosystem damage. There is a more chronic situation, of exposure to varying amounts of pesticides, including those distributed through food chains. The result is that many individuals collected in the wild contain near lethal levels of pesticide residues, accelerating the natural death rate. Numbers of the more sensitive species decline, resulting in a general shift in species composition. Because of the potentiality for food chain accumulation, a problem with the more pirsistent pesticides, the greatest dumage is often done to predators, especially those at or neer the top of the food chain. Many fish species are important predators in aquatic ecosystems and, thus, environmental pesticide contamination has contributed to the decline of a number of important fisheries.

It is difficult to make a precise estimate of the amount of ecosystem damage. As Frank Egler noted.[10] the lack of adequate long-term multidisciplinary studies in ecosystem ecology has meant that we have only a very incomplete view of pesticide damage to natural ecosystems. Suppression has been especially effective in preventing the emergence of full scale ecological studies needed to assess precisely pesticide damage and other damage from human activities.

Thus, we turn to information from studies on agricultural ecosystems, where persistent pest problems have forced some scientists to adopt a more sophisticated approach (and where long-term financial support has been readily available).

It was soon learned that, in agricultural ecosystems, pesticide kill not only sensitive pests but also their predators and parasites. It is the predators and parasites that normally keep pest number down, even if not always to a sufficiently low level to avoid crop damage. As a chemical pest programme breaks down because of the evolution of pesticide resistance in pests, it is frequently observed that pest numbers increase to levels which are *higher* than ever occurred before chemical control was attempted. This *pest rebound* is the result of the combination of two factors : the evolution of pesticide resistance by the pest, combined with the lack of pesticide resistance among predactors.

The reader might well ask : why, then, do not the predators evolve pesticide resistance too? The answer is that sometlmes they do, but usually only long after the pest has evolved the resistance. Because a predator must eat many prey, predators are usually in much lower numbers than pests. In addition, predators often have longer generation limes than do pests. Thus, predators have less opportunity to evolve pesticide resistance. Furthermore, the few studies which are available suggest that predators often have less genetic variation than do pest species.

Because chemical control programmes often do more damage to predators than to pests, another problem arises : *the creation of secondary pests.* The destruction of certain predator species in an agricultural ecosystem removes the checks and balances operating on certain minor crop-eaters. These minor crop-eaters then become new major pests. For exemple, in several countries it was observed that after a few years of fairly successful control of codlin moth with DDT, two-spotted mites become major pests. Normally their numbers are kept down by predators, including predaceous mites. Two-spotted mite sometimes become worse pests than codlin moth. Codlin moth might damage 10-15% of the apple crop, but their numbers can be contained by classic methods of pest control emphasizing mixed agriculture (e.g., chickens to eat conlin pupae underneath fruit trees) and vulnerability at certain times in the codlin moth's life cycle. Two-spotted mite could do more damage : by prematurely defoliating apple trees, crop yields are depressed for years. In this way, pesticides can create new pests that are as bad, or worse, than the old pests.

The combination of the evolution of pesticide resistance in primary pest species with the creation of secondary pest species forced farmers, who were persuaded to stick to the chemical control paradigm, to escalate to the use of a wide variety of increasingly toxic pesticides at higher dose rates : "the pesticide treadmill"[3a]—an expensive and dangerous form of addiction.

3. Pesticide damage to humans.

Rachel Carson's *Silent Spring* not only raised questions about toxicity to humans from chronic exposure to low levels of pesticides but even raised the issue of mutagenic effects. Although she was widely ridiculed at the time by pro-pesticide scientists, Rachel Carson has subsequently been shown to have been fully justified in her concern. It is now accepted as proven that a number of widely used pestieides are mutagens. A sizeable fraction of genetic disease in humans is the result of new mutations. It remains to be determined precisely what fraction of new mutations in humans arises from exposure to different chemicals (and to background radiation, medical and dental X-rays, and other sources of anthropogenic radiation); but, few scientists would now ridicule concern about mutation—especially given the partial positive correlation between mutagenicity and carcinogenicity among chemicals.[29]

There are difficulties in assessing whether or not a particular pesticide (or other chemical) poses a cancer risk for humans. Quite apart from numerous examples of suppression, there are fundamental difficulties in assessing cause and effect when studying imperfect samples from human populations.[30] The people who are most often exposed to pesticides are those working in pesticide manufacturing plants or those working as sprayers. Such low-prestige and unpleasant jobs are often performed by social and racial outgroups, legal or illegal immigrants. As a result, many exposed individuals cannot be traced, records are sometimes falsified, or just simply not kept. The social-genetic differences make it almost impossible to find a suitable matched control population which is not exposed to pesticides. Sprayers often use a wide variety of insecticides and herbicides. Many commercial pesticide preparations are complex mixtures of incompletely identified chemical compounds—quite apart from non-ionic detergents or carrier compounds when dealing with pesticides that have poor water solubility. Accurate measurement of pesticide residues or contaminants seems to be beyond the abilities of certain laboratories; of five highly prestigious institutions measuring levels of the 'dioxin' (TCDD) contaminant only two institutions obtained reasonably accurate results—and the well-equipped laboratory of the vested interest in this case, Dow Chemicals, was rated as "worse than normal".[31]

There are yet additional sources of noise which make it difficult to measure the true signal of pesticide toxicity. Some studies have attempted to use pesticide levels in human body fat, taken during autopsies. While the information is of general use (especially when comparing average levels of exposure in different populations at different times), it is not a fully reliable measure of total pesticide exposure.

Despite these formidable difficulties, there are now many published examples of death and serious injury arising from accidents involving pesticides, proving at the very least that there is a major problem of acute toxicity to humans for many commonly used insecticides and herbicides. Even pro-pesticide groups, such as the World Health Organization (which had initially found pesticides to be extremely effective in reducing malaria and some other diseases carried by insect veetors), have urged caution. It has been estimated by WHO that accidents involving pesticides kill 5,000 people per year, together with injury to 500,000-1,000,000.

Such figures are almost certainly a serious underestimate. Many cases of death are not correctly diagnosed, even in First World countries (where the number of autopsies has declined markedly in recent years), Many cases of serious injury are not reported. Sprayers and pesticide workers sometimes cultivate a *macho* pride in their symptoms and seldom seek medical attention e.g., the "kepone shakes" observed in many workers at the pesticide plant in the U.S.A. We observed that many orchardists do not seek that medical attention upon repeated pestlcide poisoning. Severe headaches, vomiting, involuntary twitching, and chest and muscle pains are just considered part of the aftereffects associated with certain spraying tasks.

Pesticides are responsible for many deaths, including some major disasters. in Third World countries. The 1984 example of Bhopal, in central India, illustrates the problem all too well. The American-based transnational Union Carbide used Bhopal as a place to manufacture a carbamate pesticide by a method what involved a highly toxic intermediate MIC. (metyhl isocyanate). Union Carbide uses a much safer method for synthesizing the same pesticide in the U.S,A. The accident in Bhopal released a drifting mist of MIC—killing over 2,000 people and injuring about 200,000.

It is surprising how frequently agricultural chemicals (primarily pestieides) are involved in accidental injury to children. In 1973 we obtained a breakdown of data on poisoning of children in Adelaide, South Australia.

during the period 1967-1972, data supplied from the National Safety Council of Australia. Out of 8,450 cases of poisoning, "internal medicines" topped the list with 2,641 cases. "Household products" were second with 944 cases. "Pesticides, agricultural and veterinary products" were second with 1,577 cases. "Pesticides, agricultural and veterinary products" were third with 944 cases. This is remarkable when one considers that children have far more opportunity to consume, or otherwise interact with, internal medicines or household products, whereas in many houses there will be few opportunities to be poisoned with pesticides or other agricultural chemicals. As another example of suppression, the response to our 1987 inquiry of the National Safety Council of Australia for an up-dating of these earlier figures was to inform us that such records were not available.

Nearly all data on pesticide toxicity to humans are data on *acute toxicity* where the effect closely follows the cause, often a dramatic effect observed within days or even minutes of exposure. Far less is known about *chronic toxicity* the cosequences of prolonged exposure to low levels, or to repeated small doses.

Recently, it has become recognised that some adverse effeets of pesticide exposure show up only long after the original intoxication episode or after a prolonged period of subclinical exposure: *delayed neurotoxicity*.[34] A further complication is *behavioural change*. where pesticides ultimately lead to neuro-psychiatric problems rather than the more typical symptoms of poisoning. Behavioural changs has been observed in experimental animals exposed to low levels of insecticides or herbicides before birth (or, in the case of birds, exposed to the pesticide prior to hatching).[35] Analysis of data concerned with 37,751 babies in New Zealand, where the mothers had lived in regions subjected to different amounts of spraying with 2,4,5.-T, reveals some association between birth defects and herbicide dose, an association which is statistically significant for one kind of birth defect.[36] The possibility that prenatal exposure (many insecticides and herbicides cross the placental barrier readily) can result in less dramatic symptoms than certain kinds of birth defects, for example, undesirable changes in behaviour or a decline in intelligence, should be thoroughly explored for human populations. The developing nervous system is especially sensitive to chemical injury. Many metabolic mutations in humans result in some degree of mental retardation, or in pathological behaviour. (That exposure of children to low levels of lead could cause a decline in measured intelligence is now a medically accepted fact, although scientists who issued earlier warnings were ridiculed.[37]

Of the long term effects which have elicited the greatest worry there is cancer, where the lag time between exposure to a carcinogenic chemical and the development of cancer is often measured in the 10-30 year range. No marked epidemic of cancer has occurred to match that produced simply by smoking—but that is no grounds for complacency. Although some studies have yielded negative results, other studies have found a statistically significant elevation of certain types of soft tissue cancers in individuals exposed to phenoxy herbicides.[38] It appears that there are reasonable grounds for concern about the carcinogenic potential of some commonly used herbicides and insecticides.

It is not only humans but also their associated animals which are at risk from pesticides. Some of the more potent pesticides used in Green Revolution agriculture killed even the hardy water buffalo, thereby depriving the farmers of their major source of power for cultivating wet rice fields. In many Third World countries wild or domesticated fish are part of the agricultural ecosystem, grown in rice paddies or in special ponds. These fish are a major source of dietary protein. On the whole, fish are often much more susceptible to pesticide poisoning than either birds or mammals.

4. Polluted Exports

The fouth major cost of pesticides is the only one not considered in Rachel Carson's *Silent Spring* and the writings of other ecologically concerned people in the 1960s. This may be the result of the one major error in the writings of the environmentalists of that period: a failure to realise the extreme difficulties in predicting limits to resource utilisation, including agricultural productivity. Far from the widespread famines predicted by some writers, the 1970s and 1980s have been characterised by rapidly rising agricultural production, with consequent falls in many farm commodity prices in international trading and increased competition among the major exporting countries.

Food contamination has become a political issue in a number of countries. Thus, despite the suppression and the sheer power of the agrichemical lobby, a number of countries have made definite attempts to regulate pesticide use. These include *restricted use* (i.e., the pesticide can be used only on certain crops), *total ban* and limits to the levels of contamination which are considered acceptable in certain foons (with some American limits being set at *zero tolerance* i.e., for certain carcinogenic pesticides no detectable residues are tolerated).

In the 1970s and 1980s we noticed that, almost every year, there were newspaper reports of Australian agricultural produce being rejected by importing countries on the grounds that it was contaminated with unacceptable levels of certain pesticides, We inquired for further information from various governmental agencies. Again, suppression reigned. This is clearly a subject about which the government wishes to restrict discussion—despite the fact that polluted exports, as with the previously discussed product substitution scandals, are probably costing this country billions of dollars in lost markets.

After repeated episodes of polluted exports, matters finally came to a head in 1986-1987. Long after being banned outright, or scheduled only for highly restricted use, In many countries, in 1987 it was reported that American authorities had found high levels of DDT in some shipments of beef from Australia and that this finding has threatened a $750,000,000 a year export market.[39] At about the same time it was revealed that beef from South Australia was contaminated with cyromazine, a chemical not normally used to treat arthropod pests on cattle but sheep blowfly.[40]

What is required to bring social action on unnecessary pesticide use?

It is the polluted exports theme that brings the final irony to our discussion of the rise and decline of pesticides. The 1960s period of environmental concern resulted in some legislation to limit pesticide use, but such legislation was often either inadequate or unenforced. Suppcsedly banned or restricted pesticides could often be seen for sale in large quantities in agricultural supply houses or even in retail stores, Some First World countries 'solved' the problem of especially dangerous pesticides, no longer desired for home consumption, by exporting them to Third World countries.

It was not the original 1960s arguments about the ecological damage of pesticides, nor the risks to human health, that resulted in real action (except, to a limited extent, in the USA, and to an even more limited extent in the European Economic Community later).

It was not the rapidly rising number of cases where pesticides failed to give satisfactory control of primary pests, or even created scrious secondary pests. Even the many examples of economic ruin brought by "the pesticide treadmill",[29] economic ruin to both small farmers and to major agricultural development projects, were not enough. The evolution of pesticide resistance in pests, predicted on the simple principles of Darwinian evolution and varified by earlier examples, such as industrial melanism, was not enough to break through the suppression barrier. All that occurred was that, by the 1970s and 1980s, some formerly pro-pesticide entomologists—when confronted face-to-face with super-pests—shifted their emphasis in the direction of more balanced pest control programmes, such as integrated pest management.

Finally, after repeated examples of lost export trade due to chemical contamination, the real motivation for action is revealed. In 1987 the headline in Australian newspapers tell the story : "DDT in agriculture to be outlawed", "DDT to be banned by 1988" and, most remarkable of all, "Queensland to press for national ban on DDT"[31] Even the agribusiness-dominated National Farmers' Federation is urging action on polluted exports.[02]

Now we can better understand suppression and its costs. Thanks to agribusiness dominance and sycophantic scientists there has been a 'body count' of thousands of unnecessary deaths and millions of unnecessary injuries. So effective has been the agribusiness lobby that there has been little progress made in devising safer delivery systems for pesticides. let alone only slow progress in biological control and in integrated pest management. Only a direct blow to the private greed of powerful vested interests has brought action on pesticides : the threat to profits lost in the highly competitive market for agricultural exports, □

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