The Ecologist

Journal of the Post Industrial Age Vol. 16 No. 1 1986 £2

The Rape of Gaia: Why Europe's Trees are Dying

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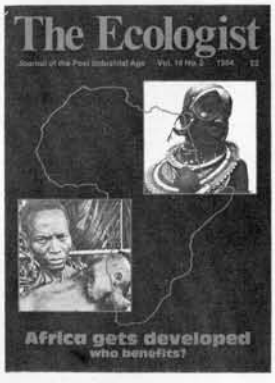

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Erratum

We apologise to David Abram for a mix-up of paragraphs in his article *The Perceptual Implications of Gaia* in *The Ecologist*, Vol. 15 No. 3, 1985. The passage on page 101 should read as follows:

This, I believe, is the deeper significance of James Lovelock's ideas concerning what he calls the 'terraformation' of other planets (mentioned by Margulis and Sagan in their article in *The Ecologist* 13:5, and criticised by Bunyard in the same issue). By contemplating how humanity might someday transfer the complex Gaian metabolism to other planets in order to make them habitable by human life, Lovelock is underscoring the fact that neither humanity nor any other species we know can exist outside the incredibly complex Terran metablism of which our own bodies and minds are an internal expression—if we wish to colonise other worlds we shall have to bring this metabolism with us. We are entirely a part of the life that envelops this planet, and thus the living Earth as a whole is the constant intermediary between ourselves and the rest of the universe.

Gaia and the Death of her Trees: Waldsterben in Europe

The acidification of lakes, rivers and soil profiles in parts of Scandinavia, in Scotland and other parts of Europe, equally the dying of forests over a vast area stretching from Italy to Russia are issues that can no longer be ignored. Latest reports indicate that up to 7 million hectares of Europe's forests—an area equivalent to one third of the United Kingdom—show signs of damage, with at least 250,000 hectares dying or dead, while in southern Scandinavia tens of thousands of lakes are now entirely devoid of fish. Indeed, in South Norway alone more than 30,000 square kilometres of lakes are either fishless or have reduced fish populations.

As Professor Peter Schütt of Munich University, makes clear, the entire woodland ecosystem in many parts of Europe is breaking down, giving the coup de grace to centuries of deforestation. And even if not the worst affected, Britain has not escaped damage to its trees, an initial survey carried out by Friends of the Earth on beech and yew showing many trees to be suffering the same symptoms as found in Europe. Britain, meanwhile is one of the least forested countries in the world.

While few doubt that acidification is linked to acid rain and the increasing burden of acid precursors carried in the atmosphere, particularly over the industrialised north, the dying of the trees appears to be caused by different, even though linked phenomena. What 'waldsterben' as the Germans call forest die-back, and acidification undoubtedly have in common are man's industrial activities. And since both types of ecological crises have really manifested themselves in recent years, certainly post World War 2, the conclusion must be that the changes to the environment are caused by relatively new industrial practices and ways of living. Tree death and acidification have both been observed before, but always in the vicinity of massive industrial processes—huge steel works for example. The worrying aspect of today's environmental damage is that it is taking place in relatively pristine environments away from industry and people. Indeed waldsterben was first discovered on the hilly slopes of the Black Forest and in southern Bavaria.

What then, and who are to blame? One would have thought the acidification story to be clear-cut. Scandinavia, the worst affected area in Europe, imports for instance far more sulphur in the form of dioxide than it generates within its own borders. Thus each year on average some 600,000 tons of sulphur are deposited in Sweden, mostly in the south, while only 100,000 tons come from Swedish sources. Britain meanwhile produces some 2,670,000 tons on average, of which less than one third are deposited in the country itself, the remainder being carried out over the North Sea by the prevailing winds. Indeed the UK contributes almost as much sulphur to the Swedish environment as does Sweden itself, and given Sweden's commitment to reduce emissions to one-third the 1978 level by 1995, the UK by then will actually be depositing more; that is unless there is a fundamental change of heart in Britain's attitude.

At the Helsinki meeting last July on long range transboundary air pollution, 21 countries signed the 'Protocol' on sulphur emissions by which they committed themselves to reducing their emissions or transboundary fluxes of sulphur dioxide by at least 30 per cent before 1993. Britain was one of 14 countries that did not sign. According to Minister of the Environment, William Waldegrave, Britain had already reduced its sulphur emissions by 25 per cent since 1980 and further efforts to bring emissions down to meet the deadline inscribed in the Protocol were not justified. Britain's official attitude has consistently been that the causes of acid rain and acidification are not properly known and that the effect of Britain's own transboundary emissions on the Scandinavian environment remain unproved.

Some 60 per cent of Britain's sulphur emissions come from its coal-fired power stations, none of which have any means of entrapping sulphur. And whereas Sweden and other European countries have embarked on various schemes to reduce sulphur emissions, France for instance levying a charge on such emissions from thermal installations of greater than 50 megawatts capacity, Britain's Central Electricity Generating Board, with government support, obdurately refuses to install flue gas desulphurisation. One reason given for the refusal is cost, the CEGB claiming that any such measures will add at least 12 per cent on electricity bills. Another reason is the CEGB's claim that a cut in sulphur emissions will not necessarily lead to equivalent reductions in deposition, the implication being that there are other, as yet unidentified sources of sulphur oxide emission and deposition.

But the British government has another card up its sleeve. If the emphasis on coal-fired generation can be switched to one on nuclear power, then sulphur and nitrogen oxide emissions will be sharply reduced without incurring additional cost. According to the evidence given by the CEGB at the Sizewell Inquiry on the generating cost of a pressurised water reactor, electricity costs will come down in relative

terms by introducing a PWR programme even 'ahead of need'. However, the CEGB's figures do not stand up under critical analysis, and as Stewart Boyle of Friends of the Earth points out, the nuclear option would incur an enormous cost penalty. Instead, he favours pollution control of existing and new coal-fired stations. Thus, "assuming the relatively crude and costly Wellman Lord system of flue gas desulphurisation, coupled with 5 per cent electricity conservation on the CEGB's Scenario C for growth in electricity consumption, the EEC targets could be met (by 1995) at a cost of £1.432 billion—adding 3 to 4 per cent to electricity costs over ten years. Whereas" he says, "To meet the EEC directive by building nuclear power stations to reduce sulphur emissions would cost £17 billion—more than 12 times as much as pollution control on existing coal stations—even with a crash programme of one Sizewell every year for 20 years, and even then we'd only reach the EEC target by 2005. So the nuclear route would be too expensive, too late—and too risky."

On scientific grounds the CEGB has a point; we are still abysmally ignorant as to the precise mechanism of either acidification or waldsterben. In both instances complex photochemical reactions are at play in the atmosphere. What is increasingly certain is that the sum of our industrial activities is at the root of the problem, basically through upsetting natural nutrient cycles. Certainly the British approach to pollution control is much to blame, particularly that of 'discharge, disperse and dilute', for we have assumed that as long as the chimney stacks are tall enough, and the discharge pipes into the sea and estuaries long enough, the environment will do the rest for us, taking our pollutants away from our own shores and hopefully diluting them sufficiently by the time they reach anyone else's.

Eutrophication of the Seas

As we point out in the article on waldsterben in this issue, it can hardly be coincidence that the worst affected forests in Europe are those downwind from the tall stacks of industry. Similarly the 400 foot high stacks of the CEGB's coal and oil fired power stations must have something to do with the burden of sulphur and nitrogen oxides reaching Scandinavia. Yet there are other sources of sulphur and nitrogen compounds which may be equally important, and which to date have largely been ignored. The discovery of massive algal blooms in the North Sea has prompted Jim Lovelock to suggest that a major source of sulphur may be of marine origin. Indeed nutrient run-off into the offshore environment—sewage from our cities, nitrates from farming and horticulture—is leading to eutrophication of the sea. Dimethyl sulphide is one product of that enhanced growth. At the same time we have accelerated the oxidation pathway over the northern hemisphere through our injection into the atmosphere of nitrogen oxides and hydrocarbons. Increased ozone and hydroxyl radical production are the result, and the consequence is more rapid oxidation and fall-out of acidic oxides. To complicate the matter still further, increased manure production because of animal feedlots and intense animal husbandry is leading to large ammonia and ammonium hydroxide releases into the atmosphere. In parts of Sweden spruce and pine appear to be dying from excess nitrate uptake of manurial origin, the algal slime covering the needles suggesting a kind of terrestrial eutrophication.

Motor vehicles are the other main source of nitrogen oxides and hydrocarbons, but they have become such an important part of our modern way of life that no government would consider imposing restrictions on their use. Instead the aim is to curb pollution through technical fixes, catalytic converters or lean burn engines for example. And when governments, such as the Federal Swiss and German governments, have suggested imposing speed limits to reduce nitrogen oxide production, they have met with a storm of protest from motorists at the attempt to curtail their freedom to travel at speed. Again there is controversy over the extent to which motor vehicle use has caused die-back in trees. While no one can dispute that heavy traffic causes photochemical smog under bright sunlight, the emissions from high stacks may be important over the mist-covered hills of the Black Forest.

The tragedy is that we are already in the throes of an environmental crisis and anything we are doing at present, especially the half measures we are taking, may be too little too late. To wait for science to give us exact answers as to the cause of acidification and waldsterben, as our government and the CEGB are intent on doing, is an act of callous irresponsibility. We will have to act on all fronts, considering all sources of pollution as potentially to blame.

Peter Bunyard

THE DEATH OF THE TREES

by Peter Bunyard

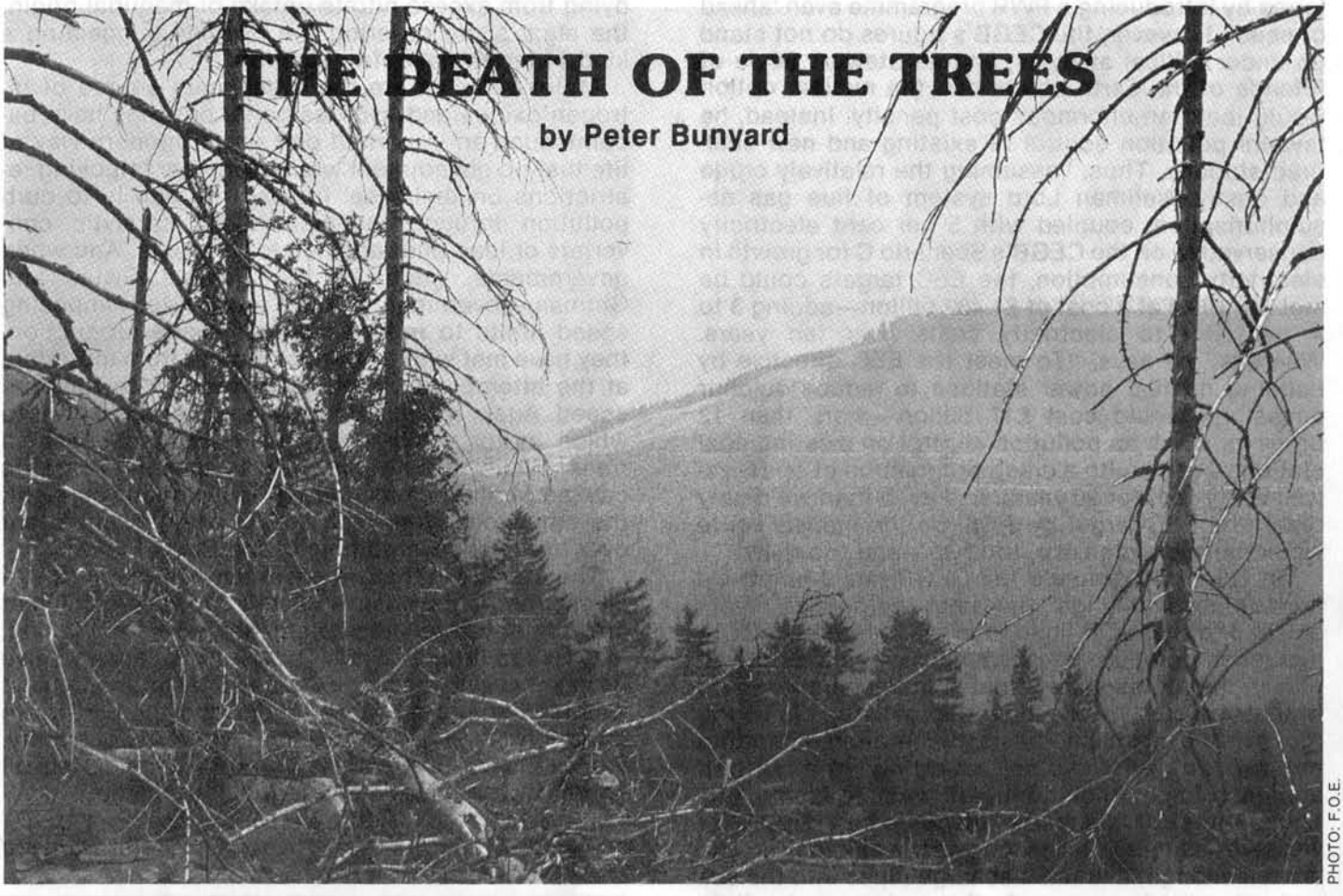


PHOTO: F.O.E.

IS THIS THE FUTURE? The hill top of the Hornisgrinde in the Black Forest littered with dead fir and spruce.

Since the late 1970s, and with increasing severity, a new phenomenon leading to the dying and death of its forests has been sweeping across Europe. Although some species appear to be more resistant than others, one by one they are succumbing—spruce, pine, fir, beech, oak, ash, rowan—and if the pace of death continues large tracts of once forested areas will soon be virtually denuded of trees.

Whether the phenomenon of forest death—waldsterben as the West Germans call it—will spread to all woodlands and forests throughout Europe is a moot point. The rapidity with which the disease has struck trees first in one forested area and then another is extremely disturbing, and a forest that shows few signs of damage one year may present a very different picture one or two years later when as many as half the trees may be suffering die-back. The disease was first discovered in the forests of West Germany, particularly in the Black Forest to the South West and the Bavarian forests to the South and South East. Elsewhere, foresters have been slow to appreciate the extent of the phenomenon, in Britain for instance, denying its existence altogether. But the political ramifications of a disease pattern that appears to correspond to atmospheric pollution fall-out are clearly very great.

Peter Schütt of the forestry department at the University of Munich, is a foremost authority on the diseases of trees in West Europe. He is convinced that the disorders affecting the trees are different in kind from anything foresters have ever seen before, certainly not conforming to conventional tree diseases, whether caused by classical air pollutants such as sulphur dioxide or by pathogens. Professor Schütt, who has been editor of the *European Journal of Forest Pathology* since 1970, has come to the distressing conclusion that the entire forest ecosystem is breaking down.

"What we are seeing today," he told me, "is a stress situation of the whole system—not just of the trees but of the rest of the flora. Indeed, very often we find dead and dying trees surrounded by a ring of clear ground where once there had been herbaceous vegetation."[1]

Different species of tree appear to be afflicted by a variety of different disorders, some leading to death within one or two years, others to a more prolonged decline. In general, common symptoms include a fall-off in growth as measured by such parameters as ring-width; abnormal growth of branches and leaves, altering dramatically the normal appearance of the tree; a shrivelling of the feeder-root biomass; and a pathological loss of needles and leaves. Indeed, while healthy conifers usually retain their needles for seven or more years, damaged trees appear to lose them after one or two years at most. Meanwhile affected beeches and other deciduous broadleaf species lose their leaves still green as early as June. A particular stress symptom is the abnormal production of seeds and cones, beeches for instance will suddenly start producing a profusion of nuts every year instead of every six or seven years,

as is normal. Not surprisingly trees weakened by the symptoms of waldsterben are susceptible to a wide range of pathogens, such as bacterial wetwood infection in silver fir, a clear sign of deranged water metabolism, or to root pathogens such as phytophthera or armillaria. All such infections, says Schütt, are secondary to the prime causes of waldsterben, as are increased attacks by bark beetles and ants. Although some scientists have floated the idea that viruses are implicated in the disease, the evidence to date simply does not support such a contention.[2]

In West Germany, the silver fir—*Abies alba*—was the first species to be affected, the mysterious new disease becoming widespread and intense by the late 1970s. During 1979 and 1980, while carrying out an inventory of the damage to silver fir, foresters noticed that Norway spruce (*Picea abies*) was showing a dramatic change in appearance, especially in those trees in the mountains to the east and south, as well as in the low-elevation forests on the plains surrounding Munich, where, according to Schütt, "the symptoms progressed very rapidly, from partial to total defoliation and eventually to death of the trees."

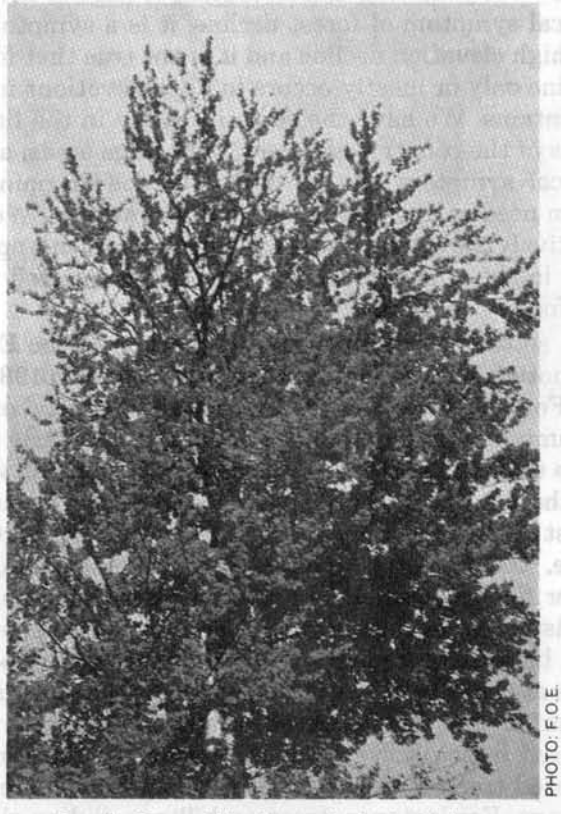
The disease, which appears to manifest itself in similar ways in spruce and fir, has now taken on extremely serious proportions, insofar as both those species together, account for more than 40 per cent of the total forested area in West Germany. Between 1980 and 1984 the spruce forests throughout much of Central Europe, southern Scandinavia, northern Italy, parts of the Balkan countries and over Eastern Europe, began to show signs that they too were suffering die-back.

By 1981 Scots pine (*Pinus sylvestris*) was found to display similar symptoms, but even more surprising a totally new, mysterious disease began to afflict the European beech—*Fagus sylvatica*—even when growing on what were deemed optimal conditions of soil and climate. Again the disease was soon found over a large part of Europe and of Southern Scandinavia.

By 1984 as much as 50 per cent of the forested area of West Germany showed signs of waldsterben, the extent of which increased from 8 per cent of the total in 1982 to about 34 per cent in 1983. In Switzerland, by the beginning of 1985, 34 per cent of the forest was affected; in Luxembourg the diseased area jumped sharply from 5 per cent in September 1983 to 52 per cent one year later; while in Czechoslovakia at least one-third of the forests were already completely dead. France, which like Britain originally considered the die-back of the forest to be a German phenomenon, suddenly found that it too had a problem on its hands with 25 per cent of the trees in the Vosges mountains to the west of the Rhine valley in a sickened state. France reacted quickly by introducing a series of measures to reduce 'harmful emissions'.[3]

In Britain controversy still rages as to whether any of its trees are suffering the effects of waldsterben. In its 1984 survey on *Forest Health and Air Pollution* the Forestry Commission spoke of its scepticism that its own forests in the United Kingdom were suffering the effects of the disease. The Commission thus emphasised that the yellowing of needles found in spruce in West Germany was not a symptom found in Britain. It also suggested that the true extent of waldsterben in Europe had been exaggerated, insofar as many areas within the overall regions covered in the survey remained clear of the disease. Thus the 11,000 hectares given as the total area of dead trees in a 1984 West German report, were made up, said the Commission, of the sum of a multitude of pockets of the disease rather than representing entire devastated regions. "The phenomenon is still to date essentially one of scattered decline and death."

And where the forestry commission has found a new type of forest damage, for instance in Cumbria and the west of Scotland, including browning of needles and needle loss, the cause is considered to be climatic stress rather than air pollution. Damage to trees elsewhere in Britain, affecting between 30 and 50 per cent of the stock, most of it classified as "slight" is not suggestive, say the commissioners of "a new or unusual state of affairs". The Commission, in fact, went to considerable lengths to blame the hard winter of 1983/4 for the damage, claiming that it "began to occur in March, and became first evident in pines which showed quite severe browning in some parts of the country, particularly Cumbria."[4] Dr W.O. Binns for the Commission did admit that "the damage bears striking similarities to damage that occurs in Germany which has been described by Professor Schütt". However, Dr Redfern, Binn's colleague at the Commission, claimed that "crucial differences between the new, widespread and severe damage" to British and German trees were that British conifers did not exhibit "needle yellowing" and especially no magnesium deficiency, and that the damage all dated to the winter of 1983/4 except in "one or two very rare exceptions."



Beech: Crown thinning and cluster twigs.

Taking its cue from the Forestry Commission, the Department of Environment stated to a House of Commons Select Committee on Acid Rain: "Although a new form of damage to trees has recently been observed in north and west Britain, this bears only a superficial resemblance to that associated with air pollution in Germany[5]." Meanwhile the Forestry Commission spread the word to the Press that . . . "there is no sign of the yellowing of needles which characterises the damage occurring in German forests . . . This survey (its 1984 survey) has shown no signs of the damage seen in West Germany nor any unexpected abnormalities and is thus very reassuring . . .".

Sceptical of the Forestry Commission's conclusions Friends of the Earth has been carrying out its own survey of damage to British trees, and its conclusions, supported by evidence from German and Scandinavian forestry experts, are of widespread disease to a variety of species of trees, both coniferous and broadleaf, that matches closely the pattern of disease in Europe. Dr Joachim Puhe, from the University of Gottingen, after a brief visit to Britain in May 1984, during which he visited 47 sites, including the Lake District and Forest of Dean, reported to Friends of the Earth: "If we had observed these signs in Germany we would have classified them as being caused by air pollution[6]." It later transpired that it was his remarks that first prompted the Forestry Commission to carry out its own 1984 survey—and on the strength of its survey to deny any association with waldsterben.

But the Commission's insistence that essential differences exist between the British and German disease, and therefore its reassurance to the British Government that air pollution is not the cause in the UK, finds no echo abroad. Thus, with regard to the lack of yellowing in Britain, Peter Schütt pointed out that: " . . . yellowing discolouration of needles is not a typical symptom of forest decline, it is a symptom of the high elevation decline and it is not true that forest decline only or mostly occurs in high elevations in the mountains. We have the same intensity in the flatter parts of the country over very, very large areas, and a typical symptom of this decline is the dropping of green needles and leaves, and not yellow ones. We are relatively sure that the discolouration which appears only in the upper elevations is closely connected with the foggy conditions."[7]

In setting up its own survey, Friends of the Earth did not attempt to emulate that carried out in 1984 by the Forestry Commission. Indeed it was critical of the Commission on a number of counts, particularly that trees under 45 years were selected for inspection when on the continent the damage appeared to be at its worst in trees of 60 years of age and older. Furthermore, the Forestry Commission avoided looking at silver fir, the species found to be most vulnerable to waldsterben, and to broadleaf species such as beech. And because of its assumption that the most exposed trees at the edge of the stands would be the most likely to suffer the ill-effects of weather, they too were ignored in the survey; yet it is precisely those most exposed trees that are the first to suffer waldsterben damage. For instance, trees on hilltops and on slopes may receive six times more pollutants from a point source than those down in a nearby valley. In Germany the worst damage has been found on those slopes where deposition of wet and dry pollutants is highest.[8]

Because both species are native over most of their range in Britain, Friends of the Earth decided to concentrate their survey on yew—*Taxus bacca*—which shares many similarities with Douglas Fir, and on beech. In their final report, *Tree Dieback Survey* for Friends of the Earth, Chris Rose and Mark Neville comment that they were "struck by the similarity of the pattern of growth, needle retention and loss between yew and fir, particularly Douglas fir which we were shown in Holland in May (1985) near Eerbeek. In New Year 1985, one of us had noted a spate of damage to yews in the London area. It may be a coincidence that this was a period of particularly low temperatures, sustained frosts and very high episodes of sulphur dioxide pollution in the area. Our attention was drawn to the yellowing, bleaching and drop of older needles, the shedding of green year-shoots and sudden twisting and wilt of foliage on yew at this time, together with the appearance of brown tips with chlorosis on adjacent tissue, because these symptoms were consistent with published descriptions of sulphur dioxide damage and the combination effects of SO_2, acid rain in general and frost."

Beech was chosen for the survey because the symptoms seen on trees on the Continent were unequivocal, including leaf curl, green leaf fall and 'cluster twigs' where the foliage gathers on stunted short side twigs, the lateral branches that are normally found in healthy trees, dying off.

Some 500 people took part in the FoE survey, 372 sites being surveyed for beech and 427 for yew, much of it growing in churchyards. Of 1,638 beech only 30 per cent appeared to be healthy, with 14 per cent showing advanced 'die-back' and 2 per cent moribund. Only 22 per cent of 1,546 yew were found to be healthy, an equal proportion displaying the symptoms of advanced die-back and 4 per cent being close to death.

In addition to the survey on beech and yew in which Rose and Neville claim to have found symptoms that match the waldsterben symptoms found on the Continent, Friends of the Earth invited Professor Bengt Nihlgard of the University of Lund in south Sweden, to examine the state of some woods in England and Wales in the light of his knowledge of tree diseases in Sweden. In his report he noted that "Norway spruce was often in a really bad condition . . . The needle loss was usually more than 50 per cent and the needles also showed the gas necrosis symptoms on older needles, visible as tiny yellow spots, soon attacked by fungi and causing an early needle fall . . ." Professor Nihlgard also made comments on oak and birch, in the latter, remarking that "you could see straight through the canopy . . . I have noticed this type of birch in Scania only in the most 'acid rain' impacted west region . . . Summing up I must say that the only place where I have seen correspondingly bad situations in Central Europe before is around the biggest airports in West Germany. Not even in Ertzgebirge, where spruce is dying at soil pH of about 2.2 and

WEST GERMANY—WALDSTERBEN

The forestry Commission's complacency at the state of its own forests, contrasts sharply with that of foresters elsewhere. West Germany has undoubtedly set the standards and created the methodology for surveying damaged, diseased trees. In Baden—Württemberg, for example, which encompasses the Black Forest, almost the entire forested area has been checked on the ground and through aerial survey, using infra-red photography to pick out sick and dying trees. In the forestry journal *Allgemeine Forst Zeitschrift* of December 1984, the originators of the surveying technique, Professor Walter Schöpfer and Dr Joachim Hradetzsky of the University of Freiburg, report the results for 1983 and 1984 in which the state of health is assessed according to four grades of needle or leaf loss, representing normal through sickly to very sick and dying. The data reveal an extremely sorry state of affairs particularly among the trees older than 60 years.

Thus by 1984 only 15 per cent of spruce could be considered healthy with some 50 per cent showing signs of damage, 25 appearing sick and 5 per cent very sick. The situation was even worse for fir. Meanwhile only 60 per cent of beech and oak were found to be healthy, with at least 10 per cent in the very sick bracket. Both oaks and beech are hardy trees in general, oaks particularly so, and their succumbing to waldsterben, although proportionately less compared with conifers is a worrying sign.

On the ground the inventory is carried out on the basis of checks every four kilometres apart in a north to south direction. Six trees are then sampled at the four points of the compass 25 metres away from the reference point, making a total of 24 trees per 4 kilometres. In that way the entire forested region of Baden-Würtemberg has been covered, some 60 foresters being involved in the inventory. 1983 was the first year, with three years, 1985 included, being completed so far.

The aerial survey has been established to speed up the process and reduce costs. The planes, flying at 5,000 feet make passes in a north to south direction every 8 kilometres apart, the intention being that they will be covering at least some of the trees studied from the ground. In fact, good correlation has been found, an experienced observer being able to pinpoint the state of health of an individual tree from the colour and shape of its foliage as seen in the three-dimensional aerial image. The infra-red film filters out blue light and so is able to penetrate haze; it also picks out subtle differences in the foliage, a healthy specimen appearing yellow in the film; one with a 20 to 40 per cent loss of needles or leaves showing up as green; 40 to 60 per cent loss, red; 60 to 80 per cent, blue; and 80 to 100 per cent loss as violet.

with very high sulphur dioxide episodes, have I seen similar damage to all the deciduous trees."

Waldsterben—The Causes

The suddenness with which the trees of Europe have become sick and the lack of an obvious pathogen suggests that the cause itself may be new. Few doubt that the cause must be linked in some way to man's industrial activities, but the question then arises as to what is new and different today with regard to pollution compared with pollution in the early post World War 2 years. Or is the damage now evident among Europe's forests the result of an accumulation of pollution going back 50 years or more into the industrial past?

A number of hypotheses have been proposed, none of which on their own seem to satisfy all symptoms in all places where damage is manifest, and the idea that waldsterben is the result of general stress brought about through a combination of man-induced changes in the environment, some stronger than others in different places, is gaining ground. Most foresters are now agreed that trees are becoming unusually susceptible to climatic stress, whether droughts or heavy frosts, but like the patient dying of pneumonia the real nature of the disease is to be sought elsewhere.

The Aluminium Hypothesis

Perhaps the best known explanation for waldsterben is Bernard Ulrich's acidification—aluminium toxicity hypothesis, which he and his colleagues proposed in 1979, even before any real damage to the forest had been detected. Based on long term studies of nutrient cycling on the Solling plateau near Göttingen, Ulrich proposed that acid deposition from the atmosphere was accelerating the natural acidification of forest soils with the result that aluminium mobility was considerably enhanced. The fine roots of plants were found to be particularly sensitive to aluminium, suffering necrosis and losing their ability to take up water and essential nutrients. Trees would therefore become stressed, particularly in extreme climatic conditions.

Other Possible Causes of Disease

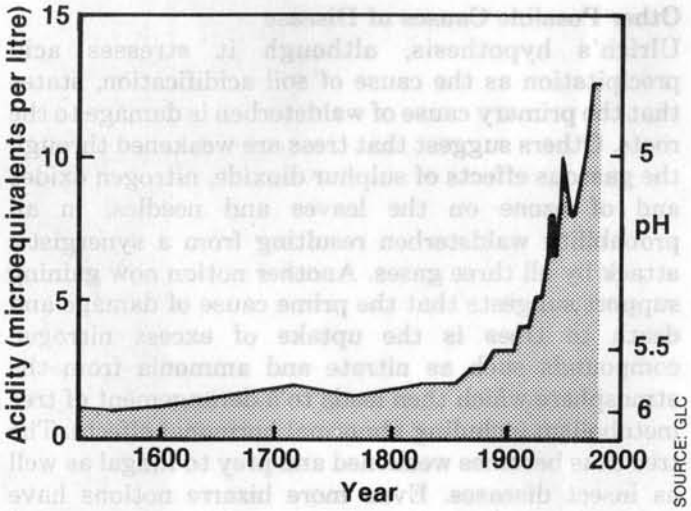
Ulrich's hypothesis, although it stresses acid precipitation as the cause of soil acidification, states that the primary cause of waldsterben is damage to the roots. Others suggest that trees are weakened through the gaseous effects of sulphur dioxide, nitrogen oxides and of ozone on the leaves and needles, in all probability waldsterben resulting from a synergistic attack by all three gases. Another notion now gaining support suggests that the prime cause of damage and death to trees is the uptake of excess nitrogen compounds such as nitrate and ammonia from the atmosphere which then leads to a derangement of tree metabolism including abnormal hormonal effects. The tree thus becomes weakened and prey to fungal as well as insect diseases. Even more bizarre notions have been floated, including one in which the increased ionisation of the atmosphere through gaseous dis-

charges from nuclear power stations and through the transmission of electricity along high voltage power lines amplifies the effect of other pollutants in the atmosphere. Microwaves emitted by radar stations and communication transmitters have also been implicated. Studies in southern Germany indicate much higher levels of damage to trees downwind of nuclear power stations and close to transmission lines.

Sulphur Dioxide and Acidification

Unequivocal evidence has now been gathered to show that soils, lakes and rivers in parts of Europe, Scandinavia and North America have become acidified in recent years. In general areas with young soils and therefore reduced buffering capacity appear to be most at risk. As long as 15 years ago we pointed out in *The Ecologist* (Vol 1, No 3, 1970) that rain and snow falling over many parts of the northern hemisphere were becoming increasingly acid. Rainwater is normally on the acid side, with a pH close to 5.6, on account of dissolved carbon dioxide as well as of biogenic sources of sulphur and nitrogen oxides. By the early 1970s median pH values had fallen a full unit or more from the normal, suggesting a ten-fold increase in acidity. Since then rains of extreme acidity have been recorded in different parts of the northern hemisphere, one downpour over Pitlochry in Scotland in April 1974 registering a pH of 2.4, therefore 1,000 times more acid than normal. Even lower pHs have been measured.

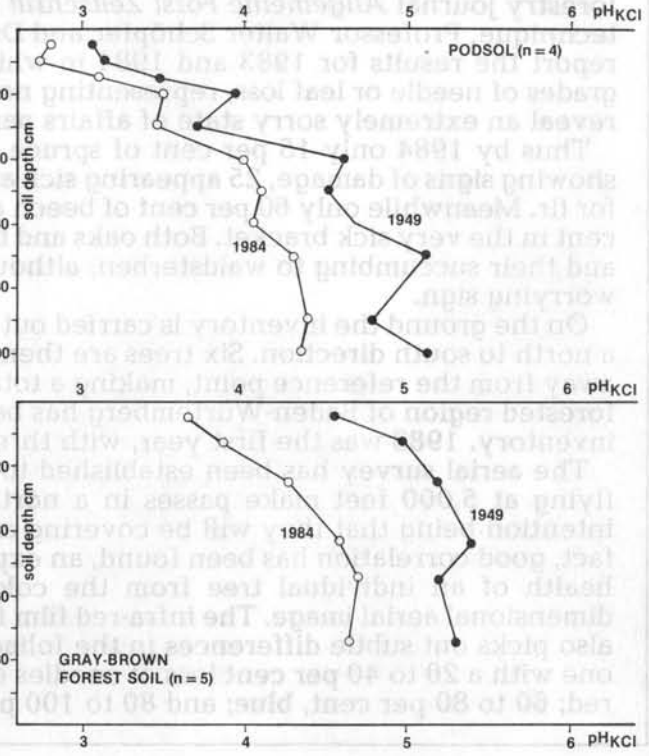
Many lakes and streams in Canada and Scandinavia have become acidified in recent years, with pHs dropping below 5. Indeed studies of siliceous phytoplankton in the sediments of lakes in Sweden and Scotland indicate that the pH remained relatively stable, around 6 for centuries, until the late 19th century, when it began to fall precipitously. Like Ulrich's hypothesis for the trees, high aluminium concentrations in the water, brought about through leaching from acidified soils, is blamed for killing off the fish, salmon and trout being particularly sensitive to both acid and aluminium. In Canada and Scandinavia the decline in the populations of Atlantic salmon has been particularly rapid since 1940 and many lakes and rivers are now fishless.



Reconstructed acidity of Round Loch of Glenhead, a small lake in SW Scotland.

Damage to Soils

Until recently soils were considered relatively insensitive to acidification, it being believed that most of the acid brought down in precipitation would run off in groundwater or be adequately neutralised in the soil. However soil analyses carried out in southern Sweden in recent years both under spruce and broadleaf forests



The pH changes at different depths between 1949 and 1984 in forest soils of south Sweden. Means of four podsols (above) and five gray-brown forest soils (below). The average pH decrease is 0.7-0.9 units in most horizons of the gray-brown soils and the B horizon of the podsols. (From: Falkengren—Grerup 1985)

such as oak even when growing on calcareous bedrock show a substantial decrease in pH compared with measurements made some 40 years ago; moreover the fall in pH, of 0.7 units or more, is found throughout the soil profile, indicating that the soil's buffering capacity has already been surpassed. As Professor Germund Tyler, of the Department of Ecology at the University of Lund, points out, a decline in the pH of 0.7 is enough for half the base cations, including calcium, magnesium and potassium, to be lost from the soil and replaced by hydrogen and aluminium.

Tyler professes himself to be astonished at the extent of the change in Swedish soils over such a short period of time and concerned for the future of the forests should soil acidification continue. Spruce forests are particularly prone to acidification, the reason partly being the greater internal production of acidic constituents compared with broadleaf forests. Another important difference results from the ability of spruce to sequester and concentrate substances from the atmosphere, including hydrogen, aluminium and cadmium ions. These then flow down the stem, adding to the acidity already present in the rainfall. Indeed, whereas rainfall passing through beech and birch may slightly lose its acidity, that passing through the spruce canopy may become more acid by as much as 0.7 of a pH unit. It would appear that

spruce is a particularly bad species to plant when the air is already loaded with acid pollutants. Meanwhile the clear felling of spruce accelerates soil acidification, there being a 0.02 pH decrease following cutting and removing the slash. Leaving the slash will slightly increase pH.

On the other hand Tyler makes it clear that spruce plantations are not in themselves responsible for undue soil acidification. "What we are seeing today," he says, "cannot be the result of a natural biological effect." Tyler therefore subscribes to the notion that the lowering of pH in the soil is having a two-fold effect; first to bring about a significant loss, one half or more, of base cations essential for plant nutrition; and second to dissolve out from the soil toxic elements such as aluminium and cadmium, both of which will have harmful effects on root structure and plant growth. As he points out, many soils in south Sweden have now reached the point where aluminium and cadmium solubility has increased by a factor of three or more.

Acid Rain—The Source

In the 1960s the elctricity generating boards in the UK embarked on a policy of building large fossil fuel fired plants with tall stacks to disperse pollutants. Industry as well as power utilities elsewhere in the world followed suit and increasingly sulphur and nitrogen oxides began to be carried over large distances whereas before they would have fallen out—either as dry or wet deposition—much closer to the source. Equally important, the plumes of gases from tall stacks are carried at heights and for distances where they are more likely to be subjected to photochemical changes. Ozone production through the catalytic action of nitric oxide on hydrocarbon in the presence of sunlight is certainly enhanced in the clearer atmosphere travelled by the plume from industry and power plants.

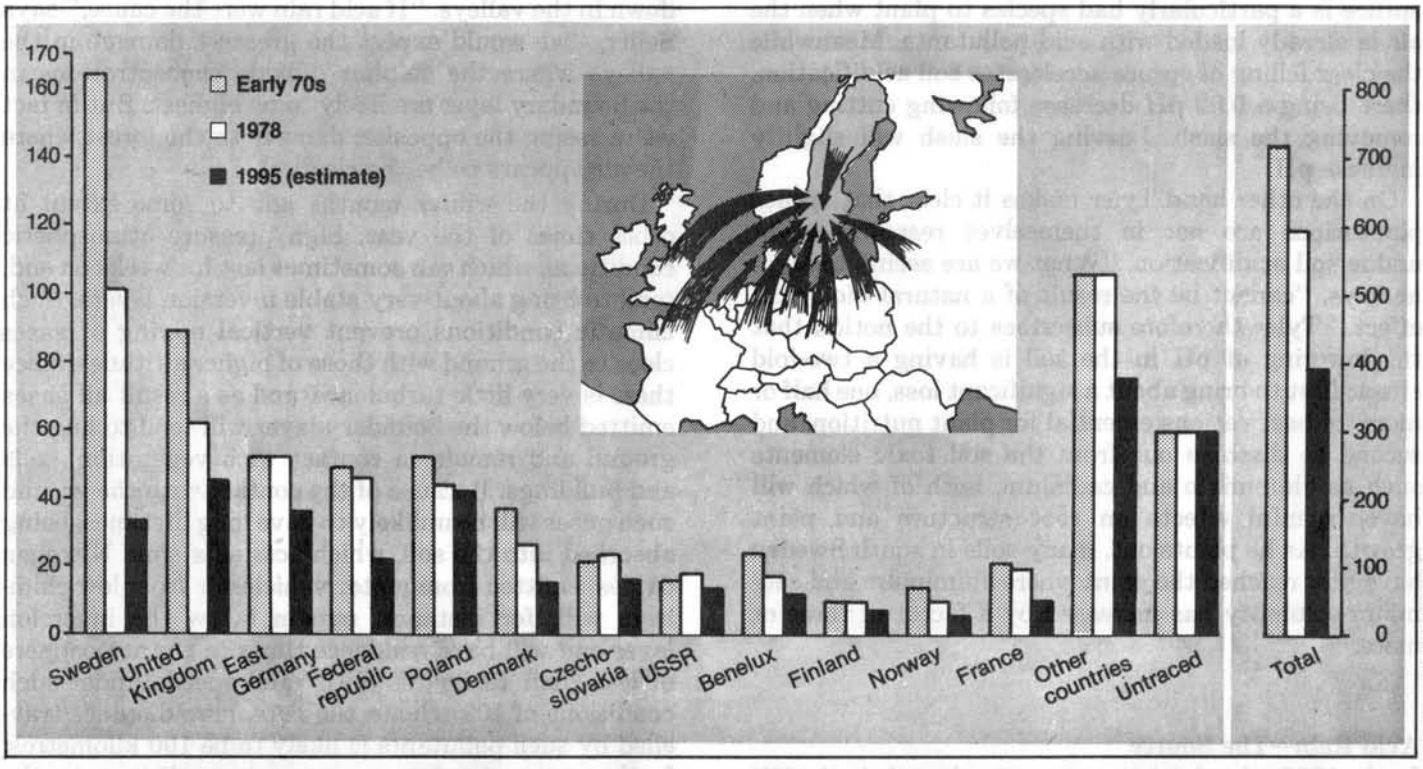
Atmospheric chemists have started to take measurements of the layers of gases resulting from industrial emissions to see how well they disperse and what chemical reactions take place. The technique is to fly 'dolphin style', making rapid ascents and descents through the air to be measured, and that way derive profiles of specific gases such as carbon monoxide, nitric oxide and ozone. Professor W. Seiler, and his colleagues at the Max-Planck Institute for Chemistry in Mainz have followed a massive plume of industrial pollution, 6 kilometres up on its way from Siberia towards the North Pole and back again across Greenland, Britain and then over the North Sea to Germany and the East. They have found distinct profiles for carbon monoxide, the nitrogen oxides and, forming in a layer just above, ozone.

Professor Seiler, like Professor Schütt, is convinced that air pollution, rather than soil acidification, is the prime cause of waldsterben, and like Schütt he believes that a new mechanism is at work. His reasoning is as follows: Single standing trees and trees at the border of the forest tend to suffer the worst damage. Furthermore waldsterben is much more pronounced up the mountainside and facing prevailing winds than down in the valleys. "If acid rain were the cause," says Seiler, "we would expect the greatest damage in the valleys where the sulphur dioxide concentrations in the boundary layer are likely to be highest. But in fact we're seeing the opposite; damage to the forest where the air appears to be the cleanest."

During the winter months and to some extent at other times of the year, high pressure atmospheric conditions, which can sometimes last for weeks on end, tend to bring about very stable inversion layers. Such climatic conditions prevent vertical mixing of gases close to the ground with those of higher altitudes, since there is very little turbulence, and as a result all gases emitted below the boundary layer will tend to hug the ground and remain in contact with vegetation, soils and buildings. Because of the contact with the ground such gases will be unlikely to have long lifetimes, being absorbed into the soil, which acts as a sink. Nitrogen oxides, emitted from motor vehicles or from low chimneys will, for instance, remain below the inversion layer and will have residence times in the atmosphere of less than 10 hours. With wind speeds under such conditions of 10km/hour, the maximum distance travelled by such pollutants is likely to be 100 kilometres; furthermore, the foggy, overcast conditions in the inversion layer will prevent any photoxidation, and little ozone will be generated.

On the other hand, above the inversion layer, some 300 to 500 metres above sea level, the sky will be completely clear and the hills exposed to brilliant sunshine. Seiler is convinced that it is there, up in the clear sky, that the real damage to the forests is taking place, for it is just at those altitudes, above the boundary layer, where one finds the plumes of pollutants that have been emitted from tall stacks. And at such altitudes the winds are strong enough and constant enough to carry the pollutants for many hundreds of miles from the source. Seiler therefore suggests that a flow of concentrated pollutants are impinging on the exposed forest just above the inversion layer, where because of temperatures from as low as -10°C all kinds of substances, including photoxidation products, become trapped in ice that forms on the needles. Formaldehyde would be one of the substances arising from photoxidation, and it may be that toxic compounds are formed as a result of interactions with substances such as terpenes and isoprenes released from the needles.

No research has yet been carried out to prove or disprove Seiler's thesis; nevertheless there is one corroborating fact: the trees most affected in the Black Forest above Freiburg are those facing the prevailing winds coming across the Rhine valley from France and Switzerland at an altitude which coincides with the upper part of the inversion layer. Furthermore, as gaps are created in the forest through the death of trees, the disease is carried in, suggesting that the cause must be windborne. Indeed foresters in the Black Forest are now struggling to keep the forest dense to create a buffer and prevent wind penetration. How successful they will be remains to be seen, but young trees planted to replace those lost appear, for the time being, to be growing normally.



Sources of the sulphur deposited over Sweden, thousands of tons per year. Actual and estimated amounts up to 1995.

Sulphur Deposition

As a result of the industrial revolution the quantities of sulphurous gases released into the atmosphere have become very large. The USSR probably tops the world with emissions of 25 million tonnes of sulphur dioxide each year, followed closely by the USA with 24 million tonnes. Then comes China with 12 million tonnes, followed by Britain with some 4.7 million tonnes. Most of the other European countries, including the eastern bloc, and Canada have emissions in the range of 2.7 to 4.5 million tonnes. A broad assessment of the anthropogenic sources of sulphur dioxide emitted into the atmosphere suggest a worldwide total of 100 million tonnes, with the major contribution by far coming from the industrialised countries of the Northern hemisphere.[9]

How much man's sulphur-releasing activities compare with the natural sulphur cycle is not properly known. Atmospheric chemistry is a relatively new discipline and it is only in recent years that some of the complexities of the chemical interchanges between land, sea and the atmosphere have been unravelled. Living organisms, particularly marine algae, are now known to play a major role in the sulphur cycle. Indeed the discovery of sulphur dioxide at levels around 80 ($\pm$30) parts per trillion by volume high over the remote oceans indicates a source of the gas other than from volcanic activity or from man's industrial activity.

Undoubtedly that enormous input of sulphur into the atmosphere, most of it in the northern hemisphere from man's activities, is altering atmospheric gas balances. In *The Ecologist* Vol 15, No 3 1985 we pointed out that atmospheric oxidation processes might well be accelerated in the northern hemisphere as a result of nitric oxide acting as a catalyst in the production both of ozone and hydroxyl, through interactions with carbon monoxide released through combustion and with hydrocarbons such as methane.

THE SEA — AN IMPORTANT SOURCE OF SULPHUR

In 1972, Professor Jim Lovelock and his colleagues[10] found relative high concentrations of the volatile gas, dimethyl sulphide, over the ocean and suggested then that dimethyl sulphide might be a possible contender for the generation of large quantities of biogenic sulphur dioxide through its rapid interactions with the free, highly active hydroxyl radical. As a source of sulphur in the atmosphere, the dimethyl sulphide was likely to be just as important, said Lovelock, as that emitted through anthropogenic processes.

More recently, Meinrat Andreae and others have found high levels of dimethyl sulphide associated with photosynthetic activity, as measured by chlorophyll concentrations in the surface layers of the ocean. The most abundant producers of the volatile sulphur compound are minute, exquisite organisms known as coccolithophorids, and haptophytes such as *Phaeocystis poucheti*. In all probability the precursor of dimethyl sulphide is the osmotic substance, dimethyl sulphoniopropionate, which enables organisms to withstand high salt concentrations, such as those found in the normal marine environment.

Preliminary measurements indicate that the global sea-to-air sulphur flux from dimethyl sulphide lies in the range of 39 million tonnes per year. Dimethyl sulphide and other reduced sulphur compounds are also released from continental sources, including salt ponds, and D.F. Adams and his colleagues calculate the amount of sulphur from such sources as 64 million tonnes worldwide, one-fifth from dimethyl sulphide. The total global biogenic sulphur flux is now estimated to be 103 million tonnes annually; practically equal therefore to the anthropogenic flux of 104 million tonnes. (See *D. Sagan, Towards a Global Metabolism—the Sulphur Cycle*, p.14).

Nitrogen oxides—catalysts to environmental disaster

Nitrogen oxides are formed during high temperature combustion, as occurs in motor vehicles and, particularly since the 1940s, there has been a spectacular two or three fold rise in the emission of such gases in industrialised and industrialising countries. Primarily because of the continuing increase in road traffic throughout the world the levels of nitrogen oxides are still rising, in contrast to those of sulphur dioxide. In 1982, for example an estimated 1.8 million tonnes of nitrogen oxides were emitted in the UK, split equally between power stations—42 per cent—and road vehicles. The remaining 16 per cent came from other industries and from the release of nitrogen oxides from the oxidation of nitrogen-containing artificial fertilisers and farmyard manures.

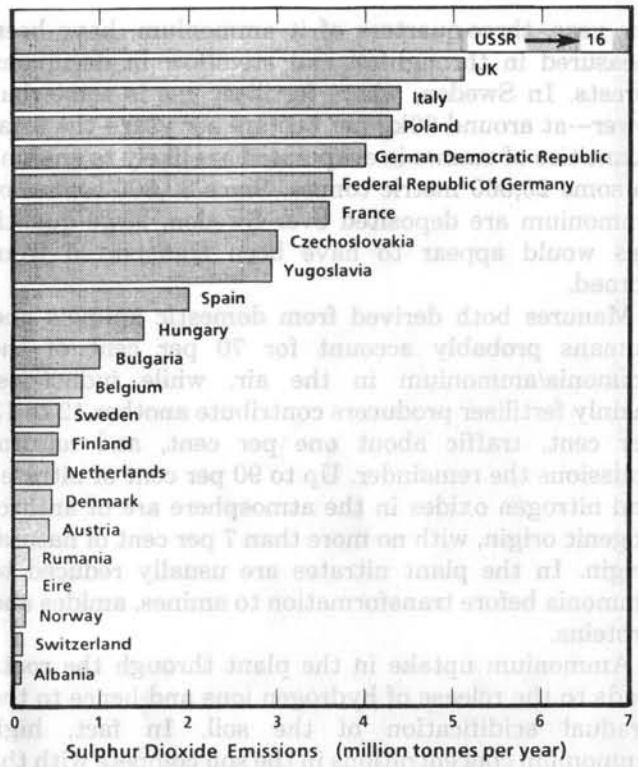
The importance of nitric oxide as a catalyst in atmospheric photo-oxidation reactions should not be underestimated. Paul Crutzen, at the Max-Planck Institute for Chemistry in Mainz, estimates that for each molecule of methane oxidised in the atmosphere in the presence of nitric oxide, as many as five ozone and two hydroxyl radicals may be produced. The net result is the generation over an extremely short period of time of an atmosphere which will cleanse itself very rapidly of gases such as sulphur dioxide and its precursors, depositing them as acid rain.

Therefore, even though the total quantities of sulphur-bearing compounds emitted into the atmosphere may have remained much the same over the past half century, the rate of deposition may have increased considerably. Should such a mechanism prove correct, action taken through flue-gas desulphurisation to reduce sulphur emissions may not be enough. Equally NO_x reductions through catalytic converters or through reductions in the temperature of combustion would appear to be essential.

Britain's Record

Britain's fossil fuel power stations are a major source of air-borne sulphur compounds over Europe, particularly over Scandinavia, and as much as 8 per cent of the sulphur deposited in Sweden comes from British sources, making the UK the single largest contributor from overseas. Should the British Government and the Central Electricity Generating Board continue to refuse to comply with the EEC 1984 draft directive on acid rain and so ignore requests to install flue gas desulphurisation units, then by 1995 Britain will be exporting more sulphur to Sweden than will actually be generated there.

The levels of sulphur fall-out in relatively pollution-free areas, the more northerly parts of Canada for instance, amount to less than 10 kilograms per hectare per year. The average levels in open country in south Sweden are as high as 24 kg/ha/year and therefore sufficient to cause damage to soil and surface waters. Indeed A.E. Lucas and D.W. Cowell state that: "A loading of 20 kg/ha/year of sulphate in precipitation has been identified as being clearly associated with degradation of the more sensitive surface water[11]". In Sweden at least 18,000 out of 20,000 lakes are now acidified to the point where they are incapable of supporting fish. Nevertheless the controversy over the origin of the sulphur continues. Professor Lovelock has added to the polemic by pointing out that the North Sea is becoming a gigantic 'eutrophied' lake with massive algal blooms being formed as a result of fertiliser and sewage run-off. The net result of those blooms will be the production of large quantities of sulphur-bearing compounds.



Estimated sulphur dioxide emissions in Europe in 1980.

Nitrogen and the Ammonium Hypothesis

The precipitation of nitrogenous compounds from the atmosphere has increased by a factor of between 20 and 60 over certain regions compared with clean areas. For instance over 'clean' parts of the United States and Scandinavia the deposition rate for nitrogen compounds such as ammonium and nitrate is less than 1 kg/ha/year. Over parts of south Sweden as much as 20 kg/ha/year are deposited and at the edge of some forests as much as 60 kg/ha/year. Professor Bengt Nihlgard points out that trees in particular become stressed at such high levels of nitrogen metabolites, and he believes that excess nitrogen may be a prime cause of waldsterben.

According to Nihlgard the ammonium concentration in bulk precipitation has increased 2 per cent per year and nitrate by 4 per cent a year since the 1950s. Compared to natural biological fixation of nitrogen, the deposition rate may be from 10 to more than 100 times greater.[12]

Most of the ammonium deposited derives from fertiliser, as much as 10 per cent of that used evaporating into the atmosphere before precipitation. In the Netherlands where as much as 580kg of nitrogen per hectare are applied to farmland each year, the quantities volatilising and falling-out are considerable. Indeed figures exceeding 60kg of nitrogen per hectare

per year, three-quarters of it ammonium, have been measured in throughfall and stemflow in deciduous forests. In Sweden, where fertiliser use is somewhat lower—at around 80kg per hectare per year—the total quantities of ammonia evaporated are likely to amount to some 25,000 metric tonnes. Since 80,000 tonnes of ammonium are deposited over Sweden, large quantities would appear to have been transported from abroad.

Manures both derived from domestic animals and humans probably account for 70 per cent of the ammonia/ammonium in the air, while industries, mainly fertiliser producers contribute another 12 to 13 per cent, traffic about one per cent, and natural emissions the remainder. Up to 90 per cent of nitrates and nitrogen oxides in the atmosphere are of anthropogenic origin, with no more than 7 per cent of natural origin. In the plant nitrates are usually reduced to ammonia before transformation to amines, amides and proteins.

Ammonium uptake in the plant through the roots leads to the release of hydrogen ions and hence to the gradual acidification of the soil. In fact, high ammonium concentrations in the soil compete with the uptake of magnesium which is essential for chlorophyll functioning and protein synthesis. Ammonia and ammonium are also taken up by the leaves through the stomata as are nitrogen oxides. Such uptake may cause visible damage to the leaf, including chlorosis and necrosis, and physiological damage owing to the loss of essential ions such as potassium and magnesium.

Analyses of frost-damaged young spruce trees in south Sweden indicated excess nitrogen in the needles, half of which was found to be non-protein. The most affected trees had a nitrogen content of three per cent in their needles compared to normal levels of 1.3 to 1.8 per cent. Levels higher than 1.8 to 2.0 per cent are associated with reduced frost hardiness. Excess nitrogen makes trees vulnerable to fungal diseases as well as insect attacks, supporting Chaboussou's trophobiosis theory[13] in which unbalanced nutrition leads to excess amino acids in plant cells (see this issue p. 29). One curious phenomenon related to excess nitrogen is the growth of a greyish blue algal slime over the needles. Spruce in south Sweden, particularly those at the edge of a stand appear to be most affected in this way.

Other studies show the roots of trees to suffer damage when excess available ammonium is present in the soil. The microbial biomass as well as the mycorrhiza tend to decrease, probably because of reduced secretion of mucopolysaccharides from the tree roots, and as a result phosphate uptake into the plant may be impaired, adding to the deficiency problems associated with high levels of ammonium and nitrates in the leaves.

Ozone

High nitrogen oxide levels in the air when hydrocarbons are present lead inevitably to ozone production. In many parts of the northern hemisphere ozone concentrations are already at levels where they may do damage. For instance in south Sweden and parts of West and East Germany levels may exceed 200 micrograms per cubic metre during the summer months. The highest levels recorded are at Rim Forest close to Los Angeles, reaching as much as 1160 micrograms per cubic metre on occasions.[14] The average ozone levels now found in such 'clean air areas' as the southern Black Forest and the Bavarian Forest range from 60 to 110 µg per cubic metre.[15]

Fumigation experiments to test the effects of ozone on various tree species indicate varying sensitivity. Ozone levels of no more than 60 µg/m³ over 48 hours have caused visible damage to *Pinus strobus* (eg stern white pine) and of 100 µg/m³ for 80 hours to *Pinus ponderosa*. On the other hand, certain broadleaf species such as beech and oak are relatively tolerant to ozone. The silver fir, *Abies alba*, also appears to be tolerant and fumigation continuously with 600 µg/m³ for 56 days has failed to produce visible symptoms.[14] Nevertheless, as Arndt and his co-workers point out, much lower concentrations of 100 µg/m³ delivered for 7 hours daily over 42 days bring about a reduction in photosynthesis.

Overall Pollution

In fact those species most affected by waldsterben in West Germany and elsewhere in Europe and Scandinavia appear to be those that are most resistant to the effects of ozone. Yet in many instances the affected trees are in those 'clean air areas' where ozone levels are high compared to those of other atmospheric pollutants, and one possibility is that the same or similar photo-oxidation processes that give rise to ozone are giving rise to other phytotoxic substances whose effects have not yet been evaluated. That brings us again to Professor Seiler's boundary layer theory in which intense photo-oxidation just above the inversion layer gives rise to a pot pourri of highly reactive chemicals, ozone and hydroxyl included. Should that be the case, then at least for the higher altitude damage to trees, tall stacks and the transboundary flow of pollutants may well be responsible. It would fit the facts too that tall stacks are a relatively recent phenomenon and their use is coincident with the manifestation of waldsterben.

However the die-back of trees is now taking place in a number of different environments, some more or less exposed to classical pollutants, and we can only conclude that a number of different processes are at work, a combination of which are damaging to trees, even to pollution-resistant species such as oak. We have now altered radically the chemistry of our atmosphere, particularly in the northern hemisphere, and one main consequence is that we have accelerated the natural process by which sulphur and nitrogen-bearing compounds are recycled between the land, sea and atmosphere. Acid rain is just one such consequence.[16]

For too long we have considered the global commons—the land, seas and air—as repositories for our effluent and waste without considering that even subtle changes in the natural balance will have wide-reaching effects. We have yet to feel the full impact of

increased carbon dioxide and other greenhouse gases such as methane on our climate, but in the meantime we cannot expect to operate our cars, factories, and intensive agriculture systems with impunity. What goes up must come down, albeit transformed into a more virulent form.

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PHOTO: HANS ÖSTBOM

Clear evidence of the deposition of foreign pollutants upon Sweden.

Towards a Global Metabolism— the Sulphur Cycle

by Dorion Sagan

Certain elements form part of the planet's lifeblood, indeed carbon, sulphur, nitrogen, phosphorus, oxygen and hydrogen are, together with other elements, essential to life on earth. Yet the amounts available to the biosphere are limited at any one time and so like blood in the organism such elements must be continually recycled through the system. But unlike an animal, there is no central heart pushing this global flow in a simple beat, but rather a complex of different forces all pulsing in syncopated rhythm. These cyclers include wind and ocean currents, the uplift and erosion of the earth's crust and the metabolism and motion of organisms themselves.

Although it has become more feasible, tracking out global elemental cycles is still a Herculean task. But NASA, in its studies of planets as whole entities, is turning its resources toward Earth. Every other year a NASA-supported group called Planetary Biology and Microbial Ecology (PBME) brings academics, researchers and space scientists together to consider the connections between life and the elements it needs to sustain itself. In 1980 the group ambitious, but naively looked at all the elements. In 1982 the focus was carbon. In 1982 PBME-NASA tried to determine sulphur's elusive path through the "veins" of the world. Clearly, if we are to understand the contribution of sulphur to acid rain we must first find out the essential components of the sulphur cycle.

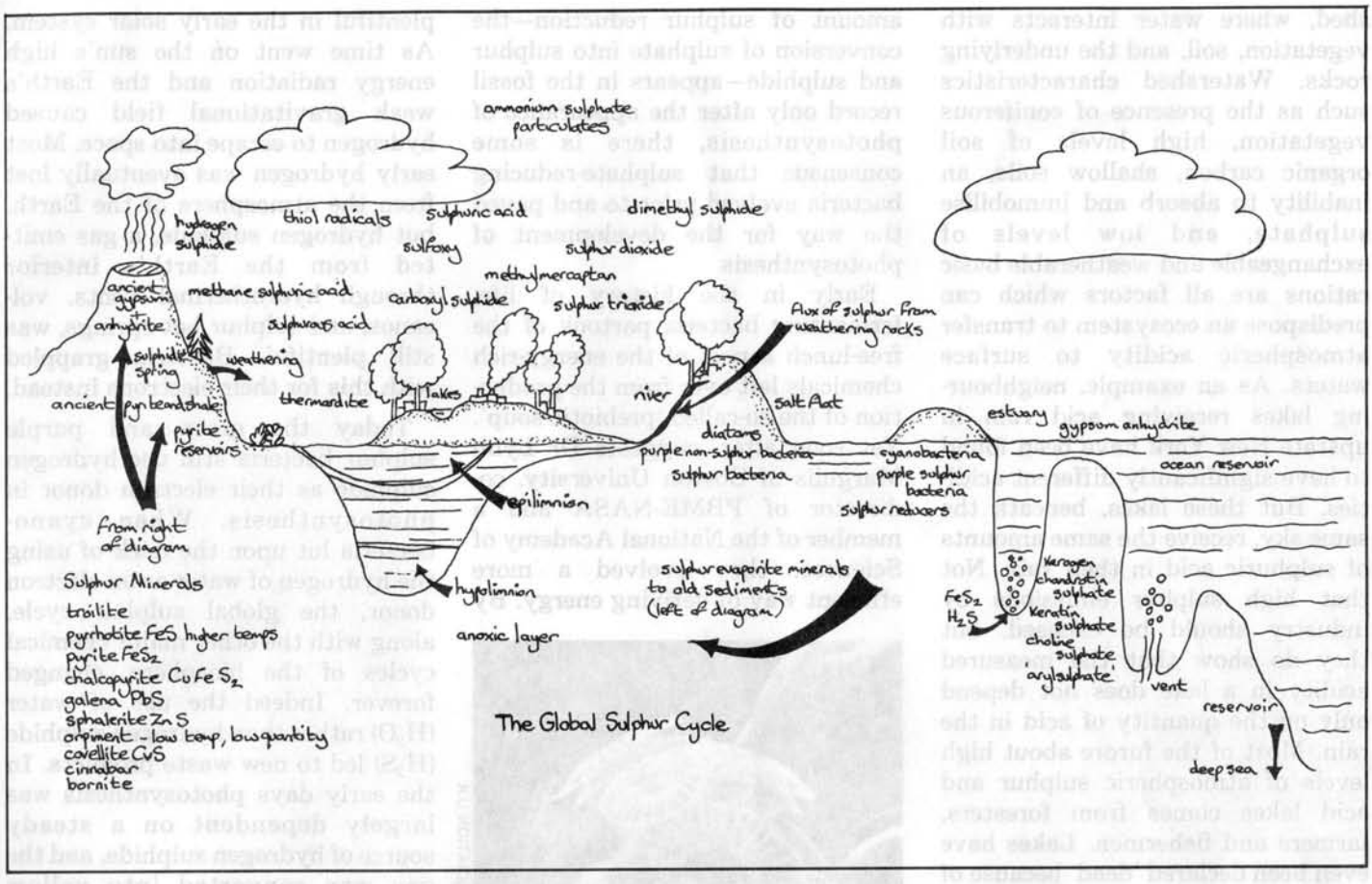
Many of the major transformations that make elements accessible to life take place in hot springs, salt flats, and deeply textured sediments called microbial mats. Participants of PBME met in San Jose, California and explored the San Francisco Baylands, Alum Rock Wild Life Refuge, and Big Soda Lake in the two-casino town of Fallon, Nevada. In piecing together the puzzle of sulphur—using microbes and the global sulphur cycle, PBME-NASA's valiant long-term goal, through a blend of space technology and microbiology is to come up with a map of global metabolism. But in the short-term the scientists must go amid the stench of rotten eggs and cabbages, and brave pools of mud.

Just as metabolism may be defined as the complex of chemical activities that maintain the structure of organisms and their component cells, so the metabolic activities of all organisms sharing the Earth are intimately linked in giant metabolic cycles. Sulphur, part of this earth-wide metabolism, is found in the proteins of all organisms and is therefore required for all growth. The element exists in both hydrogen-rich forms and in highly oxidised forms. Chemical reactions from hydrogen-rich to oxidised compounds yield energy. Life processes sulphur and other elements through such chemical reactions, building up cell material or releasing energy for physiological processes. Many bacteria, such as *Desulphovibrio*, *Desulphuromonas*, and *Desulphotomaculum* turn oxidised sulphates and sulphur into hydrogen-rich sulphides. Sulphides, often in the form of the gas hydrogen sulphide, are then used as an energy source for other bacteria, such as the long filament *Beggiatoa*. But while *Beggiatoa* need oxygen to get energy from sulphide, photosynthetic bacteria like *Chromatium* can oxidise sulphide in the light and absence of gaseous oxygen, by using instead the oxygen bound to metabolites such as lactate, pyruvate or ethanol.

Microbes are the key to the concept of element circulation and they can be important in bringing about the deposition of major sulphur-containing minerals, such as the gypsum found in salt flats. According to Professor William Holser of the University of Oregon in Eugene, even pyrites, the familiar iron sulphide mineral known as fool's gold, is a result of bacterial action on marine sulphate. If such mineral deposits depend on, and in a real sense are part of life, why are they considered static, inanimate, and nonliving? In fact, it may be better to look at such deposits as part of a global skeleton or storage system, one that is drawn upon by life in the way a pregnant woman draws upon the calcium of her bones to feed an unborn baby.

Until recently the general belief has been that little sulphur is in the atmosphere except for that in oxidised sulphur compounds coming from coal mining and other industrial activities. But the discovery of atmospheric dimethyl sulphide has given rise to a change of perception. Ten years ago dimethyl sulphide, which "makes the sea smell like the sea", was found to be the source of huge amounts of sulphur that passed from the ocean to the atmosphere. These sulphurous migrations, like most chemistry on Earth, are largely the result of life.

Dorion Sagan *is a writer of science and magician. His recent books are* Origins of Sex, *published in early 1986 by Yale University Press and* Microcosmos: *Four Billion Years of Evolution from our Bacterial Ancestor, published by Summit Books, Simon and Schuster, N.Y. (Both books co-authored with L. Margulis.)*



The Global Sulphur Cycle

Dr Meinrat Andreae at the Department of Oceanography in Florida State University has now discovered a correlation between the population density of marine algae such as *Phaeocystis* and *Emiliani* and the build up of dimethyl sulphide over the sea. Some of this gas, which brings so much sulphur up from the sea water into the air, is produced by *Phaeocystis poucheti*. This obscure microbe apparently uses the precursor to atmospheric dimethyl sulphide as an osmolyte, to regulate intracellular salt concentration. For oceanic plankton exposed to the vicissitudes of changing salt concentrations, osmolytes are vital commodities. Osmolytes can also be based on nitrogen compounds, but sulphur osmolytes which are major sources of atmospheric sulphur gases appear to be common in ocean-faring organisms.

By no means are all atmospheric sulphur gases produced by microbes. As New York City commuters from Northern New Jersey know only too well, the activities of people also make significant contributions to the sulphur cycle. All factories and automobiles emit sulphur dioxide when sulphur-bearing fossil fuels such as gasoline, coal and oil are burned. In photo-chemical reactions sulphur dioxide and oxygen react in the atmosphere to form sulphur trioxide, the latter then combining in water to make sulphate droplets that become the sulphuric acid which, swept by winds from such places as the heavily industrialised Ohio Valley, falls as acid rain in New York and New England.

According to Dr Andreae, non-human biological processes emit sulphur gases at rates at least comparable to the sulphur dioxide flux from fossil fuel burning. The amount of sulphur dioxide given off from the biota to the air is, he says, of the order of a hundred million tonnes per year. By far the most important processes of the biogenic (nature, as opposed to man-made) release of sulphur gases to the atmosphere are the chemical transformation of ocean sulphate into other forms of sulphur compounds by bacteria. Indeed, Dr James Lovelock, believes that the quantity of such sulphur compounds—those produced by organisms other than man and released into the atmosphere—may in fact be regionally far greater than those produced by factories, power stations, and automobiles. As part of conventional oceanography, environmental sulphur dioxide readings have traditionally been taken at sea. Andreae, Lovelock, and others feel, however, that estimates of sulphur gas production over land are probably wildly inaccurate. Part of the problem of determining the nature of the sulphur cycle is the difficulty of taking meaningful measurements: sulphur gases can vary by several orders of magnitude over a period of hours at one spot on the coast. Most of the acid rain precursors have been measured on land on the context of some specific, local pollution problem rather than in the context of a total understanding of the Earth's atmosphere.

Dr Robert Fuller, in the Department of Civil Engineering at Syracuse University, reminds us that acid rain is only one of a string of factors determining the acidity of lakewater. A lake is frequently a small part of a much larger water-

shed, where water interacts with vegetation, soil, and the underlying rocks. Watershed characteristics such as the presence of coniferous vegetation, high levels of soil organic carbon, shallow soils, an inability to absorb and immobilise sulphate, and low levels of exchangeable and weatherable basic cations are all factors which can predispose an ecosystem to transfer atmospheric acidity to surface waters. As an example, neighbouring lakes receiving acid rain in upstate New York have been found to have significantly different acidities. But these lakes, beneath the same sky, receive the same amounts of sulphuric acid in their rain. Not that high sulphur emissions by industry should be excused, but they do show that the measured acidity in a lake does not depend only on the quantity of acid in the rain. Most of the furore about high levels of atmospheric sulphur and acid lakes comes from foresters, farmers and fishermen. Lakes have even been declared 'dead' because of their relatively high concentrations of sulphuric acid. But not only trees, fish, and forest mammals are affected by acid rain. In acidified lakes, as in sulphide-rich waters, there are many organisms that positively thrive. Indeed, unusually lush algal and bacterial growth may even identify a lake's acidity. Animals may flourish in high-acid lakes too: while trout are decimated or even totally killed off in very acidic lakes, causing indisputable economic hardship to fishermen, certain species of crayfish crawl about and reproduce to high population densities unperturbed. The types of bacteria that form coatings and mats especially along the bottom of acid-rich lakes are organisms with multibillion year histories. These prolific microbes must have been involved in the formation of the earliest sulphur cycles.

PMBE participants believe the major environmental sulphur transformations are fundamentally biochemical processes that evolved inside bacterial cells. Bacteria coevolved with the earliest biosphere, their remains existing as fossils in some of the oldest unmetamorphosed rocks. Although geological evidence for a massive amount of sulphur reduction—the conversion of sulphate into sulphur and sulphide—appears in the fossil record only after the appearance of photosynthesis, there is some consensus that sulphate-reducing bacteria evolved prior to and paved the way for the development of photosynthesis.

Early in the history of life, fermenting bacteria partook of the free-lunch aspect of the energy-rich chemicals left over from the production of the so-called 'prebiotic soup'. Yet soon after, suggests Dr Lynn Margulis of Boston University, co-director of PBME-NASA and a member of the National Academy of Sciences, they evolved a more efficient way of deriving energy. By

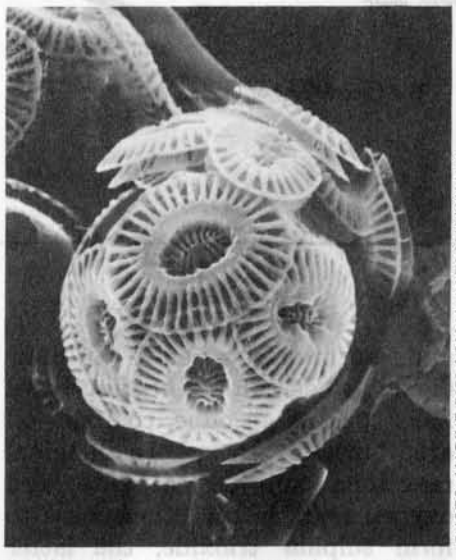


PHOTO: MARINE BIOLOGICAL ASSOCIATION U.K.

Emiliana huxleyi—a cocclithaphorid (dimensions approx. 10 millionths of one millimetre) forming gigantic algal blooms over the continental shelf of the North Atlantic.

diverting high-energy electrons away from the process of fermentation via electron carriers, some kinds of anaerobic bacteria evolved the ability to breathe the common oceanic ion sulphate. The ability to breathe sulphate and to use it, instead of prebiotically produced complex organic sulphur compounds like methionine or cysteine, gave such early anaerobic bacteria an evolutionary advantage. The more complete oxidation of organic matter provided them with additional energy.

To reduce carbon dioxide from the air into the hydrogen-rich carbon compounds of cells, microbes needed a source of electrons. An excellent early source of electrons was gaseous hydrogen, which was far more plentiful in the early solar system. As time went on the sun's high energy radiation and the Earth's weak gravitational field caused hydrogen to escape into space. Most early hydrogen was eventually lost from the atmosphere of the Earth, but hydrogen sulphide, a gas emitted from the Earth's interior through hydrothermal vents, volcanos, and sulphur hot springs, was still plentiful. Bacteria grappled with this for their electrons instead.

Today the green and purple sulphur bacteria still use hydrogen sulphide as their electron donor in photosynthesis. When cyanobacteria hit upon the trick of using the hydrogen of water as an electron donor, the global sulphur cycle, along with the other major chemical cycles of the biosphere, changed forever. Indeed the use of water (H_2O) rather than hydrogen sulphide (H_2S) led to new waste products. In the early days photosynthesis was largely dependent on a steady source of hydrogen sulphide, and the gas was converted into yellow sulphur deposits on the ground or into globules in the water which were later oxidised to make ocean sulphate. But now as water replaced hydrogen sulphide as the largest reserve of electrons for photosynthesis, oxygen began to build up in the air. As the oxygen-producing cyanobacteria spread, the entire planet underwent dramatic oxidation. By 1800 million years ago, during the Proterozoic aeon, hydrogen-rich iron, uranium, and sulphur-bearing minerals at the Earth's outer crust practically disappeared. They were replaced by oxygen-rich forms. An oxidising planet that yet preserves the biochemical legacy of the early hydrogen-rich environment in the form of life is an astronomical oddity. Because of life Earth has a great potential for the energising and energy-releasing reactions exploited by life. The transition to an oxygenic biosphere had many literally earth-changing consequences, among which was the removal of some bacteria, those that had previously flourished at the surface, into a new subsurface realm of marine muds, seaside evaporite flats between the stalks of salt marsh grasses and at the edges of warm

geysers and hot springs. To this day oxygen-shunning bacteria make up the lower layers of the flat purple and green communities known as microbial mats.

Dr Yehuda Cohen of Hebrew University in Jerusalem, Israel introduced the use of microelectrodes as a means of measuring minute concentrations of oxygen and sulphide together with pH in microbial mats. The new technique, first applied to microbial ecology by N.P. Revsbech of Aarhus University in Denmark, allows detailed vigils over chemical transformations at the earth's surface. Microelectrode work (physiology) coupled with ultrastructural study (anatomy) show that the sedimentary layers of organisms that form these microbial mats are distinct in the same way that skin, fat, and muscle tissue are composed of differentiated flattened masses of animal cells.

Certain chemical conditions, oxygen and sulphide concentrations, and levels of light penetration typify each layer, but differences in these variables can cause major changes in community interaction, and changes in community interaction in turn can feed back into changes in the variables. Cohen's team examined community relations among microbes in the salt flats near Leslie Salt Co. in Newark, California. They looked at the surface and subsurface microbes in the sulphur springs of Alum Rock State Park in San Jose, California. The tiny millimetre-thick region in all these locations that separates cyanobacteria from the sulphur bacteria rises slightly during the night and descends correspondingly during the day. Because light is not available for oxygen-producing photosynthesis, the microelectrodes detected increased levels of hydrogen sulphide closer to the surface during the night. Like the chest of a sleeping man the chemical boundary moves. Each day the hydrogen sulphide/oxygen interface rises; each night it falls.

Some bacteria living in this zone are very versatile, for they must be able to cope with potentially poisonous concentrations of both hydrogen sulphide and oxygen. *Oscillatoria linnetica*, for example, uses either hydrogen sulphide or hydrogen during photosynthesis. The cosmopolitan microbe *Microcoleus chthonoplastes* has a chameleon physiology. This organism, recognisable because it looks like microscopic bundles of insulated wire sometimes lives like an ancient bacterium never producing any oxygen. Other times it performs the oxygen-producing photosynthesis typical of plants under concentrations of sulphide that would poison plants, animals and algae, and many species of bacteria. It seems plausible that such versatility comes from a time when the gas mixture of the Earth's atmosphere was totally lacking in oxygen.

The daily movement of the boundary layer between oxygen and sulpide may at times not reflect changes in the composition of communities of organisms so much as flexibility in the metabolism of those organisms. The surface of marshes, salt ponds, and muds bombarded from light above and permeated with gaseous fluids from below present a stunning array of energy sources and opportunities. Those organisms able to vary their metabolic repertoire, to complement or enhance the metabolism of others, or just generally at home in the melee of deposition and gas exchange around the surface zone of sunlight grow like weeds. And they make great contributions to the sulphur cycle.

To follow an element whose territory is the entire surface of the globe is not simple. Sulphur, like any element important to life, has multiple guises and creates a web of activity crossing subtly between animate and inanimate realms. The marriage of microbial and planetary studies is an ambitious new enterprise.

PHOTO: MARINE BIOLOGICAL ASSOCIATION, U.K.

A massive *E. huxleyi* bloom, covering an area of 7,200 km^2, off the Brittany coast. Taken by the Coastal Zone Colour Scanner, May 1982, this bloom represents a calcite mass of at least 70,000 tonnes. Apart from generating dimethyl sulphide, such blooms contribute to the building up of limestone cliffs along the continental shelf. They therefore act as important sinks for carbon dioxide.

Professor Robert M. Garrels of South Florida, takes the idea of a giant circulatory and living system seriously, as shown by his remark that "The Earth's surface environment can be regarded as a dynamic system protected against perturbations by effective feedback mechanisms." But he has also warned, "We all build more and more complicated geochemical models until no-one understands anyone else's model. The only thing we do know is that our own is wrong." Still, he remarks "The chief purpose of our models is not to be right or wrong but to give us a place to store our data."

NASA's life sciences programme has been expanding in recent years to include Earth as a planet to be viewed from space and compared with lifeless Mars and Venus. Accordingly a hybrid discipline consisting of microbiology, geology, and chemistry has come into being. We will have to wait to see where this chimaeric discipline leads, and whether it will ever be able to discover the metabolic workings of the Earth or plot the movement of the elements as they are taken up and emitted by bacteria.

Note:
The scientific results, lectures, abstracts and references of the 1984 PBME *The Global Sulphur Cycle* (D. Sagan, editor) was published by the NASA Life Sciences office, Washington D.C.

Acid Rain and Pollution Control Policy in the UK

by Nigel Dudley

"In 1976 to 1977 we were working together here in Tovdal. We did our experiments together, we had the same explanations, we saw the same thing. Then suddenly in—I think it was around 1978 something happened that—well, they found other reasons for the results they got themselves and we got . . . In my opinion, it was more obvious political reasons for it than scientific reasons."

The Norwegian researcher who made that comment on a "Horizon" TV programme in 1982 was right to suspect the CEGB and the British Government of playing politics over acid rain. The scientific evidence in favour of reducing SO_2 and NO_x emissions is now overwhelming.

In August 1983, the Central Electricity Generating Board (CEGB) announced that before it took any action to reduce sulphur dioxide (SO_2) emissions, the Royal Society would carry out a five year research programme into acidification in Scandinavia, funded jointly by the National Coal Board (NCB) and the CEGB itself.[1] The Scandinavians responded with surprise and anger. After decades of patient investigation, they were finally receiving international acceptance for their claims that European air pollution was acidifying their lakes and killing fish. The UK's intentions, which amounted essentially to checking the Scandinavian research, was regarded as a slap in the face; one Norwegian scientist described it as 'dirty money'[2] and the Swedish conservation groups accused the CEGB of buying time.[3]

The angry exchanges were further signs of an increasing breakdown in relations between British and European researchers, and of the poor reputation of the UK government with respect to environmental issues. There are also sharp divergences of opinion within Britain between the CEGB on one hand and many scientists in universities and the Civil Service on the other.

The seriousness of pollution from SO_2 and nitrogen oxides (NO_X), including acid precipitation, the dry deposition of gases and the formation of photochemical ozone, is no longer seriously open to doubt. The widespread acidification of freshwaters in the north, the catastrophic damage to Central European forests and the rapid deterioration of many ancient buildings and monuments has made the issue an international priority. However, until quite recently, it was thought that Britain's chief role was as a polluter, exporting SO_2 and NO_X to Europe via the releases of gases from high chimneys, rather than as a victim of acidification. Moves to reduce air pollution would in that case have been mainly for the advantage of countries abroad and were tacitly regarded as being of little vote-pulling potential at home.

Arguments about Science

Many scientists believe that this attitude had had a strong influence on the scope and direction of UK research and especially on the CEGB which, as Britain's largest SO_2 emitter, has considerable vested interests in acidification. The Board's avowed aim has been as a Devil's Advocate, testing the various theories put forward elsewhere, and it has certainly helped refine these by showing up inconsistencies in hurried research work. However, taken as a whole the CEGB research has angered many other scientists who regard it as nit-picking; worrying away at the edges of the subject rather than taking an objective view. Writer Steve Elsworth summed up this attitude in his book about acid rain: "The CEGB's scientific research is framed so that it does not ask the question 'what causes acid rain?' . . . but rather 'what apart from sulphur oxide emissions could cause acid damage to the environment?'[4]

Britain's own Pollution Problems

The political situation altered dramatically in 1983, when the possibility that Britain might also be suffering from acid rain was first widely publicised. In retrospect, the fact that few people had apparently considered British acidification problems is itself remarkable, especially as the country has a very long history of SO_2 damage. John Evelyn wrote a tract against air pollution called *Fumifugium* as early as 1661[5] while another Englishman, Matthew Smith, invented the phrase 'acid rain' in 1865, in a book examining various air pollution effects which had resulted from the Industrial Revolution.[6] Conifer plantations were abandoned in parts of the Pennines during the 1930s because of high pollution levels which killed trees;[7] sulphur dioxide was identified as the culprit here and its role in the decline of British foliar lichens has been carefully documented.[8] Papers suggesting a link between freshwater acidification and air pollution were published over a decade ago, but largely ignored thereafter.[9]

In the event, it was left to a visiting Norwegian team to publish the first report overtly looking at the effects of acid precipitation on British freshwaters. Members of the

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Oslo-based SNSF project, accompanied by scientists from the Freshwater Fisheries Laboratory in Pitlochry, visited Scottish lochs in habitats similar to those where acidified lakes occur in Scandinavia, and found that acidification had apparently already occurred in parts of Galloway in south-west Scotland.[10] This news was again largely ignored by the media and politicians until it featured in a 1983 *Observer* article,[11] which was itself inspired by a sponsored press tour of an acidified area of Norway organised for British journalists by the 'Stop Acid Rain Campaign' of Norway.[12] Meanwhile, analysis of diatom species* in the sediment of Galloway's lochs suggested that accelerated acidification had been occurring there throughout Britain's industrial period. Since 1983, unnaturally rapid acidification has also been discovered in Wales,[13] the Lake District[14] and parts of southern England,[15] while researchers believe similar effects may occur in the Pennines, Charnwood Forest and areas of Scottish and English heath.

Information on acidification of British freshwaters is still very incomplete. About forty lakes in Galloway have been identified as being without fish and in some of these fish populations have disappeared within living memory.[16] This correlates with diatom studies which suggest that acidification in Galloway progressed gradually for a century or so and then suddenly became more acute in the last two decades.[17] Studies in Wales suggest the interaction of acidification from conifer plantations and air pollution in the disappearance of fish from streams and rivers such as the Teifi.[18]

A more serious problem for fish is often caused by an 'acid pulse', when a sudden peak of acidity is caused by melting snow or heavy rains following drought; in both cases large amounts of acid can be washed into freshwaters, releasing aluminium into solution which later settles out again once pH has returned to normal. If the aluminium is subsequently deposited onto fishes' gills it can cause death, resulting in the possibility of a large kill of fish in rivers and lakes where acidity is usually not a problem.[19] Fish kills of this sort have been seen in the rivers Duddon and Esk in the Lake District[20] and acid snowmelt has been blamed for salmon deaths in a Scottish hatchery.[21]

Attitudes to forest death are also changing very rapidly. In March 1983, a Forestry Commission report on dieback in German forests was sceptical about the role of air pollution, pointing instead to climatic factors like drought. It stated: "There is undoubtedly an element of neurosis involved in the readiness of many foresters and some workers to attribute any decline or dieback in forest tree species to the combined effects of atmospheric pollution and acid rain without adequate critical examination."[22] Whilst there may be some justification for this remark, the rapid deterioration of the Black Forest led to a fairly quick reappraisal published early in 1984,[23] and by September of that year one of the authors, William Binns, stated at a conference that damage of a type previously unknown in Britain had been detected in March 1984.[24]

Meanwhile John Gibbs, the Commission's chief pathologist, has conceded that air pollution damage cannot be ruled out as a causal factor.

Similar changes in attitude seem likely to develop for air pollution damage to crops. It has long been accepted that high SO_2 levels can retard crops, but SO_2 pollution in Britain was not considered severe enough to make a significant impact on agricultural productivity. However, recognition of important synergistic effects (that is, the accelerated damage which results from the combined action of several pollutants), and the discovery of high ozone levels,[25] themselves formed largely by NO_X, have opened the possibility that pollution is already making a measurable reduction to crop yields in some areas.[26]

Acid rain's rapid rise to notoriety has brought other problems into the limelight. Deterioration of sandstone and limestone has occurred for decades in areas like London, other large cities and the Trent Valley, but

PHOTO: HARDING

Effects of acid corrosion on a church statue in Surrey.

recent evidence of large scale building damage in Europe has highlighted the issue. The CEGB's failure to examine corrosion damage to cathedrals was strongly criticised in a recent House of Commons Select Committee report,[27] and corrosion to well known landmarks such as St Paul's Cathedral has already been well documented.[28] However, again the arguments are by no means decided, with some researchers believing that the effects seen today are the result of historical damage rather than fresh pollution, and the issue further confused by the effects of poorly applied and unprofessional restoration, which can occasionally cause more damage to buildings than the pollution itself. Now Roy Butlin of the Building Research Station is conducting a detailed survey of three buildings—Lincoln Cathedral, Wells Minster and Bolsover Castle—and helping co-ordinate a national monitoring system and a listing of important buildings which may be at risk.[29] Although frequently underplayed in discussions which centre on ecological damage, the implications of any pollution damage to buildings go beyond the risk to heritage. The US Council for Environmental Quality estimated that structural damage causes $2 billion worth of damage a year in the USA.[30]

* Diatoms are unicellular algae with a silaceous cell wall which is preserved in the sediment of lakes. Diatoms change in type and proportion of species present in water of differing acidity; therefore an analysis of the diatom cases present in a core of lake sediment enables a picture of changes in acidity over time to be built up.

Similarly, effects on wildlife are also more serious than was previously thought. Swedish research has linked acidification with the decline of fish-eating birds like the osprey,[31] and with eggshell thinning in passerine species (that is, birds of the order *Passeriformes*, including most perching and song birds of about sparrow size).[32] In Britain, the dipper is declining in areas where acidification of streams has reduced aquatic invertebrates.[33] The flora of part of the Pennines is known to have undergone major changes as a result of SO_2 pollution.[34] The Warren Spring Laboratory released a report on acidity of rainfall in 1984,[35] showing that precipitation acidity in Britain was artificially high, and the Nature Conservancy Council published a report on the wildlife effects of acid rain which are no longer seriously open to doubt.[36]

The Reasons for Britain's Response

The direction of British research is important in two ways. Firstly, it has caused widespread doubts, both inside and outside the UK, about the impartiality of nationalised industry and the government in setting the tone of the scientific debate. It is hardly a new phenomenon to find arguments about bias in nationalised or privately-owned industries with respect to environmental issues, but these criticisms have seldom been expressed as vehemently as over the acid rain debate in the 1980s. Secondly, it is sobering to see how a major problem can develop undetected, even in a country with relatively high levels of research funding, if there is no incentive to investigate it. (Of course, the reverse is also true, and 'problems' can be found where none exist if enough people believe in them, but the evidence for acidification effects within Britain is now compelling.) It is significant that even given the amount of publicity afforded to acid rain in the recent past, it has taken visiting European scientists, and British pressure groups, to initiate several lines of research into freshwater, tree and material damage.

Some of the reasons for this are historical. Britain's introduction to the problems of air pollution came early, as did the first steps to control it, and the Clean Air Act which followed the great smog disaster of 1952 has been used as a model of legislation by many other countries. Cutting out the visible signs of pollution and building tall chimney stacks to disperse the rest undoubtedly improved urban air quality, leading to improved human health and limited recolonisation of inner cities by pollution sensitive plant and animal species.[37] Having been convinced that air quality was improving, people have found it very difficult to accept that the dispersed air pollutants are having more subtle but arguably more important, effects elsewhere.

Political Responses

The rapid escalation of damage has produced a flurry of legislation in individual countries and moves towards international pollution control agreements and laws within the EEC and the United Nations. An important step was the formation of the '30 per cent Club', comprising twenty nations with a commitment to a 30 per cent reduction on 1980 SO_2 pollution by 1993. The EEC is proposing several new directives, including a 60 per cent reduction in SO_2 and 40 per cent reduction in NO_X from large industrial and electricity generating plant by 1995 and a proposal to limit NO_X from car exhausts to Japanese levels within ten years.

Countries that joined the Thirty per-cent Club in 1984

Western	Eastern
Austria	Bulgaria
Belgium	Byelorussia
Canada	Germany, DR
Czechoslovakia	Ukraine
Denmark	USSR
Finland	
France	
Germany, FR	
Italy	
Liechtenstein	
Luxembourg	
Netherlands	
Norway	
Sweden	
Switzerland	

SOURCE: G.L.C.

During the various conferences and negotiations, Britain's attitude has become increasingly isolated. The UK is the largest SO_2 emitter in Western Europe and its high stack policy has long angered the Scandinavians who argue that British SO_2 affects their own freshwaters. For many years the CEGB claimed that no British pollution reached mainland Europe. While this has now been well and truly disproved, the amounts crossing the North Sea are still disputed and the CEGB says high stacks only add 15 per cent to long range pollution.[38] However, Britain's major role as a polluter is not open to doubt and has produced strong European pressure for a reduction in emissions. This Britain has steadfastly resisted, blocking resolutions within the UN and European Parliament wherever possible.

Initially Britain had an influential ally in the Federal Republic of Germany. However, catastrophic forest dieback resulted in a spectacular German turnaround in 1984 and the commitment of £5 billion to halve the emissions of SO_2 within ten years. The Germans are also reducing NO_X by compulsorily fitting catalytic converters to car exhausts and proposing similar EEC legislation. Now Britain is alone among major polluters in objecting to EEC power station legislation; the other countries to seek exemption—Ireland, Greece and Luxembourg—do so on the reasonable basis of their small level of industrialisation. While France and Italy also oppose car exhaust legislation the unilateral German move seems to be forcing car manufacturers to fit them in any case.

Britain's Arguments for delaying Pollution Legislation

Given that Britain is now effectively isolated within Europe, it is worth evaluating the arguments that the government uses to support this stance.

(1) *The Link between Air pollution and Ecological damage is unproven*

There will inevitably be disagreement with any theory, and the tiny minority of researchers who dispute any connection between pollution and acidification have been used to justify funding research rather than pollution control. A further £30 million was allotted to research in October 1984. The frustration of this attitude was summed up by a Canadian minister in 1982: "It's a bit like saying it looks like a skunk, it walks like a skunk and it's stinking the

house out like a skunk, but we're not prepared to commit ourselves that it is a skunk without four more years research . . .''[39] Attitudes in Europe are that sufficient information is now available to justify any risk in funding pollution control measures, when compared with the risk of hoping the problems will disappear, or have some other, unknown cause; Britain is still officially advocating holding off action while more information comes in, but this is looking increasingly more like a holding operation than realistic research.

(2) *Sulphur Dioxide is less destructive than Nitrogen Oxides or Ozone*

The discovery of forest dieback at a time of steady SO_2 emissions and rising NO_X levels has prompted long arguments about their relative importance and, in turn, which one should be reduced first. In practice, both are apparently involved in most effects and those countries taking pollution control seriously are reducing sulphur and nitrogen oxides simultaneously. This is a necessary trade-off for our incomplete knowledge of pollution pathways and effects. Given the lack of data on the separate effects of both pollutants, and the even greater dearth of data on their additive and synergistic effects, the scale of damage occurring dictates that both pollutants be cut back to minimise the effects of dry and wet deposition.

(3) *Pollution free Nuclear Power will soon be replacing Coal Stations*

The nuclear power issue is frequently raised at conferences and may well be an underlying factor in the CEGB's strategy. However, the most wildly optimistic nuclear scenario relies on an enormous coal input for many decades to come and no-one in government can seriously expect a distant and uncertain switch to nuclear power to be acceptable politically as an excuse for ignoring coal pollution at the moment. Even if a new nuclear power plant were ordered immediately, it would not be generating early enough to affect SO_2 emissions within the timescale of the proposed EEC legislation.

(4) *The Relationship between Sulphur Dioxide and Rainfall Acidity is not linear*

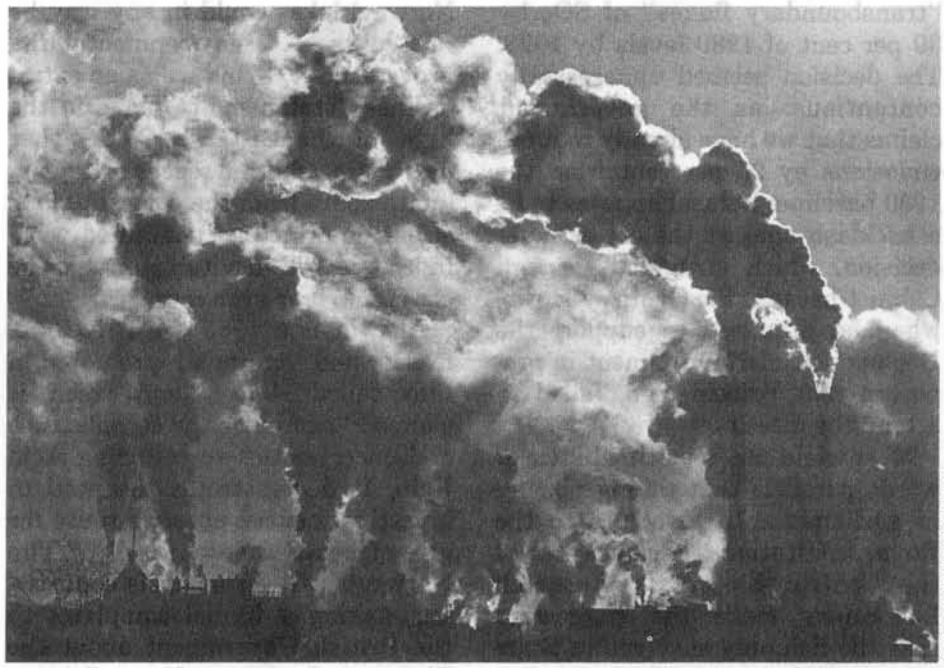

PHOTO: HANS OSTBOM

Smoke emissions over Sweden.

It has been argued that the emission of hydrocarbons is the most important factor in determining the levels of atmospheric acidity, so that reducing SO_2 may not initially make very much difference. Recent research suggests that this is untrue. The reduction in UK sulphur emissions over the last few years has led to a measurable decrease in average Scottish rainfall acidity.[40] These experimental results back up expected figures calculated from long range transport models.[41] It appears that reducing sulphur dioxides does indeed reduce acidity.

(5) *Britain has already reduced Sulphur Dioxide levels by about 30 per cent since 1980*

It has, but largely because of the recession. If the promised recovery takes place, SO_2 levels can be expected to rise up again. Increased use of natural gas and changing industrial fuel mix have also made an impact which is likely to last longer but the availability of low SO_2 gas is uncertain, again raising the possibility of future SO_2 increases.

There is one other crucial political factor in Britain's ability to resist legislation; the United States administration has also completely ignored pleas from Canada, and from within the USA, to reduce sulphur pollution. At present Margaret Thatcher and Ronald Reagan are supporting each other and observers believe that a policy change in one country would isolate the other so much that they would be forced to introduce greater pollution control methods.

It is still by no means certain which will be the first to break. The CEGB's chairman, Lord Marshall, responded to the House of Commons Select Committee report advocating greater pollution controls by saying that he had "never seen a select committee report where the written statement so clearly contradicted the evidence they received''[42] and the government duly rejected the report's recommendations in December 1984.[43] A cabinet committee did approve the new EEC vehicle exhaust standards in summer 1985, albeit reluctantly after William Waldegrave, Under Secretary of State for the Environment, had gone beyond his brief by agreeing with them in Brussels.[44] However, this agreement does not appear to be legally binding and the UK shows signs of ignoring it for the time being at least.

There was a notable set-back for hopes of an early British commitment to pollution reduction when the UK joined America and Poland in refusing to sign an emission abatement protocol under the Convention on Long Range Transport of Air Pollutants, held under the auspices of the United Nations Economic Commission for Europe, and agreed by eighteen other countries from western and eastern Europe and Canada. The protocol binds signatories to reduce emissions or

"transboundary fluxes" of SO_2 by 30 per cent of 1980 levels by 1993. The decision seemed unnecessarily contentious, as the government claims that we have already reduced emissions by 25 per cent from the 1980 baseline. Refusal appears to be a backlash against the car exhaust decision, which struggled through Cabinet because Sir Geoffrey Howe, who had promised to support the Department of Environment in proposing that Britain sign, failed to attend the meeting.[45]

Meanwhile, the scientific battle of words parallels that taking placing in parliament. In a lecture to the Royal Institution, Peter Chester of the Central Electricity Research Laboratory made the suggestion that the fish only survived in Scandinavian lakes in the first place because of the neutralising effects of calcium dust in air pollutants, and that the removal of this had paved the way to acidification. "It is quite possible that fifty years ago, our production and export of neutralising mineral dust, including calcium, equalled or even exceeded our production and export of sulphate . . . it is interesting to speculate whether the low levels of calcium in (southern Norway) lakes could in any way be related to . . . environmental improvements."[46] This seems an extraordinary statement to make in the light of the CEGB's claims that very little pollution reaches Norway, (quite apart from the other dubious scientific principles contained within it), and will inevitably enrage the Scandinavians even more.

Also in late 1985 the CEGB released, and vigorously promoted, a film called *Acid Rain*, which it claimed "examines the complexities and uncertainties surrounding Acid Rain. It demonstrates the need to investigate every possible route for an effective solution."[47] The Norwegian Government is considering making a formal complaint to the British Government about the film and Professor Hans Seip, a leading expert on acid rain says "the film gives a very unbalanced and biased view of the effects of acid precipitation."[48] Our own Department of the Environment has also apparently distanced itself from the film.

Meeting the EEC requirements on large plant pollution would add about 4 per cent onto electricity costs,[49] a figure which the CEGB have not denied. There is also scope for reduction by way of a more comprehensive energy conservation policy. Despite the outward appearance of a hard line, there are sharp divisions within the Conservative Party about this and both Labour and the Alliance are committed to reducing SO_2 pollution. The issue has also been significant in the fissures it has opened up within the scientific community; environmental campaigners, used to being out on a limb, have had the rewarding experience of hearing academics and civil servants castigating some of the CEGB scientists, albeit off the record. The speed with which West Germany changed its policy on SO_2 and NO_X pollution may be an indication of how fast Britain will move when pressure builds up enough, and it is widely thought that the current attitude disguises a delaying tactic to avoid fitting scrubbers onto old plants with little working life left. Future developments will depend on how far the various pressure groups are prepared to push. As one government official said: "The evidence for taking action on lead was not nearly as good as that for acting on acid rain."[50]

NORWEGIAN CONCERN OVER THE CEGB PROPAGANDA FILM.

The Central Electricity Generating Board (CEGB), operator of some 90 per cent of Britain's coal and oil-fired power plants, has produced a video film called "Acid Rain", which, in the opinion of the Norwegian environmental authorities, conceals and twists facts about the problem of acid rain.

Norway has conveyed its concern to the UK authorities regarding both the biased content of the film and that an important body such as the CEGB has produced part of the film in *Norway* without contacting Norwegian authorities and major Norwegian research bodies.

The film uses unfortunate methods to minimise the problem of acidification. In the segment about Norway, only one researcher is heard asserting that Norwegian fish deaths are not caused by acid rain. The film ignores that the great majority of Norwegian and international scientists regard it as proven that acid rain is the major cause of regional freshwater acidification.

An interview with a Swedish researcher gives the impression that liming is a simple and effective solution to "repair" acidified waters. In the original interview, the researcher strongly underlined that liming does not remove the cause of the problem and may be used only in certain areas. But this part of the interview was deleted from the film.

The one researcher interviewed about death of forests claims that ozone, and not sulphur deposition is harmful to trees. The film neglects to mention that most researchers also regard sulphur and other air pollutants as significant contributing factors. There are strong indications that without air pollution and its wide dispersion, the recent forest damage would not have occurred in its present form and extent.

It is well known that biological effects of acidification in terms of fish loss in Norway have increased despite reductions in UK sulphur emissions in recent years. The film presents this as evidence that emission reductions are of no benefit. The explanation of the phenomenon—that the effect of acidification on fish and other biota may be delayed up to ten years—is completely ignored. The film also neglects to mention well-documented examples of positive effects of reduced sulphur emissions. Both theoretical calculations and observations indicate strongly that reductions in emissions will lead to closely corresponding reductions in deposition, and to improve water quality.

The film concludes that it is highly doubtful that UK sulphur emissions cause any damage, although the CEGB, will reduce emissions if damage is proven.

"Proof" leading to 100 per cent agreement is a rare commodity in the field of ecology. But contrary to the impression given by the film, European environmental authorities now accept that our knowledge is more than sufficient to establish that sulphur emissions are detrimental to environment and health.

Royal Norwegian Embassy, Press Release December 1985

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This article is an extract from a forthcoming book edited by E. Goldsmith and N. Hildyard, *Green Britain or Industrial Wasteland,* Polity Press, Oxford.

SWEDEN—CHOOSING THE RIGHT ENERGY PATH

by Peter Bunyard

With extraordinary efficiency and determination Sweden has embarked on a quiet revolution in the way it procures and utilises energy. The costs are undoubtedly high and with world prices of coal and oil tumbling because of the present-day glut, a few cynics have been left wondering whether Sweden hasn't jumped the gun. That certainly was the reaction of some of the engineers who were on the Study Tour of Swedish Energy Planning organised by the Town and Country Planning Association (UK) in conjunction with Sweden's Lund University. Although deeply impressed by the quality of the engineering work whether in conventional plant or in new energy schemes, the British engineers were somewhat dubious that the innovations and commitment to alternative energy sources—including geothermal—could be justified in economic terms. Indeed they felt that Sweden's approach to energy planning was not particularly relevant to Britain given the latter's very different energy base.

Nevertheless Sweden's achievements are impressive, and according to Peter Bunyard who participated in the Study Tour, Sweden may have much to teach us as to how to achieve a more energy efficient future.

As elsewhere in the world, Sweden's post World War 2 development has been fuelled largely by oil. Indeed by the late 1970s some three quarters of Sweden's total energy supply was in the form of imported oil, and with a gross consumption of more than 25 million tonnes, Sweden had the dubious distinction of being one of the highest per capita consumers of oil in the world. Such dependence on a single fuel made the country extremely vulnerable to price rises and to oil embargos, and after the rude awakening following the Yom Kippur war of 1973, when oil supplies were threatened, the Swedish Parliament decided in 1975 on an energy programme which would cut the need for oil through substitution and conservation.

The Car—A Holy Cow

Transportation and mobility have increased phenomenally since World War 2, and by 1980 the numbers of cars on the roads had increased 15-fold from the 1950 level, adding significantly to the dependence on oil. Today transportation consumes more than 30 per cent of total oil used and 20 per cent of the energy, but as in the West generally, the use of private transport in Sweden has remained sacrosanct. Today more cars and more miles are being driven than ever before and the expectation is that energy use for transportation will rise by up to 15 per cent over the next ten years, more than offsetting any gains achieved through improved vehicle performance.

Space-heating

In the 1970s oil was by far the most important fuel for space heating and hot water supply in residential and commercial buildings, producing up to 90 per cent of the energy used. Meanwhile oil provided up to 50 per cent of the total energy consumed in the industrial sector so that altogether the consumption of oil for heating and hot water in residential, commercial and industrial premises comprised some 50 per cent of the total used in Sweden.

Conservation—The Target

Buildings in all three sectors were to be a special target for energy conservation and in a special bill drawn up in 1980/81 the Swedish Parliament called for a 30 per cent energy saving in the 1978 building stock of some 48 TWh (terawatt-hours) over ten years, with the lion's share, some 28 TWh, to be saved in residential buildings. If achieved, the overall saving would lop some 15 per cent off total energy consumption in Sweden, which by the late 1980s was expected to fall to some 354 TWh from a peak of just over 400 TWh a decade previously. Another bill called for a cut in overall oil consumption through the use of a combination of energy sources, including coal, biomass fuels such as wood and peat, solar heating, heat pumps and conversion to electricity.

Meanwhile in a referendum on the future of nuclear power in Sweden, the majority voted for the phasing out of all nuclear power stations by 2010, including those at present under construction. With all nuclear power stations in operation the expectation is for 58 TWh per year to be generated, therefore close on 50 per cent of Sweden's future electricity needs. Sweden will have to find alternatives to nuclear power over the next 25 years, coal and biomass fuels being two of the substitute fuels under consideration.

Today some 60 per cent of Sweden's electricity is generated by hydropower. Hydropower in Sweden could probably be doubled, but on ecological grounds Sweden is now opposed to any further damming of rivers, and it seems as if hydropower will not rise significantly above its present level.

With such a large proportion of hydropower in the

generating mix, it is hardly surprising that Swedish electricity should be some of the cheapest in Europe. In fact electricity prices have increased by more than 20 per cent in real terms since the 1970s owing to the growth of nuclear power. According to the National Energy Administration, hydropower is costing approximately 1 öre/KWh compared with 7 öre/KWh for coal and nuclear alike.

Despite the economic recession electricity demand in Sweden has continued to grow rapidly, practically doubling from 60 TWh to 120 TWh between 1970 and 1984. Since 1980 growth has accelerated to a rate approaching 7 per cent per annum, but a slow-down in growth has again been predicted with demand forecast for 1990 of 128 TWh and for 1995 of 133 TWh.

Sweden's electricity demand on a per capita basis is very high compared to Britain's. Indeed with just under half Britain's total electricity consumption and with one-seventh the population size, each Swede therefore consumes on average between three and four times the amount of electricity consumed by each Briton. The relative cheapness of Swedish electricity and the abundance of hydropower is obviously one explanation for its high use. The splitting of the Swedish family into separate households with each parent demanding facilities that would otherwise have been shared is undoubtedly another reason for Sweden's relatively high electricity demand and for an overall energy consumption that is at least one-third greater than that found in Britain. On the other hand, more and more Swedes have become interested in living in collective housing with shared facilities such as canteens and play areas, and should such lifestyles become fashionable average energy consumption could fall.

Swedish Pragmatism

The Swedish move to save energy and to extricate itself from such heavy dependence on oil has more to do with self-interest and determination to be "well-off" than with altruism for anyone else's energy problems. "For the Swede", says Professor Lennart Thönqvist, of the Department of Heat and Power Engineering, Lund University, "the purpose of living is to keep up energy standards. There is no real saving ethic, energy is just a question of living." Not that the Swede sees himself as profligate in the use of energy; indeed he will be the first to encourage any attempt to make energy go further as long as the cost is acceptable.

That energy standards have been kept up in Sweden must be attributed to some extent to its having a relatively small population—some 8.3 million in a land mass encompassing 450,000km^2. But Sweden's high standard of living is also the result of a commitment to welfare and to fairly well-defined energy policies and practices both at the national and local level.

A Tradition of local Management

The tradition of municipal involvement in energy dates back at least 100 years, with municipally owned gas supply utilities being established in the 1860s. By the end of the 19th century most of the gas supply companies were owned by local authorities. At the same time an electricity supply and distribution network was built up, initially with municipal utilities operating the generating plants and distributing the electricity, and then as a national grid system was developed buying the electricity from outside operators.

PHOTO: STATENS ENERGIVERK

Sweden looks for energy alternatives

In the 1950s many municipal authorities decided to build up district heating networks, the intention being to get back to some extent into electricity generation through the use of combined heat and power plants (CHP).

Today approximately one-third of the municipalities have district heating plants, supplying 29 TWh of heat in 1984 which is just under one-third of Sweden's total demand for heat in its buildings. Present plans are to have as much as 40 TWh of heat supplied in district heating systems by the mid 1990s, which given the energy conservation measures now underway would take the district heating contribution to over 40 per cent of total heat requirements in Sweden. For district heating to be economic the heat load in the area to be supplied must not be lower than 30 to 35 GWh per square kilometre. Some 500 built-up areas in Sweden have been identified with such heat load densities, 300 of which have no district heating to date. Indeed of 9,300 MW of heat that could be supplied in such schemes 6,200 MW is now provided.

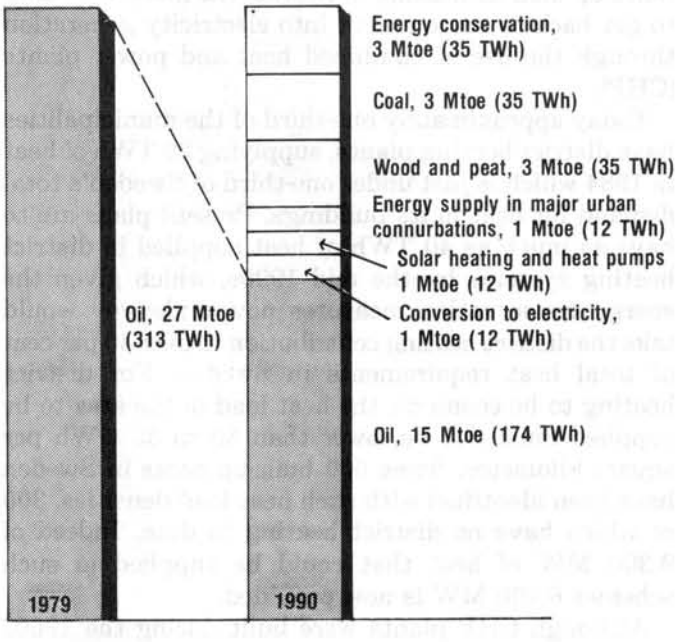
Although CHP plants were built during the 1960s with a capacity to meet one-tenth of district heating requirements and to provide up to 20 per cent of the

municipalities' electricity needs, they were all oil-fired and given the high cost of oil and cheap hydroelectricity in Sweden, it is hardly surprising that most CHP plants are now shut-down. In fact it is cheaper for municipal power utilities to buy in electricity for electric burners than to resort to CHP.

A Broad-Based Energy Strategy

Sweden has a tax base which is very different from Britain's. In 1982 for example the average Swede contributed 30 per cent of all taxes paid to the local authority and just 13.5 per cent paid directly to the State. Meanwhile up to one-quarter of the country's workforce are employed in municipal and county council activities. Local government therefore has considerable powers in Sweden, a factor which underlies local authority involvement in energy schemes and provides an explanation for the rapidity with which fundamental changes have taken place in energy production and utilisation, despite relatively long lead times. In Sweden local government is now responsible for 20 per cent of the country's Gross Domestic Product.

Having been given a lead from the Swedish Parliament in the late 1970s, local authorities have moved rapidly to find alternatives to oil burning, each seeking the alternative which best suits its particular situation with regard to energy sources. As the following figure shows, the cities of Stockholm, Helsingborg and Malmö have chosen different mixes of energy supply systems to meet their present and future heating requirements for their district heating systems. Stockholm for instance has moved from 100 per cent dependence on oil in 1978 to less than 25 per cent today, the difference being made up with heating from coal, electricity, heat pumps, waste heat from industry. The intention is to reduce oil consumption to no more than 10 per cent by 1995. Meanwhile Malmö has already reduced oil consumption to no more than 5 per cent, having already replaced a 100 per cent dependence in 1975 with 50 per cent coal, 20 per cent refuse incineration and the remainder with contributions from electricity, heat pumps, and industrial waste heat. By 1997 waste heat from industry is expected to make a contribution of at least 20 per cent. Indeed waste heat utilisation is one means by which industry can improve profitability. Thus the Bolliden Chemical Industry, which already supplies some 40 per cent of the heat for Helsingborg's district heating, is able by selling the waste heat to generate an annual revenue of some £3 million.



Oil substitution potential from 1979 to 1990, classified by energy form. (Bill No. 1980/81:90.)

The City of Lund has found a good source of energy in water-bearing sandstone some 500 to 800 metres below the surface, a few miles outside the city. The temperature of the water is no more than +25°C but after circulation through a heat pump can be boosted to the level necessary for the district heating system. By 1990 the Lund Energy Authority anticipates that at least one-third of the city's heat for district heating will come from its relatively shallow geothermal sources. Another 15 per cent of the heat will come from waste sewage water, again boosted by means of a heat pump after passing through a heat exchanger to temperatures suitable for the district heating system. Four-fifths of all the homes in the cities of Malmö and Lund gain their heating and hot water from the district heating system.

According to Swedish scientists and engineers involved with the Lund geothermal scheme, the United Kingdom has a good geothermal potential with reasonable supplies of water at around 40°C. The answer is not to look for geothermal energy in deep granite strata such as in Cornwall, but to exploit instead shallower sedimentary basins. The problem is to prove that sufficient quantities of water exist for cycling; moreover the drilling has to be accurate. Obiously the rate of extraction determines the lifetime of each well. The expectation with the Lund project is for the temperature in the extraction well to fall some 2°C over 20 years. The payback time on a £10 million investment is assessed at three years, while the delivered heat is expected to cost no more than half that from burning oil or natural gas. Altogether Lund hopes to save some 35,000 cubic metres of oil each year through its use of geothermal, while sulphur discharges will be reduced by 350 tonnes.

A great advantage of the district heating system, although not foreseen when the system was laid down in Sweden some 20 years ago, is the great flexibility it offers with regard to energy and heat sources. Geothermal, refuse incineration, solid fuel, waste heat from industry, or from sewage, combined heat and power plants, or electricity itself can all be used, the quantity of each used depending on availability and price. And when a heat source is at too low a temperature for district heating, it can be raised by means of a heat pump, which because of its high COP (coefficient of performance) can provide up to three times the heat at the point of use for the electricity

consumed compared to an electric boiler which itself may be close on 100 per cent efficient at the point of use.

By 1984 Sweden had 70,000 heat pumps installed for heating purposes, providing altogether some 2 to 3 TWh/year. Only 30 of these heat pumps had outputs of 10 MW or more, the rest were relatively small devices used for detached properties or in residential developments and industry. The heat source for the pump is usually outdoor air or air from the exhaust air ventilation system. But other sources have been successfully used. At present some 2,000 heat pumps have been installed to utilise the heat stored in lakes, calculations indicate that 10 to 15 kWh per square metre of lake surface per year can be extracted without risk of environmental or ecological effects; hence each square kilometre of lake surface could provide the heat for 1,000 average-sized detached houses, and if all lakes were exploited up to 10 TWh per year could be extracted.

Sweden has 1,400 sewage treatment plants in which the temperatures of the waste water are +20°C in summer and +8°C in winter. If one quarter of all the heat passing into the sewage system were extracted then 4 to 5 TWh could be provided leading to a saving of some 900,000 cubic metres of oil.

Surface earth heat pumps allowing an extraction of some 30 to 40 kWh per square metre per year, and leading to an output of 10kW from 300 to 400 metres of hose buried beneath 300 to 400 square metres of soil are another possibility. Today some 13,000 such systems are in operation with 3,000 per year being added. Altogether some 800,000 detached houses could be supplied with all their heating requirements from such a system. The effect on the microflora and fauna of the soil from surface earth heat pumps is not properly known, but the earthworm population appears to be reduced.

Heat pumps can also be used to extract heat from groundwater and from industrial waste heat, both of which could make a useful contribution to total Swedish heat demands. Surprisingly, given its northerly latitude, Sweden has also looked into solar energy heat systems. Since the heat is required in the winter months when insolation is negligible, the more interesting systems are those combined with an extensive heat storage system.

At Lyckebo, some 13 kilometres north of Uppsala, 550 detached houses are being built which will have most of their heating requirements met by solar energy. In the first stage 4,320 square metres of high temperature flat-plate collectors have been installed which supply some 1.3 GWh per year of heat, equivalent to 15 per cent of the total requirement. When the remaining 85 per cent of collectors are installed the intention is that they will meet the entire annual heating requirement of the housing scheme.

The heat store has been carved out of rock, its roof being some 30 metres below ground. Altogether the store contains some 100,000 cubic metres of water and at the end of the summer the temperature of water at the top of the 30 metre deep cavern should be up to +90°C and at the bottom at around +40°C.

PHOTO: SIAB

Energy-efficient environment? The new look for Swedish housing.

The flat plate collectors developed in Sweden now have performances approaching vacuum tube collectors and even better than concentrating collectors. The annual efficiency at Lyckebo for example is 35 per cent.

Economically, solar energy and heat storage systems are considerably more expensive than conventional systems and are unlikely to provide more than one per cent of Sweden's total energy requirements by the year 2000.

One solar energy based system that appears to have favourable economics is derived from biomass. In one experimental scheme basket willow has been planted in a 70 hectare plot, with some 20,000 saplings to the hectare. Harvesting of the wood is to be carried out every three to four years using a tractor-drawn cutter which leaves no more than a couple of inches of stem above the ground. Preliminary assessments suggest that up to 45 tonnes of wood can be gained at each harvest from each hectare. At that rate a 50 hectare plantation could supply 3,200 MWh per year, enough for a 1.2 MW boiler. The city of Halmstad—120 kilometres north of Malmö on the West coast has now embarked on a 50 hectare scheme in collaboration with the engineering company, Sydkraft. Altogether some 500 hectares have now been set aside for wood-based biomass schemes in Sweden.

The big question is whether Sweden would have spent so much energy on its heating schemes and on energy conservation if its climate were less rigorous than it is. Britain, perhaps because it has a more maritime climate and less harsh winters, may have less

incentive than Sweden to seek the same standards of protection from the weather. Certainly in recent years Sweden has achieved remarkable success in improving energy efficiencies, and Thomas Johansson and his associates suggest in *Science* (Vol 219 January, 28, 1983 pp355-360) that total energy consumption in the country could be reduced by 35 per cent just after the turn of the century from its present level of around 1,400 picojoules, and allowing for considerable growth, in some sectors of up to 50 per cent compared with the 1975 level.

In housing Sweden has achieved remarkable success in reducing energy demands. The Folksam office building in Stockholm, completed in 1977, requires one sixth the heating of a comparable office block elsewhere in Sweden, while houses with one seventh the heating requirements of average Swedish homes are already available on the market.

Undoubtedly Sweden has shown initiative and courage in pressing ahead with some of its energy schemes. While Britain, the originator of pressurised fluidised bed combustion systems, is still debating whether to scale up the Grimethorpe prototype, the City of Stockholm has already ordered two coal-fired PFBCs which will simultaneously generate 130 MW of electricity and provide 215 MW of heat for the district heating system. For aesthetic reasons the coal will be stored underground. Moreover, because of its compact boiler system, the PFBC plant will not spoil the Stockholm skyline. Apart from its 10 per cent lower cost and improved thermal efficiency compared with conventional combustion plant, owing to its combined gas turbine and steam cycle, PFBC needs no control for NO_x emissions on account of its low combustion temperatures while sulphur can be controlled to acceptable limits through using limestone as bed material.

As recipient of other countries sulphur and nitrogen oxide emissions, Sweden has now set out to put its own house in order, and is fitting flue gas desulphurisation plants and baghouse filter systems to its existing coal-fired facilities. The aim is to reduce sulphur emissions within Sweden from some 160,000 tonnes per year in the 1970s to less than 35,000 tonnes by 1995.

Conclusion

By having a decentralised system with strong powers at the level of local government Sweden has shown itself able to adapt remarkably quickly to State policies on energy, and in particular on oil burning and on energy conservation. Nevertheless energy use per capita in Sweden remains relatively high, a measure in part of the fragmented nature of modern Swedish society with its high proportion of single parent families and need for high mobility.

There are lessons to be drawn from the Swedish example, and it is highly disturbing to see Britain, practically at every step taking the diametrically opposite pathway from Sweden's.

HOW PESTICIDES INCREASE PESTS

by Francis Chaboussou

Do pesticides create pests? This is essentially the question asked by Edward Goldsmith in his article in *The Ecologist* in March 1980, which was inspired by a Shell report that agricultural pests were flourishing despite the increased use of pesticides.[1] Goldsmith came to the logical conclusion that Shell's announcement, rather than encourage the increased use of pesticides, must demonstrate the complete failure of these synthetic products in bringing about any reduction whatsoever in the destructive effects of parasites.

In fact, researchers have frequently underlined the apparently incomprehensible increase in plant diseases (including viral infections) and in destructive insects, without providing any kind of valid explanation for this phenomenon. On the other hand, we can show that the origins of this destructive process—which can be dramatic when it comes to the loss of basic food crops like rice—are to be found in the uncontrolled use of synthetic pesticides. In the theory proposed here, for which there is increasing evidence, pesticides derange plant metabolism, making them vulnerable to disease and infestation.

The 'secondary effects' of pesticides have attracted the attention of a number of plant protection scientists. In France, one working group periodically makes a survey of all reported observations but without committing itself by giving advice. However, the terms used by this group to qualify failures in treatment that result in damage by insects and those which lead to disease are significantly different.

In the first instance, damage by insects including aphids, and lepidoptera, as well as by mites and nematodes, is referred to as 'infestation' or 'proliferation'. On the other hand, when fungicides fail to deal with disease whether cryptogamic, bacterial, or viral this phenomenon is called 'resistance'. These terms in fact offer an explanation, but how far is that attitude justified?

The use of a different terminology reveals the bias behind the explanation for these phenomena. In fact, according to the 'classic' notion, an increase in the numbers of destructive insects following pesticide treatment must be caused by the elimination of their natural enemies, suggesting a breakdown in the 'natural' equilibrium in favour of the target pest. Such a position implies then that the biotic potential of the pest is entirely dependent on a balance between it and its predators.

However, this explanation on its own is far from adequate. For example, it cannot account for the repercussions of using pesticides when they are not applied to foliage but are incorporated into the soil. This applies in particular to infestations of mites in potatoes growing in soil treated with various chlorinated insecticides.

Furthermore we have registered the numbers of mites living on treated foliage as compared to controls and found significant differences. Briefly, the proliferation brought about by the pesticide arises from an increase in fecundity, longevity and a change in the sex ratio in favour of females. Thus, the biotic potential is raised indirectly through nutrition, and we must conclude that the pesticide leads to a modification in the physiology of the plant and one which is nutritionally advantageous to the mite[3]. Similar phenomena have been demonstrated with regard to infestations by aphids[4,5,6].

These results with animal pests have led us to investigate the mechanism behind the increase in serious diseases, whether caused by pathogenic yeasts, bacteria or viruses, a problem which continues to puzzle phytopathologists. We have been able to show that fungicides of the dithiocarbamate group (maneb, zineb, propineb) used to treat vine mildew lead to twice as much of the disease as in control vines treated with pure water[7]. Thus we showed that, as with animal ravagers, increase in disease following pesticide application was nutritional in origin. Indeed, the biotic potential of the parasitic fungus increases owing to a nutritional substrate produced by the action of the pesticide on the treated plant. But what is the nature of this substrate which favours the parasite? Here we agree with the eminent French physiologist and biologist DuFrenoy. He stated:

> Every circumstance unfavourable to the formation of new cytoplasm, ie. any situation unsuitable for growth, tends to lead to the accumulation in the vacuolar solution of cells of unused sugars and amino acids; this accumulation of soluble products appears to favour the nutrition of parasitic micro-organisms, and so diminish the resistance of the plant to parasitic diseases.[8]

In effect, analyses of plants 'sensitised' by pesticides show an accumulation of such soluble substances in their tissues, and particularly of unbound amino acids or soluble nitrogen compounds. Certainly we are not claiming that all parasitic organisms have identical nutritional requirements; we know for example that particular aphids prefer particular amino acids. Nevertheless, the various parasitic organisms demonstrate a definite preference for *soluble* nutritional products, as DuFrenoy suggested.

The result is that the sensitivity of a plant to disease is correlated with a high level of soluble substances in

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which proteolysis predominates. By contrast, resistance or immunity of a plant is linked to a high degree of protein synthesis. It is precisely by interfering with this protein synthesis that pesticides sensitise plants to different parasites. These considerations lead to our theory of biotrophy: a parasite only attacks a plant when it can find the necessary nutritional elements necessary for its growth and reproduction.

Therefore, examples of so-called 'resistance', where 'fungicides' are seen to fail against disease, must be examined more closely. Indeed we find that such resistance occurs very rapidly and is usually a result of nutritional stimulation of the parasite. We have already cited the example of vine mildew which was increased by various dithiocarbamates, however, the same kind of imbalance can also arise with bacteria, as we shall see in the following section. For instance, Deep and Young[9] noted a recrudescence of Crown gall caused by the bacterium *Agrobacterium tumefasciens* on cherry trees treated with captan or with dichlone. These authors attributed this effect to a supposed suppression of yeasts hostile to the bacterium, although we believe that it is the result of a damaging effect on the physiology of the plant. In addition the use of captan leads to marked increases in the numbers of mites.

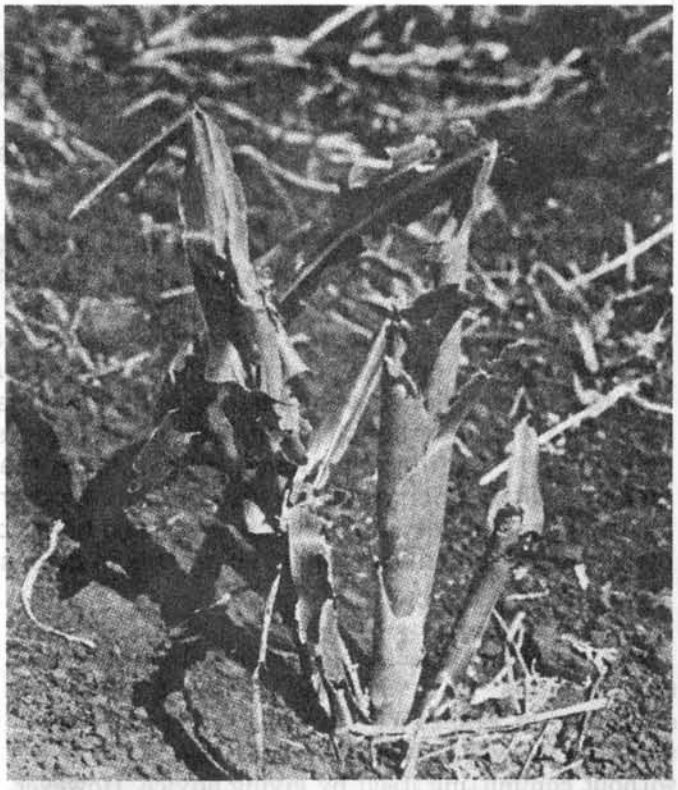
Therefore, every increase in a disease or animal pest, labelled 'abnormal' because we are ignorant of its cause, if it follows one or several pesticide treatments is the result of a change in the nutritional environment. In every instance, it involves damaging, though often insidious, attacks on the metabolism of the treated plant. Thus, the use of pesticides leads to a certain amount of 'poisoning' of the plant. This may be seen in the accumulation of soluble substances which cannot 'condense' into proteins and which are nutritionally beneficial to disease organisms and animal pests. In short it is as though the pesticide breaks down the resistance of the plant, the strength of which depends on its genetic makeup.

This damaging effect of certain pesticides, and in particular of synthetic (nitrogenous and chlorinated) pesticides, also demonstrates that the gene, vector of heredity, can only operate as a function of the environment. Thus it is useless improving the resistance of a plant to such and such a disease if that 'genetic' immunity is going to be impaired by applying a pesticide aimed at some other pest.

Use of new synthetic pesticides and the correlated increase in fruit tree and vine diseases

More than twenty years ago, M Ride, an expert in bacterial diseases observed: "Bacteria have found in the conditions of arboriculture today a favourable set of circumstances for their development". Referring in particular to 'intensive' arboriculture he added: "This change seems to have been brought about by treatments with synthetic products. The almost total abandonment of copper over the last decade in some orchards has been followed by renewed infections by *Pseudomonas syringae*".[10]

The same author also emphasised a further



Although farmers in the US now use 2,265 tonnes of pesticides per year, some 12 times more than 20 years ago, the proportion of crops destroyed before they can be harvested has nearly doubled.

important point: The similarity between symptoms of diseases and deficiency syndromes. He added: "Many symptoms of bacterial infections by *P syringae* are confused with damage caused by spores or disorders brought about by deficiency diseases... Only copper-salts (and zinc sulphate in the special case of infection by *Xanthomonas pruni)* retain their importance in the battle against bacteria."

We will see later how similar the symptoms of deficiency diseases are to infectious diseases. Indeed the point that diseases develop owing to the use of synthetic pesticides seems to us to have been well established. Equally, plant resistance can be affected advantageously by certain products which alter plant physiology. In effect, experts in bacterial disease point out that, on the one hand, copper based products are not bactericides; yet the same products can be helpful in controlling bacterial diseases.

The only logical conclusion therefore seems to be that such products act in an indirect way by stimulating resistance in trees. According to the theory, copper acts on the metabolism of the plant by reducing those soluble, nitrogenated, substances which attract parasites.

These soluble nutritive elements increase when proteinolysis is greater than proteinsynthesis, as occurs when the growth of the plant is inhibited by generous applications of synthetic pesticides. Furthermore the effects on perennials may well be cumulative from one year to the next and in such instances it is not surprising that outbreaks of bacterial or viral diseases should occur without known cause.

Repercussions of nitrogenous pesticides.

Since the sensitivity of plants to disease depends

mainly on the tissue content of soluble nitrates (particularly free amino acids), the greatest attention should be given to the use of these products, whether they are added to the soil as fertiliser or given directly to the plant as foliar feed or as foliar pesticides.

With regard to nitrogenous fertilisers, it has been shown that at certain dosages currently in use in so-called 'intensive' farming these products lead to a blockage of copper. However, it is probably not only copper which is implicated in such blockage phenomena. The same occurs with boron: indeed when boron is applied to the soil, the amount of this element is reduced in the foliage. Huguet, an expert in the side-effects of fertilisers on the biochemistry of leafy tissues thus comments that, following the application of nitrogenous fertilisers, "the amount of boron decreases over the years as more nitrogenous food is applied to the tree."[11]

Is there an analogous reduction in trace elements, such as boron, as a result of pesticide foliar treatments? In fact almost all synthetic 'fungicides' are either nitrogenated products or chlorinated, if not both. Indeed that would explain why plants treated with carbamates, herbicides and synthetic insecticides show an increase in nitrogen content relative to controls.[12]

The same findings were presented at a symposium on integrated viniculture (Bologne, 1972) when it was stated that total nitrogen content increases following all fungicide treatments. As Ripper pointed out: "A weak increase in nitrogen level in plants increases attacks by parasites."[13] In agreeing completely with this statement, we would emphasise that it applies in particular to soluble nitrogen.

Furthermore, do treatments with synthetic nitrogenated products, such as the fungicides and insecticides in use at the moment, eventually lead via cumulative effects to deficiencies in some trace elements? Thus a simple criterion like boron deficiency could explain unexpected outbreaks of bacterial and viral diseases which take researchers as well as farmers by surprise. This situation is particularly found with certain diseases which damage vine and fruit trees, but it also applies to cereals.

Correlation of symptoms of boron deficiency and symptoms of various viral diseases in the vine.

To date agronomists and physiologists have tried to distinguish between deficiency and disease symptoms, so as to avoid false diagnosis. Yet, in checking through records on "Viral infections and similar diseases in the vine" (La Maison Rustique: Paris), we find that the symptoms of boron deficiency and those of viral infections are very nearly identical. Thus symptoms of boron deficiency can, we are told, be confounded with those of six important viral diseases.

A number of other observations are also worth noting: "The vineyard showed signs of many viral diseases: The symptoms (discolouration, leafrolling, changes in leaf form) making it more difficult to identify the symptoms of deficiency".[13]

All these observations may be seen in a new light if we recall what was written twenty years ago by Trocme, an agronomist specialising in trace elements:

> "It cannot be excluded that there is a relation between deficiency and certain diseases, notably bacterial and viral; either these diseases increase the chance of deficiency, or deficiency increases the chance of these diseases; for example, trees deficient in boron or in zinc may be more liable to certain bacterial and viral diseases."

While scientists acknowledge a problem in separating cause and effect, the combination of symptoms of deficiency and diseases seems logically to lead to deficiency first and disease second. This is because *all deficiency leads to inhibition of proteinsynthesis and so, via nutrition, to sensitisation of the plant to both disease and animal pests.*

The process of sensitisation in our opinion operates as follows: action of pesticide — blocking or inhibition of proteinsynthesis and via a process which may include deficiency phenomena, of trace elements in particular — increase in soluble metabolic elements in the tissues — proliferation of various animal parasites or diseases, including bacterial and viral infections.

Use of herbicides and the sharp rise in cereal diseases

In France, after an in-depth study of the frequency of cereal diseases, the Institut technique des cereales et Fourrages reported that, in 1973, "Disease has become increasingly a problem for 80 per cent of farmers over the past four or five years. Why? Because their crops are regularly infected by an average of two or three diseases".[14]

A large pesticide company pointed out, for its part: "In fact, we must take seriously into account a complex background of endemic diseases. While certain cereal infections have very rapidly acquired a serious aspect, there must be other aggravating factors which natural climatic conditions cannot account for alone".[15]

We could not put the problem of renewed outbreaks of cereal diseases better. Those which are most damaging are those which previously were considered of secondary importance. In particular this is true of *la Fusariose du pied* and *la Septoriose.* However, 'abnormal' developments also lead to *le Piétin-verse, le Piétin-échaudage* and *Rhizoctonia.* Nevertheless, the most disturbing perhaps is the very serious development of *Helminthosporium teres* and its new varieties, together with viral diseases.

Given the multiplicity of diseases, the notion of "complex infestation" has become more and more popular. This notion implies that several infestations, whether animal or vegetable in origin, may occur on the same plant—in this case cereal—either simultaneously, or in sequence. This concept applies particularly to barley which may suffer at the same time from leaf blotch, mildew and 'pietin', not to mention the new viral disease called 'dwarfing jaundice'. This disease continues to spread, as does the disease 'brown spot', or *Helminthosporium teres.* A parallel development, as one researcher notes, "appears to be linked to the major increase in surface area given over to this cereal and also to an intensification of culture, which is expressed by the resorting to techniques which favour pest development."

The writer says no more. We would interpret the term intensification, presented without further detail, as covering two essential processes: Excessive fertilisation, and particularly massive use of nitrogenous fertilisers; the equally massive use of various pesticides, in particular herbicides, as well as their 'corollaries', fungicides. Indeed fungicide treatment during the growing period has been shown to favour the development of brown spot.

Elsewhere, analyses by Altman and Campbell[16] demonstrate the causal factor of herbicides in the spread of plant diseases, particularly in cereals. These writers refer to numerous cases of disease brought about by the use of herbicides, and report a number of observations which confirm our theory:

a) that inhibition of growth in the plant treated with the herbicide led to increase in sensitivity to disease (beets treated with cycloate);

b) that soils treated with cycloate led subsequently to greater quantities of glucose and mineral salts in plants growing in them, i.e. to elements which nutritionally favour various pathogenic agents.

In fact, all herbicides inhibit proteinsynthesis, not only in the weeds supposed to be destroyed, but also partially—however 'selective' they may be—in the cereal itself, which becomes sensitised to various parasites. This process has been confirmed in a number of tests. Thus it was shown that a herbicide like atrazine may lead to increased sensitivity to Dwarf mosaic virus in maize, with the seriousness of symptoms increasing with increase in dosage until 100 per cent showed symptoms after 20 ppm of atrazine were added to the soil.[17]

Other studies have also shown that the synthetic hormone 2, 4-D, currently used as a herbicide, led in maize to:

—increase in aphids as a function of the dose;
—serious attacks by the corn borer (*Ostrinia nubilalis*), with an increase in the weight of pupae from caterpillars fed on the treated maize, which seems to be in line with the suggested better nutritional value of the treated plant;
—increase in susceptibility to *Helminthosporium teres.*

Thus once again the process of complex parasitic infestation is confirmed, involving a weakening of the plant, in this instance induced by a certain 'poisoning' which prediposes it to attacks by both disease (fungi, bacteria and virus) and by animal pests (mites, aphids, lepidoptera). Nematodes are also implicated. The 'immediate' cause as we saw earlier may be some form of deficiency, either in important minerals like potassium, or in certain trace elements, such as boron, zinc, copper. Thus the effect of herbicides on the treated cereal may be that the crop itself becomes prey to disease and insects. Such consequences can be dramatic when they affect a food crop like rice. While it appears that herbicides sensitise rice to various pathogens as described above, gentle techniques such as the use of a 'balanced' fertiliser may protect the plant without risk.

Outbreaks of disease and insect infestation in Rice

The most important enemies of rice are:

a) 'blast', a spore infection caused by *Piricularia oryzae,* which leads to serious damage, especially in India and in Brazil;

b) bacterial infection caused by *Xanthomonas oryzae,* which every year causes rice losses of up to 30 per cent in Japan and South East Asia;

c) numerous insects, including the brown rice plant hopper (*Nilaparvata lugens*), which takes its name from attacks which darken rice before it ultimately disappears. Chemical pesticides are no help, quite the contrary. According to the *New Scientist,* infestations of 'hopper burn', which was never destructive in the past, are now the result of "fundamental changes in farming practices".

Other damaging insects are: whorl maggot *(Hydrellia sasakii);* green leaf hopper *(Neptotettix viriscens);* leaf roller *(Cnaphalocrocis medinalis);* rice stem borer *(Tryporyza incertulas).*

We should point out immediately that all damage by these insects can be practically eliminated by a particular type of manure, as described below.

Finally, we should mention the rice weevil *(Sitophilus oryzae)* whose depradations have been shown to increase with use of nitrogenous fertilisers.

Damaging effects of herbicides on resistance in rice

Like many other aquatic plants, rice absorbs and concentrates chlorinated compounds (pesticides and polychlorophenyls) with rates of accumulation in relation to water, compared to dry matter, between 16 and 20,000 depending on species and product.[18] It is therefore not surprising that in such conditions 2, 4-D leads to the multiplication of the rice borer *(Chilo supressalis)* by the process described earlier.[19] In the same way, treating rice sowings with aldrin increases the number of larvae of the rice water weevil *(Lissorhoptrus oryzophilus).*[20]

The 'sensitisation' of rice is caused, as in other examples of biological disequilibrium for instance the multiplication of aphids or spread of disease, by inhibition of proteinsynthesis in the cereal and an increase in amino acids in its tissues, particularly in the stem.

The herbicide 2, 4-D is not the only one used in rice farming: three others may be used, two of them also chlorinated:

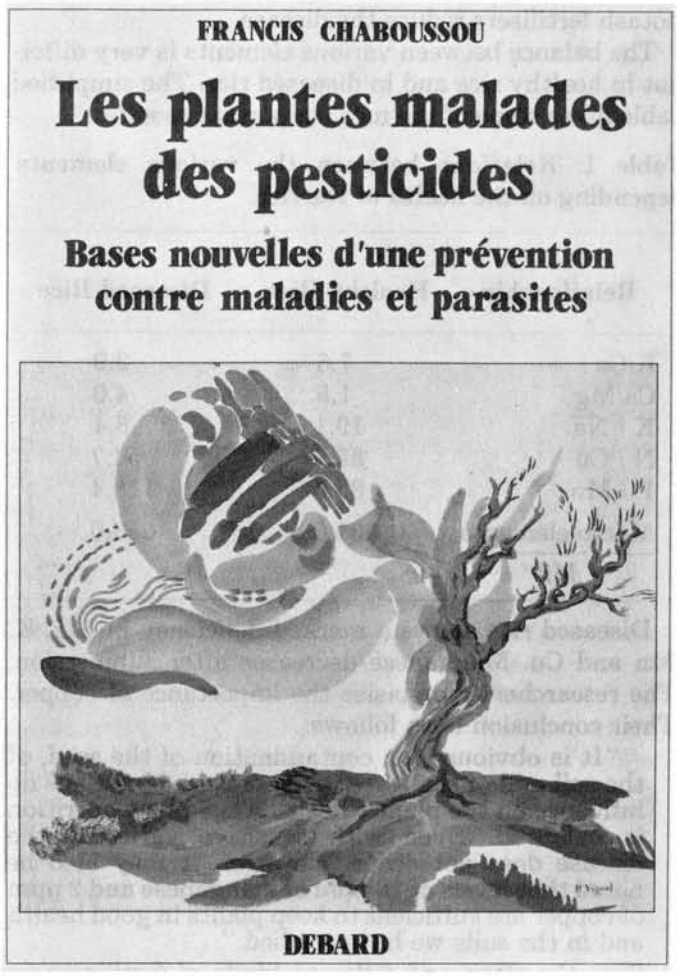
a) Fenoprop (2, 4, 5-T or trichloro 2-4, 5 phenoxy-2 propionic acid) used after pricking out, at the stage of 3 to 4 leaves;

b) Propanil or N (3-4 dichloro phenyl) proprionamide, applied before pricking out;

c) Molinate or S-ethyl perhydroazepinethioate (derivate of carbamic acid) and used as herbicide on rice before seeding or before pricking out, when it is dug into the soil, or after planting out.

Chlorinated products are well known for their action in reducing the synthesis of amino acids and leading to the breakdown of proteins.

In addition the level of nitrogen in plants treated with carbamates (herbicides or insecticides) is higher than in controls. This explains the effects of these pesticides, which are designed to inhibit proteinsynthesis, and with a selective action that can only be partial, which operate



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in the same way on the cereal thus rendering it more liable to damage by insects, bacteria and virus.

Trolldenier & Zehler[21] noted that a great many pathogenic organisms in rice depend on the soluble constituents of cells, such as sugars and amino acids. These constituents are found in high concentrations in plants supplied with large quantities of nitrogen as well as in plants deficient in potassium. Thus we can explain the influence of fertilisation and N/K balance on the resistance of the plant, especially of rice.

Fertilisers and resistance to pests in rice. Damaging effects of nitrogenous fertilisers

After studying how sensitisation is caused by herbicides, it is not surprising to find that nitrogenous fertilisers lead to favourable conditions for 'blast' *(Piricularia oryzae)*, in rice. During trials with fertilisers containing ammonia sulphate, Sridhar[22] found that a high content of soluble N in the leaves of rice favoured the development of the disease. *P. oryzae* uses various amino acids as its source of carbon. In fact both glutamine and asparagine increase in plants given fertilisers, this excess of soluble nitrogen arising in part from an imbalance in other elements, particularly of potassium.

Positive effects of potassium fertilisers on resistance to pests in rice

Different varieties of rice react in different ways to a given fertiliser. Thus Reddy & Sridhar[23] showed that increased potassium has a different effect on the bacterial disease *(Xanthomonas oryzae)*, depending on variety. No improvement in disease is found in the highly sensitive rice variety T(N)I, whereas an increase in potassium significantly reduces the disease in the less sensitive variety IR8. Furthermore, in support of the general rule, the leaves of the sensitive variety T(N)I showed higher concentrations of phenols, reducing and nonreducing sugars, and in amino acids than the less sensitive variety IR8.

This finding shows incidentally that the level of phenols is not correlated with resistance and, that it is the presence of soluble nutritional substances (reducing sugars and amino acids) which sensitise the rice to disease.

According to Reddy & Sridhar,[23] lack of potassium creates a favourable environment for the accumulation of nutritional substances in the leaves of the two varieties, when compared to plants fed generously with potassium. The same beneficial effect of potassium fertilisers on rice can be found in resistance to destructive insects, as made clear in recent research by Vaithilingham.[24]

By analysing leaves following tests in the field as well as in the laboratory, Vaithilingham showed that potassium leads to significant levels of resistance to the most important rice pests: first, brown plant hopper *(Nilaparvata lugeus)* which is especially interesting since chemical attacks on this insect are not successful; green leaf hopper *(Nepthotettix virescens)*; leaf hopper *(Cnaphalocrocis medinalis)*; rice stem borer *(Tryporyza incertulas)*; *Hydrellia sasakii.* And he concludes: "The maximum dose of 150kg per acre worked so well against the five main insects examined that not even a single application of insecticide was necessary."

For Vaithilingham the process of resistance lies in the increased use of amino acids to build proteins, while a deficiency in K leads, on the contrary, to an accumulation of various amino acids including valine, alanine, aspartic acid, glutamic acid, and arginine. He points out that in any discussion of nitrogen, one should be careful to distinguish between proteinaceous nitrogen and non-proteinaceous nitrogen, since resistance is linked to the absence of amines in tissues.

All these results confirm our theory of biotrophy, that resistance to pests in plants is linked to a high level of proteinsynthesis. We would also point out that fertilisation with potassium apparently brings about resistance not only to insects and bacteria, but also to fungal and viral infections, in support of the notion of a 'parasitic complex' which is linked to deficiency in proteinsynthesis (growth).

Optimum proteinsynthesis is, as far as we know, in part dependent on the nature of potassium itself, and in part on a balance between it and other elements which enter into the plant metabolism, and especially the availability of trace elements. According to Xie Jean Chang et al,[25] absorption of potassium is better correlated with slowly released K than with a potassium that is easily available. The quantities of K available in the soil are far from adequate for harmonious growth in rice where intensive farming practices are employed in using high doses of nitrogen and phosphate.

In fact deficiency symptoms are induced by unbalanced NPK fertilising, and while fertilisers involving large amounts of N P and K lead to higher yields, some exported nutritive elements are not replaced, as is confirmed by many studies of deficiency in the trace elements calcium, magnesium and sulphur. Thus, as Bussler points out:

> "In addition to the visible symptoms of deficiency diseases, hidden deficiencies demand more and more attention. With intensified fertilising, the balance of the principal nutritive substances takes on more and more importance, especially in light soils."[26]

In fact deficiency symptoms in nutritive elements have been observed in badly drained soils. The analysis shows that such soils were high in organic matter, but low in exchangeable K or available P or Zn. This explains why such 'organic' soils can be transformed into productive rice fields by using the formula NPK+Cu, Mo and Zn.[27]

Beneficial effects of trace elements

The beneficial effects of trace elements on resistance in rice have also been observed and demonstrated by other investigators over the past twelve years. It is even more important to pay attention to these trace elements since their deficiency may be provoked, as we have seen, by NPK fertilisation—the main culprit being nitrogen—accentuated by the use of herbicides. We have noted in fact that herbicides, principally those containing nitrogen, are cations, and may replace other cations such as Ca, Mg and Zn. Thus deficiency in some trace elements may be the first consequence in the process of sensitisation of plants, and especially rice, to various diseases and animal pests.

Thus we can explain resistance in rice to a balance in both trace elements and major elements. This aspect of the problem has been studied in depth by Primavesi *et al.*[28] Their important work showed what they called a number of fundamental biological laws:

—that abundant NPK fertilisation increases sensitivity to disease in plants;
—that the balance between elements is more important for crop production than large quantities of fertiliser;
—that there is a very delicate balance between the macro-elements and the trace elements;
—that the most delicate balance is between nitrogen and copper.

Where 'blast' *(Piricularia)* is concerned, the disease arises from a nutritional imbalance, that is, excess nitrogen as a result of deficiency in copper, copper being a trace element which acts on oxidising enzymes.

Furthermore, as in other plants, the balance N-K is important, excess N leading to a deficiency in K. Primavesi *et al* recall the fundamental change in metabolism in rice, notably in amino acids following excess of nitrogen, which led to sensitivity to 'blast'. Their finding also explains the inefficacy of fungicides.[28]

At the same time experiments by these researchers showed that rice is more resistant when grown in soil with a pH lying between 5.4 and 5.8 and that high levels of nitrogenous fertilisers increase susceptibility to *Piricularia.* Where the pH is between 6.8 and 7.3, potash fertilisers reduce the disease.

The balance between various elements is very different in healthy rice and in diseased rice. The simplified table gives some of the most important results:

Table 1: Relations between the various elements depending on the health of the rice.

Relationship	Healthy Rice	Diseased Rice
K/Ca	7.6	2.9
Ca/Mg	1.5	4.0
K / Na	19.1	6.4
N / Cu	35.0	54.7
P / Mn	35.6	118.4
Macro-elements / Mn	231.0	656.0

Diseased rice shows a marked deficiency in Mg, K, Mn and Cu. Manganese decreases after submersion. The researchers emphasise the importance of copper. Their conclusion is as follows:

> "It is obvious that contamination of the seed, of the soil and of the water by spores of 'blast' has no influence on the plant's health when plant nutrition is balanced. Even with sensitive varieties, the disease does not occur. However, it may also be noted that levels of 18 ppm of manganese and 2 ppm of copper are sufficient to keep plants in good health and in the soils we have studied."

Thus the effects of different kinds of fertilisers on resistance to different pests in rice demonstrate clearly the importance of plant nutrition, viewed as the relation between proteinsynthesis (growth) and health. While herbicides sensitise rice by inhibiting the process, the opposite occurs when plants are given a fertiliser with a balance of major and trace elements. It seems clear that this should be the direction for future research, although this should in no way diminish the need for a reduction in herbicide treatments which weaken the plant both directly and indirectly by damage both to the soil and in particular to nitrification processes.

General conclusions

1. Synthetic pesticides act upon the physiology of the cultivated plant, which affects resistance to various pests. Such effects may be serious, even dramatic, especially for basic foodstuffs like rice.
2. Pesticides are in fact poisons, not only for the pests they are designed to attack, but also for the host plant.

   Their damaging effects are linked to inhibition of growth and to enrichment of plant tissues with soluble substances, such as amino acids, which provide a nutritional base for the development of various pests (insects, fungal, bacterial and viral diseases).
3. The level of protein synthesis, which is linked to resistance, depends not only on genetic factors but also on environmental ones. Thus damage may arise not only from pesticides but also from other farming procedures, like fertilisation.

Plant protection should therefore be investigated, not by means of attempting to destroy the pest, but rather by stimulating the plant's own resistance. Such

effects are linked to the positive effects associated with protein synthesis. They may be obtained by abstaining from weakening the plant with damaging pesticide treatments (synthetic pesticides) and by using adequate fertilising elements so as to correct deficiencies.

Such a therapeutic approach should be accompanied by a proper leaf analysis so that precise biochemical criteria, such as the level of proteinaceous N compared to soluble N, or levels of trace elements which influence the activity of enzymes, can be assessed; and deficiencies treated to enhance plant resistance.

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Acknowlegement

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Pesticide Misuse in India

by Y.P. Gupta

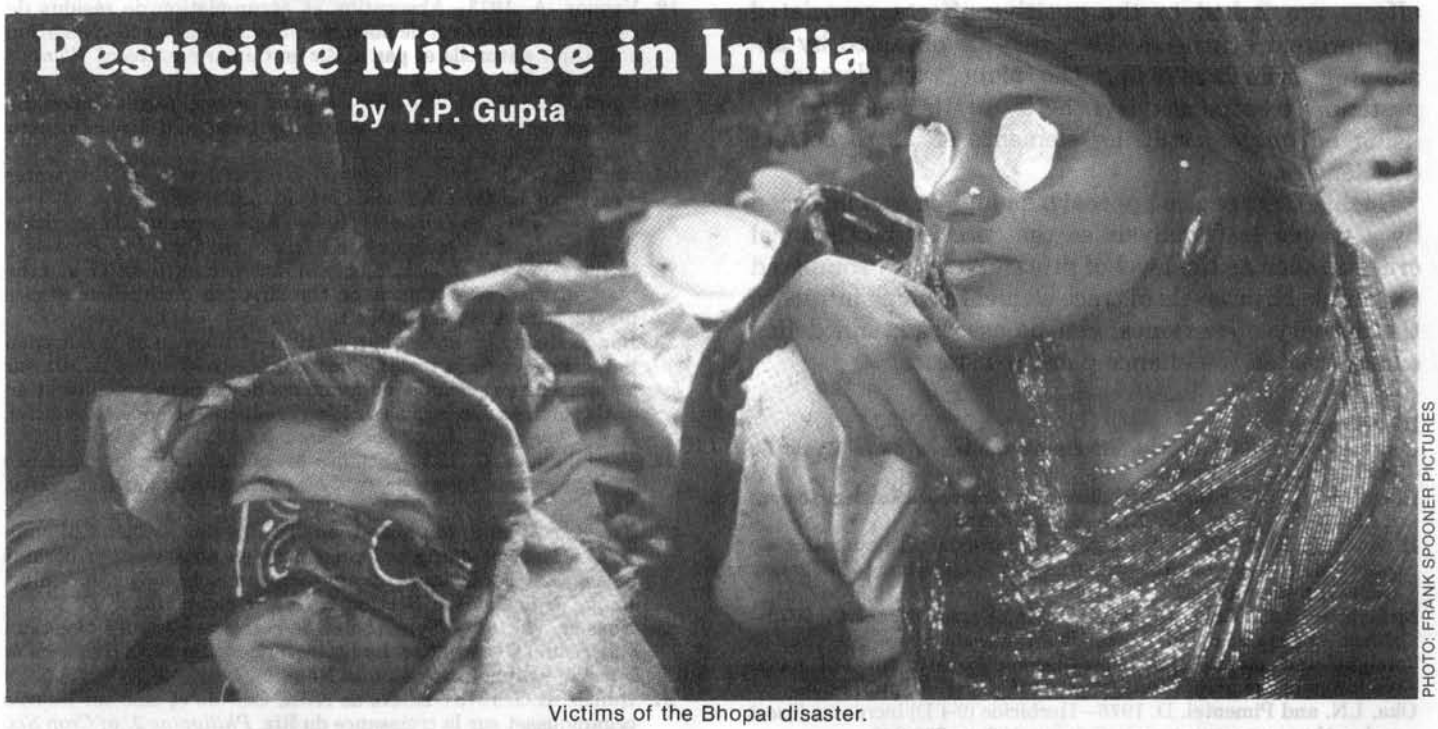

PHOTO: FRANK SPOONER PICTURES

Victims of the Bhopal disaster.

Demand for pesticides as a plant protection measure has rapidly increased in India and other regions of the developing world, but their indiscriminate use is posing a serious threat to human health.

The gruesome tragedy caused by the leakage of toxic methyl isocyanate gas in Bhopal (Madhya Pradesh) has exposed the potential dangers in the manufacture of agricultural chemicals for use as pesticides. Other dangers are also inherent in their use. The Bhopal plant was annually producing about 2,500 tonnes of methyl isocyanate based pesticides which include carbaryl, aldicarb and isopropyl phenyl carbamate. Methyl isocyanate is highly toxic, its tolerance level being 0.02 ppm.

The demand for pesticides as plant protection measure has rapidly increased in India since the introduction of high yielding seeds, a large number having been approved for use under the Insecticide Act, 1968, which was enacted to regulate import, manufacture, distribution, sale, transport and use with a view to preventing the risk to humans, animals and the environment. These pesticides have been found to be effective against various pests either through direct contact or through systemic action. Some are considered beneficial as fumigants for protection of foodgrains during storage.

In 1983-84 some 65,085 tonnes of chlorinated pesticide, 23,000 tonnes of phosphatic, 6,310 tonnes of carbamates, 120 tonnes of plant origin and 1,325 tonnes of fumigants were consumed in India. But their indiscriminate use in the developing world is posing a serious threat to human health, apart from occupational hazards. Such agricultural chemicals leave behind residues in food and produce ill-effects when the concentration exceeds the safe tolerance level.

A report of the International Development Research Centre (Ottawa) claims that 750,000 cases of pesticide poisoning occur each year worldwide, half of which occur in the Third World, and that 10,000 people die of pesticide poisoning every year in the developing countries. The report also claims that pesticide-caused diseases have overtaken endemic diseases in Third World countries. Since 1972, the annual growth of the pesticide market has been 5 per cent and pesticide poisoning cases have increased at the same rate.

Pesticide Consumption

In India, the use of pesticides has risen from 2,000 tonnes a year in the 1950s to over 80,000 tonnes in 1984-85, having increased from 50,000 tonnes in 1982-83. The cropped area under plant protection coverage increased from 6.4 million hectares in 1960-61 to 80 million hectares in 1982-83.

At present, 57 different pesticides are manufactured in the country of which 28 are insecticides; 12 fungicides; 10 herbicides; 3 fumigants, 2 rodenticides; and 2 plant growth regulators, with a total licensed capacity of 93,220 tonnes. BHC, DDT, malathion, methyl parathion, endosulfan, carbaryl, dimethoate and monocrotophos are the important ones which account for 87 per cent of total production. BHC, DDT and malathion account for more than 50 per cent of the total production and are the cheapest and therefore most popular with the small farmers. BHC is formulated by the highest number (1,198) of formulators followed by DDT (1,090), carbaryl (520) and endosulfan (299). DDT is mostly used by public health authorities. Methyl parathion, meanwhile, is used over an area of over 12 million hectares. In addition, India imports some newer and more sophisticated pesticides, which include 8 chlorinated, one carbamate and 7 organophosphates.

The demand pattern of total pesticides for 1984-85 and 1989-90 is estimated to be 99,000 and 119,000 tonnes, respectively, of which the important ones are as follows:

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Demand pattern of some important pesticides

Pesticide	(Tonnes) 1984-85	1989-90
BHC	42,500	47,000
DDT	17,750	19,750
Malathion	5,550	6,550
Methyl parathion	3,000	3,500
Endosulfan	2,250	3,200
Carbaryl	2,000	3,000
Dimethoate	1,100	1,400
Monocrotophos	1,000	1,500
Phosphomidon	900	1,150
Phorate	800	1,100

(Source: Working group on pesticides, Planning Commission)

The others are used in smaller quantities. Endrin and ethyl parathion, dieldrin and phoadrin have been phased out. Demeton-6-mephyl and pirimiphos ethyl are banned for use in India.

Despite the growing use of pesticides, the annual estimated loss to crops damaged by insects, pests and diseases has increased from about Rs 33,000 million in 1976 to about Rs 60,000 million in 1984, which includes grain losses during storage. In part the damage may be due to an increased area under crops.

Pesticide Poisoning

Even though there are restrictions and regulations on pesticide use, pesticide poisoning is widespread, particularly in the developing countries because of inadequate safety requirements. In India, the annual intake of highly poisonous chemicals is reported to be about 3,000 tonnes, and of the pesticide poisoning cases estimated in the developing countries, India accounts for one third. Farm labourers employed for spraying operations are the worst affected and most of them get exposed for long periods through working continuously with pesticides. Cases of blindness, cancer, stunted growth of farm workers' children, deformities, diseases of the liver and the nervous system from pesticide poisoning have been identified in the cotton-growing districts of two Indian states. Studies conducted by the Industrial Toxicology Research Centre (Lucknow) in collaboration with the Neurology Department of the K.G. Medical College (Lucknow) revealed that one fifth of the farm workers had damaged eye-sight following muscular degeneration. Workers engaged in the pesticide industry are equally exposed to health hazards. A recent study has shown that 73 per cent of them had signs of toxic poisoning and 35 per cent cardiovascular and gastro-intestinal problems[1].

There were 106 deaths in Kerala from consumption of wheat flour and sugar contaminated with folidol from leakage during shipment from Bombay to Cochin, which caused myosis, salivation, abdominal pain, diarrhoea and unconsciousness. Earlier, poor Harijans in the Chickmanglur district of Karnatka were afflicted with severe paralysis and other fatal diseases after eating crabs from pesticide treated paddy fields. In Udaipur (Rajasthan), aluminium phosphide poisoning caused 28 deaths when tablets were mistakenly eaten with the hope that they would provide relief for stomach pain. The symptoms were restlessness, vomiting, circulatory collapse and unconsciousness. Death occurred within four to six hours of swallowing this deadly poison.

Two distinct types of poisoning—acute and chronic—have been recognised. The acute type is caused by organo-phosphorus and carbamate compounds, requiring prompt medical attention and the symptoms are immediately visible. The chronic type is caused by chlorinated compounds such as DDT, aldrin and dieldrin, owing to the accumulation of pesticide in the body.

Different Pesticides

Organic pesticides have virtually replaced inorganic ones, being more effective and relatively less hazardous. These chemicals can be grouped according to their chemical nature. Chlorinated compounds are quite stable and persist in the environment for prolonged periods. Their tendency to accumulate in the fatty tissue causes acute toxicity affecting the central nervous system, leading to hypersensitivity, convulsions, paralysis and death through respiratory arrest. Within this group are DDT, GHC, aldrin, dieldrin, lindane, methoxychlor and endrin. Excessive DDT causes hepatic disorders. DDT is most effective against flies, mosquitoes, bugs, lice, caterpillars, Japan beetles, leaf hoppers, cloth moths and their larvae, acting as a non-systemic gut and contact pesticide. BHC is effective against soil insects, including grass hoppers, cotton pests, storage and household pests, both as a gut and contact poison. Lindane is a strong gut and contact poison, effective against a wide range of insects. It is safer for household purposes and is especially useful against the rice-stemborer. Aldrin and dieldrin are powerful non-systemic pesticides having a broader spectrum. Aldrin is widely used against soil pests, locusts and termites. Methoxychlor is a non-systemic contact and gut pesticide particularly effective against beetles. A tolerance limit of 3ppm for DDT, GHC and methoxychlor in food grains has been fixed in India.

Ethylene dichloride, ethylene dibromide, methyl bromide (chlorinated compounds) and aluminium phosphide (inorganic) are commonly used for fumigating cereals and pulses. There is however a risk of bromide residue in stored grains, since it accumulates in human and animal tissue—liver, kidney, heart, spleen organs, causing degenerative lesions. The amount of bromide residue in stored grains must not exceed 50ppm.

Organophosphorus compounds are the other group which cause acute poisoning. Toxic symptoms include an increase in pulse rate, excessive salivation, perspiration, muscular tremors, convulsions, comas and finally death by asphyxia. Such pesticides include malathion, parathion and dichlorvos. Malathion and parathion are systemic pesticides, the former being considered one of the safest, with moderate residual toxicity, while the latter is not only absorbed and retained by plants but it is highly toxic. Dichlorvos is a contact and gut pesticide and is useful for household purposes. A tolerance level of 3ppm for malathion, 2ppm for dichlorvos and 1ppm for parathion in food grains has been fixed.

Carbamates constitute another group of pesticides of which carbaryl and carbofuran are commonly used. They are contact poisons used against pests of fruits, vegetables, cotton and other crops.

Their residues produce relatively less harmful effects and are therefore considered as a safe group. Carbaryl is effective at a concentration of 0.05 per cent. They are similar to pyrethrins in their action but because of their specificity, their use is limited[2].

Among pesticides of plant origin pyrethrins are the most effective and safe to use. They are powerful broad spectrum contact poisons having a 'knock down' effect on pests when sprayed at a concentration of 0.002 to 0.004 per cent. They are not very harmful to human health as they are easily broken down to non-toxic compounds and do not leave behind residual toxicity. As they do not persist in the environment, they have to be used at a higher concentration to be effective. They can be used with relative safeness for household purposes to control insects of domestic and public health importance such as flies, mosquitoes, cockroaches, fleas, bed bugs and lice. They should not be used on a larger scale because of their limited availability and cost. Nicotine sulphate—another pesticide of plant origin is not much used because of its bad odour. Recent studies at the University of Georgia have revealed that the oil in orange peels holds great promise as a powerful insecticide.

Attempts are now being made to develop plant-based pesticides. The neem tree grows wild in Asia and Africa and holds great promise of becoming a major source of natural insecticide. The insecticide is being manufactured both as a dust and spray in the USA. Recently, an agricultural scientist in India has claimed to have developed a plant-based natural pesticide, which does not leave toxic residues. It is being tested.

Pesticide Cocktail

In an effort to make pesticides more effective, a number of combinations (cocktails) such as that of malathion, BHC and dimethoate have been formulated but such practices have been discouraged particularly since they contribute to the development of resistance among non-target organisms. The development of resistance to DDT, GHC, malathion and other pesticides by the malarial mosquito is a glaring example.

Inorganic pesticides which were widely used in the past include sodium fluoride, barium carbonate, lead arsenate, aluminium phosphide and copper compounds. These chemicals are highly poisonous and have caused accidental deaths when mistakenly mixed up with flours, baking flour and powdered milk.

Banned Pesticides

The use of a number of agrochemicals identified by the World Health Organisation (WHO) as highly toxic or hazardous has been banned or restricted in many countries. These include DDT (banned in USA, Australia, USSR, Poland, Switzerland and under voluntary restriction in the UK), BHC (banned in USA, Japan, USSR, Denmark, Sweden, France, West Germany), Aldrin (banned in USA, UK, West Germany, Sweden, Canada, Italy, USSR, New Zealand), chlordane (banned in USA, UK, Argentina, Turkey, Sweden, Denmark, Bulgaria, Italy), Endrin (banned in USA, UK, Argentina, Japan, Mexico, West Germany, Finland), Methyl Parathion (banned in Italy, Japan, Spain), Toxaphene (banned in Argentina, Finland, West Germany, Italy), Heptachlor and Lindane (banned in Western countries).

Meanwhile the reason for the continuing use of banned pesticides in India is based on the evidence that such pesticides degrade into harmless compounds much faster in tropical countries than in temperate countries[3,4].

The use of certain other chemicals such as the herbicide 2,4-D and paraquat are under review in the USA as 'suspected chemicals'. Aldicarb, carbofuran, chlorfenvinfos, dichlorvos, endosulfan, monocrotophos, oxydemelon, phorate and phosphomidon are other chemicals listed as hazardous substances which have been restricted for use in certain countries.

Pesticides in Food

According to a WHO report, the level of chlorinated pesticide intake is higher among Indians than among people of other countries. High levels of pesticide residue have been reported in various food commodities, including wheat, rice, pulses, groundnut, fish, meat, butter, ghee and cheese. India's daily diet is reported to contain about 0.27mg of DDT and the level of accumulated DDT in the body tissue of an average Indian varies between 12.8 and 31.0 ppm. The National Institute of Communicable Diseases (Delhi) reports the DDT levels of fat samples from the Delhi region to be 10.0 to 189.0ppm. Various institutions including the National Institute of Occupational Health, Calcutta, Central Plant Protection Training Institute, Hyderabad, Indian Agricultural Research Institute, New Delhi, and agricultural universities have found the levels of DDT residue in different foodstuffs to be 1.6-17.4 ppm in wheat, 0.8-16.4 ppm in rice, 2.9-16.9 ppm in pulses, 3.0-19.1 ppm in groundnut, up to 5.0 ppm in vegetables and 68.5 ppm in potatoes. Analysis of cereals, pulses, milk, eggs, meat and vegetables indicated that more than 50 per cent of the samples tested contained pesticide residues, and in more than 30 per cent, the residue exceeded tolerance limits prescribed by WHO. In fact DDT, BHC are the most common residues of chlorinated compounds but substantial quantities of malathion and lindane residues have been found in foodstuffs collected from Calcutta market and in human tissues.

In 70 per cent of the tested samples of bottled milk in Maharashtra, the amount of DDT and dieldrin was 4.8-6.3ppm and 1.9-6.3ppm, respectively, when the permissible limit is 0.66ppm. The average level of dieldrin residues in the milk sold in Bombay was as high as 96ppm. DDT and BHC residues in butter, were on average, 3.6 and 2.6ppm respectively, the tolerance limit being 1.25ppm. Baby foods from Punjab, Gujarat and Bombay contained from 1.52 to 2.12ppm of DDT. Oilseeds (mustard, groundnut, linseed, rapeseed or cottonseed), oils and desi ghee were also high in pesticide residues, as were meat, fish and poultry.

The continuous use of these poisonous chemicals have also affected ground water sources through seepage into the soil. As a

result, rivers, streams and ponds have become highly polluted with these harmful chemicals. Drinking water from ponds in the Hassan district of Karnatka contained 0.02 to 0.2ppm of pesticide. The level of BHC in water taken from the Cauvery River (Karnatka) was over 1,000ppb (parts per billion) and of methyl parathion 1,300ppb. Many forms of aquatic life including fish, birds and other animals have been greatly affected by this pollution.

After the catastrophic disaster in Bhopal, the Agriculture Commission of the United Nations Food and Agriculture Organisation is working out a code of conduct on the trade and use of pesticides and on legislation to prevent the export of banned pesticides. The sale of aldicarb which was being used at the Bhopal plant has been strictly restricted by law. Also, in collaboration with the US Agency for International Development (USAID), the World Bank has developed new guidelines on the use of pesticides to avert damage to the health and environment.

However the use of pesticides raises an important question whether such chemicals sustain and improve the quality of life or destroy it.

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Soil Erosion in Britain:
The Loss of a Resource

by R.P.C. Morgan

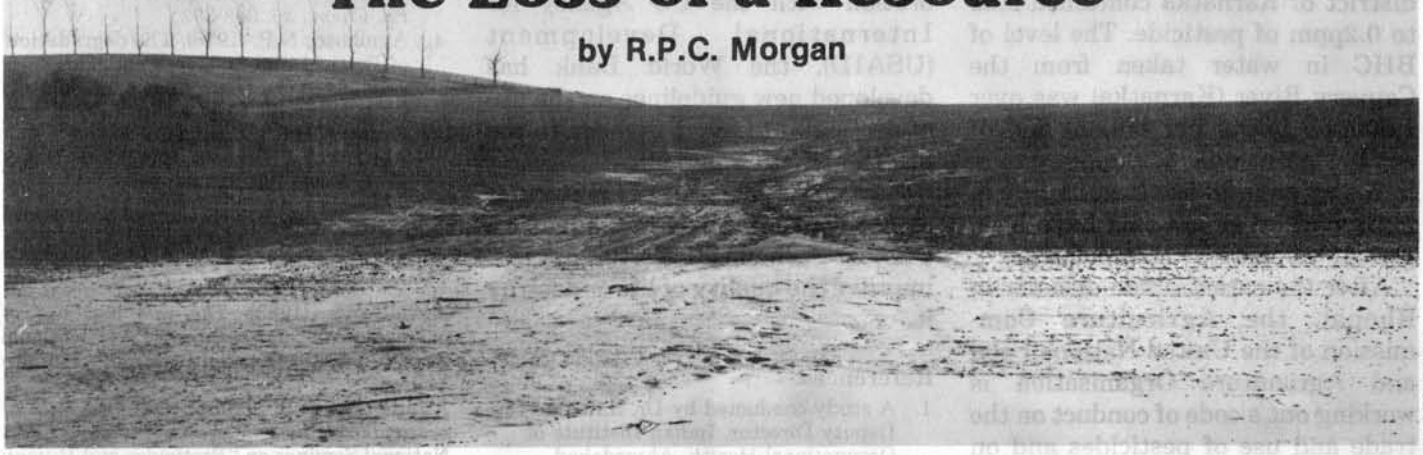

PHOTO: REED

Winter cereals buried by thick silt, the result of soil erosion. A sudden storm on light sandy soil can scar even gently sloped fields with a network of erosion channels. The soil washed out of these channels can bury crops as has happened here.

Soil erosion is becoming rampant through modern farming practices. Yet, rather than face this problem, the Government has savagely cut funding of the Soil Survey of England and Wales.

The widely held assumption that soil erosion is not a problem in Britain because of the low intensity of the rainfall and the high proportion of the land under grass and trees is invalid. The effects of erosion can be seen in the spring by the lighter coloured patches on hillsides where ploughing has turned the subsoil on to the surface. Deposits of fine material, often a metre or more thick, in the valley bottoms are further evidence. As more and more subsoil is exposed on the slopes above, however, these deposits become coarser and the lower land is covered by infertile sandy material.

Since erosion is a natural process, the problem is not that it occurs but the rate at which it takes place. The question of what constitutes an acceptable rate of erosion is much debated. It depends upon the rate at which new soil forms, the addition of organic materials and fertilisers to the soil and the depth of the top soil. American scientists in the early 1960s adopted an annual rate of eleven tonnes per hectare as the maximum acceptable but they recognised that this figure was probably too high for areas of thin, highly erodable soils. Top soil depths on the sandy soils in Britain are often only a few centimetres and soil scientists suggest that the annual rate of new soil formation probably averages less than 0.1 tonne per hectare. Thus, even allowing for the mixing of the top soil with the subsoil by cultivation and the addition of chemicals through fertiliser application, adopting a figure of one tonne per hectare may prove too high for British conditions. For a typical sandy loam soil this is equivalent to a loss of about seven millimetres of top soil in a hundred years. Since this will have hardly any effect on crop yield, however, it seems a reasonable figure to adopt.

Until the middle 1970s data on erosion rates in Britain were scarce. Most measurements had been made by geomorphologists in areas with only limited interference by man. Not surprisingly, the rates were low, generally less than 0.1 tonne per hectare as an annual average. Virtually no data existed for arable land. Measurements made between 1973 and 1979 for a variety of soils and landuse in the Silsoe area of Bedfordshire thus gave cause for concern (see Table). Not only, as expected, was the erosion rate excessive on sandy loam soils kept bare of crop but sandy loam and chalk soils under winter wheat and spring barley were experiencing erosion at more than twenty times the acceptable rate. By implication, this was also true for land under market gardening which generally provides less protection to the soil than cereals, especially where two crops per year are obtained and there is a period in mid-summer when the land is bare at the time of high-intensity thunderstorms.

Table 1. Average annual soil losses in the Silsoe area, Bedfordshire (tonnes per hectare)

Bare sandy loam soil	10 - 45
Cereals on sandy loam soil	0.6 - 24
Cereals on chalky soil	0.6 - 21
Cereals on clay soil	0.3 - 0.7
Grass on sandy loam soil	0.1 - 3
Woodland on sandy loam soil	— 0.01

Values are for slopes of 7° to 11°, except for the woodland where the slope was 20°, in undulating terrain.

Although the Silsoe study provided evidence of serious soil erosion, the rates obtained are rather conservative. The highest rate for a single storm was nineteen tonnes per hectare whereas storm soil loss rates of 156 tonnes per hectare have been measured by Dr A H Reed in east Shropshire and 195 tonnes per hectare by Dr R Evans and Dr S Nortcliffe in north Norfolk. Observations in the Silsoe area show, however, that erosion is a frequent event. Storms with soil loss greater than two tonnes per hectare from bare ground occurred in the Silsoe area in four out of the seven

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years of study, including the drought year of 1976.

Comparable data are not available for wind erosion but studies by Dr S J Wilson in the Vale of York indicate that the rates are similar to those for water erosion.

By combining information on soil properties, land capability, rainfall and wind velocity, it is possible to estimate the area with a risk of soil erosion above acceptable rates. This is about one million hectares or about eighteen per cent of the arable area of England and Wales. It should be stressed that this figure is an estimate of the problem on land classified as suitable for arable farming. It is not therefore a reflection of the misuse of the land but rather the failure to manage that land in an appropriate manner. Misuse of the land, for example by bringing land of lower class into arable production, will increase the area vulnerable to erosion still further.

Poor Farming Practices

Current management practices on arable lands are unlikely to sustain land quality. An erosion rate of twenty tonnes per hectare each year will result in a loss of 140 millimetres of top soil in one hundred years. Crude estimates of cereal yields in relation to soil depth suggest that with a starting top soil depth of twenty-five centimetres, the result will be a decline in yield from three to two tonnes per hectare. Organic content is likely to diminish from 1.5 to 0.75 per cent over the same time period with consequent deleterious effects on structural stability, increases in surface compaction and sealing, decreases in infiltration rates, increases in runoff, reductions in the amount of water available for plant growth and further increases in erosion rates. Under these conditions, the effects of compaction by tractor wheels are compounded. Successive passage of tractors over the same piece of land can be devastating with tractor wheelings developing into deep gullies. By contrast, the effects of hedgerow removal are less important. Only where the hedges were at right angles to the dominant wind or on the contour were they an effective barrier to erosion.

Approaches to soil erosion control are based on agronomic measures, soil management and the use of mechanical protection works such as terracing. The latter are generally inappropriate for this country. The erosion rates are not severe enough to warrant them; it should be possible to reduce erosion to acceptable levels through crop and soil management alone. Also, the size and shape of many of the fields would make the installation of terrace systems or even contour farming uneconomic by producing a large number of rows with very small working lengths.

Recent research has questioned the much accepted principle that establishing a crop cover will always help to protect the soil from erosion. Erosion is a two-phase process consisting of detachment of soil particles from the soil mass and the transport of those particles downslope, downstream or downwind. One way of controlling erosion is to limit the rate of detachment because without the supply of loose detached material on the soil surface there is no sediment for water and wind to transport. Different crops give different degrees of protection from detachment. The detachment rate on sandy and sandy loam soils under cereals decreases with increasing canopy cover so that it is about thirty per cent of that on bare soil with a ten per cent cover and about three per cent with a seventy-five per cent cover. With large-leaved vegetables such as Brussels sprouts, the detachment rate decreases to about seventy per cent of that on bare soil with fifteen to twenty per cent canopy cover but then increases so that, by the time forty to fifty per cent cover is attained, the detachment rate equals that recorded without a crop. Since increased detachment is usually associated with soil aggregate breakdown, surface crusting and increased runoff, this may explain why erosion is frequently observed under vegetable crops even after they have reached maturity.

Since rates of erosion are very low when the soil is covered by grass, the simplest solution to the problem is to reintroduce rotations with grass leys. These will not only reduce erosion to acceptable levels but are also the only effective way of preventing the decline in organic content on the sandy soils. If government policy continues to make this solution uneconomic, the alternatives are to accept the consequences of not being able to sustain cereal production on the lighter soils far into the next century because of the effects of erosion on yield, or to make more money available for research to develop an acceptable soil conservation technology. Unfortunately, very little research is conducted on soil conservation in this country. Initiatives are left to innovative farmers and to trials on Experimental Husbandry Farms. Although frequently successful, the measures are pragmatic and local. Without the fundamental studies to understand how and why they work, it is impossible to predict the likely success of transferring them to another area.

If mechanical methods and agronomic measures are not the bases for solutions, the potential role of soil management through tillage must be investigated. Minimum tillage has its advocates for erosion control but its effectiveness cannot be demonstrated in this country because few measurements have been made of the runoff and soil loss associated with its use. Alternative approaches might be just as effective and more acceptable to farmers. P Glassford has adapted conventional tillage to produce a surface which is resistant to wind erosion using a system of ploughing, rolling and pressing of the soil. The Glassford technique is now used by many farmers on the sandy soils in the east midlands. Research is now in its early stages to see whether a similar approach could be developed for water erosion control.

Agricultural soil erosion is severe enough to warrant attention. Complacency will only lead to a deterioration in the quality of the country's soil resources. The problem can be solved if its importance is recognised and a policy developed for its control. Such a policy requires funding so that the present limited efforts of individuals can be properly supported by a co-operative programme involving research scientists in the universities and government, the advisory services and farmers. The development of acceptable and effective conservation measures is a matter of priority.

Rural Electrification

by Patricia Adams*

The world's first great introduction to rural electrification as a panacea for "underdevelopment" was made with the inauguration of the Tennessee Valley Authority, America's largest utility. The TVA was to provide, among other services, the electricity thought necessary for regional economic development. By most accounts the TVA "saved the Valley from economic despair and made it a cornucopia". Other observers are coming to different conclusions.

A recent book, *The Myth of the TVA*, by William Chandler of the Washington-based Environmental Policy Institute, shows that the TVA provided no greater economic growth for the region than occurred in similar areas which did not receive any of the TVA's massive funding. Even more surprising to those who have grown up with the myth of the TVA, rural electrification proceeded more slowly in the TVA area than in nearby states.

According to this book, which reviewed the TVA's 50-year history, the reason is straightforward. People use electricity only as they can afford to and, compared to other rural parts of the nation which were electrifying more rapidly, the TVA region was relatively poor. Development and affluence bring about the desire for electrical services, Chandler explains, not vice versa.

Rural electrification can provide many benefits. But because its proponents have zealously adopted it as their mission and credited it with almost magical powers, it has been pushed to the exclusion of other energy forms.

Worldwide, the belief is prevalent that rural electrification acts as a catalyst to raise food production, trigger agricultural and small-scale industrial development, increase employment, reduce migration to urban centres, and even curb population growth. As if it were borrowing a script from the promotional pieces of the TVA, the Philippines National Electrification Administration described in its 1979 Annual Report how rural electrification

> has transformed sleepy and apathetic rural villages into industrial and commercial beehives . . . rural electrification indeed is the most dramatic symbol of the quantum jump of the Philippines into modernisation. With rural electrification many farmers are now set on running their irrigation pumps. With government encouragement, small and medium-scale industries are sprouting all over the archipelago.

A few dissenting words are occasionally heard, however. A 1983 study of rural electrification programme by the International Labor Organization could find no evidence to support the claims made for rural electrification. What the ILO did find was that cumulative investments in Third World electrification, estimated at between $10 and $20 billion, has resulted in little electrification actually occurring. This confirmed the World Bank's discovery, ten years earlier, that only twelve per cent of the Third World's population had access to electricity. But having access does not mean that they use it. Only one half of that twelve per cent, according to the Worldwatch Institute, could afford to purchase the power available, confirming the ILO's conclusion that the rural poor have not benefited substantially from the advent of electric power to their villages. As an editorial in India's *Economic and Political Weekly* explains, the reason why electricity is used in only ten to twelve per cent of India's 2,300,000 households that are officially classified as electrified is that:

> The electrification of rural households requires the installation of main meters and other equipment along with internal wiring which calls for an investment of between 500 and 800 rupees per household (nearly half the annual per capita income) at the very least. Obviously, the overwhelming majority of the rural population, consisting of agricultural labourers, small peasants and tenants, rural artisans, etc. is in no position to make this investment.

Eighty per cent of the Third World's electricity is supplied from a central grid, which links the electricity generating stations to large urban populations. To bring electricity to areas distant from the grid—the remote communities with low population densities and few uses for electricity—is prohibitively expensive. Even if people were to have their homes wired for free, most could only afford to buy precious little electricity.

Even subsidised, as it usually is, electricity is a "luxury good", according to the ILO. The only ones who tend to benefit from the subsidies in countries as different as Papua New Guinea, Bolivia, and India are the larger farms and wealthier families—the only ones who can afford the electricity. As the Papua New Guinea Government ex-

* Reprinted from *In the Name of Progress* by Patricia Adams and Lawrence Solomon, Energy Probe Research Foundation, Toronto, Canada.

plained in its 1978 energy policy paper:

> The research we have conducted into the distribution of existing energy forms in Papua New Guinea villages informs us that a relative few, the wealthier villagers, benefit most, and these families will certainly be the first, and perhaps the only beneficiaries of rural electrification. Because rural electrification would have to be heavily subsidised in Papua New Guinea, it could well turn into a subsidy of only the well off. Rural electrification is likely to be a much more effective instrument creating rural elites than would be the case with investment in schools, roads and other community facilities.

In Nicaragua, the failure of rural electrification is similar. "Only on the largest, most heavily capitalised farms and ranches in the three cooperative areas was electricity used for production or processing purposes," reports Development Alternatives Inc., which also found no evidence that electricity was a factor in starting these activities, or that it was cheaper.

Advocates of rural electrification are also starting to discover that their dreams are not being realised. A study of twenty-three rural communities of Colombia, Peru and Chile for AID, America's foreign aid agency, and one of the worlds leading proponents of rural electrification, found that:

> . . . in spite of the universal belief that electrification means progress, none of the electrified sites visited could report any positive economic impact attributable to the installation of electric power . . . Although questioned hopefully on other measures of "progress" . . . increased literacy, some minimal industrialisation, etc., the answers were essentially negative. The provision of electrification had not proved sufficient to trigger economic development.

Confirming this finding is another AID study of rural electrification in Bolivia which found that electricity was neither a catalyst nor a precondition for economic development of rural areas. The Inter-American Development Bank has come to the same conclusions. In a major evaluation of its $414 million loans to twenty-five rural electrification projects in nine Latin American countries, the Inter-American Development Bank found no "general agreement or substantial evidence" that gains in agricultural productivity, were the results of the projects.

The often-made claim that rural electrification leads to an increase in employment is also difficult to support. After reviewing many cases, the International Labor Organization study concluded that "there is not much evidence to suggest that electricity which is used for productive purposes has so far had any major beneficial impact on the employment/income situation of the rural poor. On the contrary, there is some evidence of net job-losses and of a worsening income distribution as a result of rural electrification."

In India, for example, most farmers now using electricity were able to release members of their family or hired labour from irrigation tasks. In the rural areas of Java and the Philippines, the coconut oil manufacturing industries are using electricity to displace thousands of workers. Apart from a few cases, such as in China where rural manufacturing and service industries absorbed labour, the evidence indicates that the workers who were displaced in most Third World countries generally found no alternative employment.

As for the popular theory that rural electrification acts as a brake on migration to urban areas, the ILO study voted no confidence here as well. AID concurred: it found that in Costa Rica electrification had a neutral effect on migration patterns.

Exuberance for the attributes of rural electrification extends beyond the economic factors to social ones, such as population control. Said an Indian Minister, "in the dark villages, the only recreation at night is procreation," and in Pakistan, a Planning Director for the Water and Power Development Authority put it like this: ". . . perhaps a most important effect of rural electrification which has largely gone unnoticed has been in the area of population control. It is generally true in Pakistan that wherever electricity has been supplied, the population growth rate has fallen noticeably." Here again, credit given where credit is not due. Electricity is used by people who can afford it—by those who are better off—and in Pakistan those who are better off are also tending to have fewer children.

In addition to the $10 or $20 billion dollars already spent on Third World rural electrification, as much as $65 billion has been slated to be spent in the 1980s, yet, says the ILO, there is not so much as "a few success stories" to justify these expenditures ". . . such stories do not yet exist". Crediting electrification with the powers to develop a rural community "is difficult, if not impossible".

Rural electrification from large central stations is still pushed as an answer to the Third World's problems, but the ardour behind the push is waning. Another form of rural electrification, based on a decentralised energy technology, has become the darling instead, and it is quickly attracting the attention of business interests as well as political leaders. The technology is solar power, an obvious choice, its proponents reason, because if there's one thing the Third World has plenty of it's sun.

Black Future for the Black Poplar—A Rare Native Tree in need of Conservation

Of all the trees that make up the characteristic landscape of lowland England, the one whose future seems most in doubt is the native black poplar. Other rare native trees may actually occur in small numbers—for example the British species of whitebeam, but the original range of such trees was small. The native black poplar was once widespread, but has declined rapidly over the centuries.

The natural habitat of the black poplar was the flood plains of lowland rivers, but that was before man exerted any serious impact on the landscape. It is likely that the male and female trees occurred in approximately equal proportions. After fertilisation, the female tree produces vast numbers of small seeds which have fluffy outgrowths upon them and which are dispersed by wind. Winter floods and rivers flowing in spate would create new bare areas by erosion and by the deposition of silt. Some of the black poplars' copious seed output would land in these newly-bared areas, and germinate; though the seed only remains viable for about two weeks after maturation in late June. The seedlings grow rapidly and by September are 10-15cm in size, with 6-10 kite-shaped leaves. However there is the ever present danger that further floods will sweep away the young trees.

Native black poplars can be recognised by their very distinctive branching pattern. Thick branches arise from the lower parts of the trunk, and frequently such branches arch downwards, sometimes actually reaching the ground. These down-arching branches were ideal for the crucks of timber-framed buildings and several barns survive with poplar crucks. Indeed, our leading authority on the history of woodmanship, Oliver Rackham,[1] has speculated that the whole cruck-framed building system may have evolved from the early use of split black poplar boughs.

Even until fairly recently it was not uncommon to take cuttings from a wild tree in order to plant a native black poplar near a farmhouse or farmyard. The wood does not burn particularly well, wet or dry, though it is ideal for clogs and for making into turned-wood bowls. As a timber it has no outstanding qualities except that it does not readily splinter. It has therefore been used for the floors and sides of carts and wagons engaged in carrying stone. Its non-splintering property would make it suitable for partitions and stalls in barns and stables, and this *may* explain its selection for farmyard planting. Normally the male trees were chosen as a source of cuttings: it is extremely rare to find a female tree by a farmyard. The explanation is fairly simple. A female tree will produce a large quantity of fluff, whether it is fertilised or not, thereby requiring much extra household cleaning; whereas a male tree has no similar undesirable properties. As a consequence, there has been a gradual reduction in the overall number of female trees, and there are now only three known locations where male and female native trees grow in close enough proximity to produce seed.

One delightful feature of the native black poplar is that every tree is very different from the next in crown shape and silhouette, despite the fact that certain features, for example down-arching branches, are shared by most individuals. The planting of trees by ponds, ditches and farmyards has helped to conserve the variability of form of the native stock, but it has—because only male trees have been selected—further reduced the possibilities of self-perpetuation. Meanwhile the old stock of trees in natural habitats has become depleted by a combination of death from old age, being blown over in gales (their susceptibility to wind-blow is aggravated by their frequent mantles of ivy) and in some cases felling. It is even possible that the tree has become extinct in locations where it has not been planted by man.

Our European native black poplar (*Populus nigra*) is to be found in North America, where it appears to have been taken over by early settlers, possibly for its potential importance in supplying timbers for cruck-framed buildings. There it came into contact with the American poplars, and particularly *Populus deltoides* with which it is fully interfertile. A little later, North American poplars were introduced to Europe. The result of contact between *Populus nigra* and the American *Populus deltoides* has been the generation of a great number of hybrids, sometimes spontaneously, sometimes as the result of controlled breeding trials. The oldest of the hybrids (collectively known as *Populus x euramericana*) is the variety *serotina* which first appeared in France in 1750 and has subsequently been extensively planted in the United Kingdom, mainly as an ornamental tree in both urban and rural settings, but also as an all-purpose hardwood timber tree with a very rapid growth rate.

Concern over the plight of the native black poplar generated considerable interest in the late sixties and early seventies, but it soon became apparent that many naturalists were confusing the declining native black poplar with the variety *serotina* of the hybrid which is widely distributed; and also to a lesser extent with other hybrids. A survey of the distribution of the native tree was therefore initiated in 1973 by Edgar Milne-Redhead, in conjunction with members of the Botanical Society of the British Isles, and its current status is now fairly well understood. The five key points of difference of the native tree are a) down-arching lower branches, b) woody bosses on the trunk, c) absence of a pair of glands at the point where the leaf stalk joins the leaf blade, d) the teeth on the

margins of the leaf are seldom hooked, and e) an absence of hairs on the young shoots and leaf stalks. However many genuine native trees may lack one or two of these characteristics.

A distribution map of the native black poplar was published in the late seventies and this showed a surprising absence of the species in Yorkshire. Two years after moving to York, I was able to remedy the deficiency by discovering two fine trees only a couple of miles from my home. Other trees have since been located, and previously published (but overlooked) references have now been included; resulting in a considerable upgrading of the country's status in the league table of abundance of this splendid tree.

In the North Cheshire plain, a form of the native black poplar grows which has fairly dark leaves and a rather regular, dense domeshaped crown. During the nineteenth century this tree found its way into the expanding industrial towns of the region; perhaps by being engulfed by urbanisation, or possibly as a result of being planted to improve the amenities of the new developments. Rather remarkably, the tree survived and flourished in conditions which few other types of tree could tolerate. It is now known to be one of the trees which is most tolerant of atmospheric pollution; it is also able to grow well with its root system largely covered by bricks, slabs, tarmacadam or concrete. The trees, all of which had the characteristically domed crown shape, became so common in and around Manchester that they acquired the name of the Manchester poplar. This is surely a most powerful example of the importance of the conservation of a wide range of life-forms. Had the black poplar become extinct in Britain in the eighteenth century, its usefulness in beautifying urban areas in the North-West of England would never have been discovered. The tree makes its greatest impact in April when the conspicuous red male catkins herald the advancing spring in a most dramatic way. Thereafter the green foliage provides a welcome contrast to the harsh colours of the brick and concrete of the conurbation.

PHOTO: GULLIVER

Native black poplars are sometimes mistaken for elms.

Once the potential of the Manchester poplar was realised, male trees were propagated by the thousand in horticultural nurseries. The number of native trees contributing to the orginal nursery stock may have been rather small. As a consequence all Manchester poplars look rather similar, sometimes a row will consist of a line of virtually identical trees. Elsewhere in the country, where the trees were derived from inter-breeding "wild" parents, variability in form is the keynote, and each tree looks very different from the next. Having established that native black poplars can grow in the Manchester area, the logical next step would be to introduce trees from other parts of the country into the industrial North-West, thereby adding some much-needed variety of form and silhouette.

To the inherent variability of growth habit of native black poplars one must add another factor, that of pollarding, which produces a completely new tree shape. At Aston-on-Clun in Shropshire there is an especially fine pollarded tree growing by a stream in the centre of the village. Each year it is dressed with flags as part of Britain's only tree dressing ceremony, which normally takes place on May 29. One version of the origin of the custom is that all the villagers were invited to the wedding and subsequent wedding feast of Lady Marston of Oaker House in 1712. To celebrate the event and to show their gratitude, the villagers decorated the local black poplar, and the custom has been continued ever since.

However, my own suspicion is that the practice is in fact of greater antiquity. It is known that in Ireland particularly, pieces of rags were attached to special trees (usually hazels) growing by holy wells and springs. The concept was that the power of the tree would penetrate the rag and would in turn bring good fortune to the wearer of the rest of the garment. Dressing the flag tree in Shropshire may be the last vestige of a similar custom.

The native black poplar does not only have a special affinity with lowland England's landscape, it also has a long association with man in a variety of ways. It is now time to take positive steps to safeguard its future. We need to know more about the full range of its growth forms; we need to conserve this natural variation; and most importantly we need to plant trees[2] of both sexes to allow natural seed production and establishment, especially in those areas where bare mud is in evidence in late June and July.

by Richard Gulliver

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ISRAEL WIPES OUT ITS BATS

The worst bat eradication programme at the moment involves Israel. All bat caves, including those in nature preserves, are being sprayed with Lindane, a highly toxic and long lasting organochlorine pesticide. Entire ecosystems of unique life forms are being destroyed, and the treated caves will act as death traps for bats, even migratory species, most likely for decades to come, even if this disastrous activity is terminated now. It is estimated that already some ninety per cent of Israel's bats have been destroyed.

In 1958, government pest control officers in Israel began fumigating bat roosting caves with ethylendibromide. Today they are using lindane,* a persistent organochlorine insecticide whose effects may last for many years. The campaign began when the Egyptian fruit bat *(Rousettus aegyptiacus)* was declared a pest by the Wild Animals Protection Law, the same law that protects Israel's 27 species of insectivorous bats.

Egyptian fruit bat populations had increased considerably during the previous 50 years, apparently due to the greater availability of food as different varieties of orchard trees and ornamentals became more prevalent. In those days, fruits were often left to ripen on the tree, making them attractive to the bats who sometimes caused damage. The bats had originally relied mostly on two native foods, the fruit of the Sycamore fig tree *(Ficus sycomorus)* in summer, and of the Carob tree *(Ceratonia siliqua)* in winter.

Unintended Victims

The fumigation campaign not only destroyed fruit bats by direct poisoning, but entire cave ecosystems, including highly beneficial and protected insectivorous species. Any cave found with bat population was indiscriminately fumigated, without regard to what species inhabited it, sometimes even including caves without bats.[1] Within 15 years, populations of insectivorous bats decreased by approximately 90 per cent.

Surveys have documented the dramatic effects. For example, the formerly very common Schreiber's bat *(Miniopterus schreibersi)*, the moderately common Mediterranean *(Rhinolophus eurayle)* and Mehley's *(R. meheyli)* horseshoe bats[2] disappeared entirely.[3] Other previously abundant species, including large *(Myotis myotis)* and lesser *(M. blythii)* mouse-eared bats and Blasius' horseshoe bats *(Rhinolophus blasii)* were found only as isolated individuals,[3] while the naked rumped tomb bat *(Taphozous nudiventris)* has changed from common to rare.

Bats are not even safe in wildlife sanctuaries. In a letter to the editor of *Teva Vaaretz* (the Society for the Protection of Nature magazine), a pest control officer stated that several instructors for the Society for Protection of Nature, and rangers of the Nature Reserves Authority willingly helped exterminate bats in nature reserves.[4] Under the Wild Animals Protection Law, the poisoning of caves containing insectivorous bats was actually illegal, a law that was the responsibility of the Nature Reserves Authority to enforce.

Long Range Consequences

The ecological consequences of cave poisoning appear to be far reaching. A population explosion of several species of *Noctuid* moths is now causing major crop damage, requiring extensive chemical control, and resulting in heavy environmental pollution. *Noctuid* caterpillars originally caused few problems,[5] but they have become major agricultural pests[6] as insectivorous bats, the main predators of adult moths, have declined.

The decline of Israel's insectivorous bats is apparently a direct result of cave poisonings, since species that live only in buildings or in places where caves have not been treated remain common. Kuhl's Pipistrelle *(Pipistrellus kuhlii)* roosts in wooden buildings and is still abundant. Its slight decline is likely due to the fact that fewer wooden buildings are now built. Bodenheimer's Pipistrelle *(P. bodenheimer)* lives in untreated desert caves around man-made agricultural oases, where it has considerably increased its populations in spite of other hazards.

Campaign Evaluated

While the effect of cave fumigation upon insectivorous bats has been profound, Egyptian fruit bats, the original target of the programme, did not decline for many

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* Lindane is among the chlorinated-hydrocarbon group of chemicals which includes, among others, DDT, PCBs, and benzene hexachloride (BHC). In the United States, they have been banned or restricted because of their ability to cause cancer, birth defects, neurological disorders, and severe harm to both wildlife and the environment. There is evidence that lindane accumulates in the central nervous system of humans. It has been found in areas greatly removed from the original application, including in bird, mammal, and fish tissues in both the Arctic and Antarctic. Lindane has come down in rainwater in several countries, and 15 years later as much as 8% of initial applications remained in the soil *(America the Poisoned; Lewis Regenstein; Acropolis Books Ltd., 1982)*.

Failure of this particular campaign against Egyptian fruit bats should not be interpreted that, in general, fruit bats are not highly vulnerable to destruction. The effect on the inadvertent victims, insectivorous bats, has clearly been devastating, while the impact on a delicate ecosystem is only now coming to light. The effect on other species, including man, is unknown.

PHOTO: MENDELSSOHN

A poison canister and some of the thousands of Geoffrey's Bats (*Myotis emarginatus*) and Greater Horseshoe Bats (*Rhinolophus ferrumequinum*) killed in Israel's cave fumigations. Greater Horseshoe Bats already are extinct or endangered throughout much of their range.

years, despite the direct poisoning of many thousands. There is evidence that populations even continued to increase. The fact that fruit bats withstood the extermination campaign much better than the insect-eating species may be due to their higher reproductive potential, combined with their greater ability to use alternative roosts. Most Egyptian fruit bats bear two young annually and can roost in a variety of places, including cellars of new buildings and even underground parking lots, thus escaping the poison. Fruit bats have finally declined, but apparently due to overpopulation, not to cave fumigations.

Today, most farmers and control officers agree that damage is negligible or non-existent. Nevertheless, many unfortunately believe that this is the result of cave fumigations. In all likelihood, the real reason that orchard owners are experiencing little or no damage is because for many years most commercial fruit in Israel has been picked green, as it is in most parts of the world. Fruit bats actually may help control such orchard pests as the Mediterranean fruit fly *(Ceratitis capitata)* if they are allowed to eat over-ripe fruits that are missed by pickers.[7]

Responsible Action Needed

Use of lindane in Israel is illegal, but it is sold, and unauthorised people use it freely. Poisoned caves are not posted with warning signs and are often visited by unknowing hikers, who may inhale the dangerous fumes. Empty and even unused containers of lindane are discarded in the caves, contrary to the law which prescribes strict control for the application and storage of pesticides.

Lindane is selected by pest control officials because of its persistence. Even if all cave poisoning were immediately stopped, its effects could last far into the future. No one knows whether many of Israel's once common insectivorous bats can be saved, but they deserve a chance, especially when one considers their value against the environmental damage, the economic waste, and the now well demonstrated futility of current policy.

You Can Help

We request that you write to the Israeli Minister of Agriculture and the Nature Reserves Authority and ask them to do the following: (1) call for an immediate moratorium on fumigations of bat roosting caves; (2) re-evaluate the policy under the Wild Animals Protection Law because of its effect on protected species and the environment; (3) re-evaluate continuing the fumigations in the face of evidence that it is ineffective even in its original purpose; (4) investigate whether or not any control of Egyptian fruit bats is warranted; (5) seek the advice of local experts; (6) draft appropriate legislation based on the facts obtained. Send your letters to: Mr A Nechamkin, Minister of Agriculture, Nahalal, 10600, Israel; and Mr Uri Bidach, The Nature Reserves Authority, Jeremiah, No. 78, Jerusalem, 94467, Israel.

by David Makin and H Mendelssohn

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David Makin *is a doctoral candidate at Tel Aviv University, Israel. His thesis is titled "Ecology and Biodynamics of* Rousettus aegyptiacus*", and he has studied bats of Israel for more than 10 years, including an in-depth survey of insectivorous bats in Israel.*

Professor H Mendelssohn *is one of the founders of Tel Aviv University and of the Israeli Nature Protection Society. He carried out extensive research on the behaviour and ecology of birds, mammals and reptiles, and initiated protection and preservation of many endangered species during Israel's first years. He initiated legislation for nature conservation in Israel, and these laws are still in effect. They are the basis for Nature Reserves Authority action in Israel. He currently is the Scientific Director of the Canadian Centre for Ecological Zoology at Tel Aviv University where captive breeding centres for endangered species are managed. Professor Mendelssohn's appeals were the first to focus attention on the fact that insectivorous bats were becoming endangered in Israel.*

Bat Conservation International Inc., (BATS), Wisconsin, USA, *is a small, but very active organisation for protecting bats wherever they are to be found throughout the world. The* World Bank *has been implicated in providing funds for bat eradication. BATS would be grateful for any information on such funding.*

Books

Escaping from Progress?

THE THEATRE OF THE MIND by Henryk Skolimowski. Theosophical Publishing House, 1984. 164pp. $6.75

More and more thinking people realise that mankind is on a disaster course. Has he gone beyond the point of no return? The theme of this book is that he has *not*—provided he now changes course and rejoins the mainstream of cosmic evolution. Skolimowski interprets this as the evolution of the "right articulation of our minds" that will lead to "increasing sensitivity". He uses this word to capture awareness, intuition, spiritual and mystical experiences.

Prophets of doom have been with us from time immemorial. But the menaces now ahead are indeed formidable, as readers of *The Ecologist* will know: pollution of the biosphere, squandering unrenewable resources, population explosion, and the irresponsible exploitation of new chemical compounds and of nuclear energy.

His book outlines how mankind started on this line of "progress" some centuries ago, and how a one-sided scientific worldview is speeding up the approach to the ending of all forms of higher life on planet earth.

The fossil record shows that evolution of life has taken many unsuccessful directions. Could mankind be yet another evolutionary failure?

The message of this book is: He could be. Whether he will, depends on how he changes and develops his thinking—his "sensitivity". Skolimowski gives some thought-provoking suggestions on how the needed change may come about. He throws us a lifeline. It is up to those of us who are ready to respond to this challenge to read and ponder what he says, and to remember the adage (Edmund Burke) *"No man made a greater mistake than he who, because he could do so little, did nothing".*

Kelvin Spencer

Vivisection under the Knife

MAN AND MOUSE: ANIMALS IN MEDICAL RESEARCH by William Paton. OUP 1984, £2.95.

This is a book I hoped I would never read, for *Man and Mouse* is a defence of the practice of experimenting on living animals. That it has been published at all is an acknowledgement of the tremedous success of the animal rights movement in the last few years. Until then the idea of an eminent Oxford professor having to justify vivisection would have been considered absurd. But with people from all walks of life condemning the practice, the scientific community is clearly on the defensive. But just how cogent is their defence?

The sub-title Professor Paron gives to his book, 'Animals in Medical Research', led me to assume that he genuinely, though misguidedly, believed such research was vital to human well-being. My suspicion was soon roused, however, when I discovered that he condoned cosmetic tests—"There is no distinction, in fact, between medicinal and non-medicinal products", claiming "it is not even possible to say that the LD50 test can be safely abolished". What the book really amounts to, then, despite a few token platitudes in the area of alternatives, is a piece of propaganda for the vivisection industry.

It is this industry, the author tells us, which has underpinned modern medicine's triumph over disease. Numerous graphs are reproduced to show the effectiveness of medicine in fighting disease, one of which plots the increase in animal experimentation along the vertical axis against scientific 'break-throughs' along the horizontal. While I would not dispute that vivisection may have led to some discoveries what I would dispute is a contribution to those discoveries to human health. Infectious diseases were rapidly declining from improvements in hygiene long before medical treatment as such was available. For example, in the UK, deaths from scarlet fever, diphtheria, whooping cough and measles had fallen by 90 per cent before compulsory vaccination and antibiotics were introduced in 1948. Since then the slope of the downward curve has not changed noticeably. Professor Paton places great emphasis on immunisation amongst the medical 'advances' based on vivisection, but I would contend that its benefits are very questionable. In Parliament in 1964 it was stated that in the twenty-five years ended December 1962 nearly two thirds of children born in England and Wales were not vaccinated for small pox, yet only four children under five died from this disease. Of the one third vaccinated, however, eighty-six died as a result, with many more seriously injured.

Man and Mouse, in fact, conveys two wrong impressions. Firstly, that modern industrial societies enjoy a high standard of health thanks to vivisection-based medicine. Yet, while infectious diseases have almost disappeared, they have been replaced by the 'diseases of affluence', such as cardiovascular disease, cancer, arthritis, and mental disorders, which are now reaching epidemic proportions. Despite all the millions of animals sacrificed in searching for cures to them, these illnesses are claiming more victims than ever before. According to a recent survey, half of all Britons over the age of forty-five suffer from some form of chronic degenerative disease. Heart disease kills 65,000 men per year aged under sixty-five. Cancer fatalities have risen from about 20,000 per year at the beginning of this century to 130,000 per year by the 1980s. Even diabetes has a higher mortality rate now than before its treatment with insulin. In these areas, and many more, orthodox medicine has conspicuously failed. It even contributes to the problem of emphasising a curative approach, rather than one of prevention based on a salubrious lifestyle. Sir Richard Doll, a renowned colleague of the author, has stated that approximately 80 per cent of cancers have their origins in environmental causes, pollution for example, yet millions of pounds are still spent on research involving experiments on animals.

Not surprisingly, medical treatment has meant the use of more and more drugs, almost all of which are either ineffective or a duplication of an already existing drug. In 1978, the World Health Organisation stated that of the 30-40,000 drugs on the market, only 220 were of any real value. Once again, Professor Paton presents a very distorted view of reality; nowhere does he even mention the pharmaceutical industry, and he assumes that every new drug developed and marketed is of benefit to human health. At the same time he does admit to certain disasters with drugs, for instance, on page 112, he mentions the 'thalidomide disaster', which he notes resulted in 'much more extensive test procedures'. However, thalidomide was tested on various species of animals, and this highlights another major drawback of vivisection: owing to differences in physiology and metabolism, human and non-human animals do not react alike to the

same drug. Many drugs tested on animals and declared safe have later harmed people. The most recent, Debendox, was taken during pregnancy and like thalidomide produced disabled children. Those affected in Britain have been told they will have to sue for compensation. The acute and prolonged toxicity of a drug is measured by the LD50 test, the dose that is lethal to 50 per cent of animals tested. This test has recently been criticised more strongly than any other, even by the scientific community. Studies of results show wide discrepancies between the susceptibility of different species and can even be affected by the sex, age, diet, etc of the animal. LD50 values can vary from lab to lab by as much as eight to fourteen times, using the same chemical, tested in the same species by the same method of dosing. In his recent study toxicologist Gerhardt Zbinden stated: 'The LD50 in animals is of very little value'. Yet Professor Paton cannot bring himself unreservedly to condemn even this unscientific procedure.

Man and Mouse is littered with inaccurate and misleading information. The author, in common with many other scientists, seems guilty of simply not asking the right questions. Working away for many years in the hermetic environment of the laboratory has produced a tunnel vision which has blinded them to reality and truth. A typical example is the issue of pain inflicted upon animals in vivisection. Professor Paton asserts that on account of the 'pain condition' of the 1876 Cruelty to Animals Act any experiment that causes pain which is severe and likely to endure 'must be terminated whether or not its end has been achieved'. This is completely false: The Act says that an animal in pain must be painlessly killed only 'if the main result of the experiment has been attained'. Whether the result has been attained or whether the animal is in severe or prolonged pain is virtually always left to the discretion of the vivisectionist, who is hardly likely to be an impartial judge. Despite being in medical research for forty years, the author declares: 'I have never seen severe pain inflicted on, or experienced by, an experimental animal'. He then goes on to say that the worst pain he has inflicted on an animal was when some soap got in his dog's eye while he was shampooing it: 'The lachrymation, spasm of orbital muscles, whining, struggling, and final escape from the operator were formidable!' In that case perhaps Professor Paton will spare a thought for the thousands of rabbits who have shampoos and other chemicals poured into their eyes and left there for up to 96 hours. How must they feel? Or perhaps dogs feel pain and rabbits do not! He defends this hideous practice (called the Draize test) by arguing that it has led to improvements in caring for sensitive or blemished skin, and it acts as a protection for those who are too irresponsible to use the product properly. What he neglects to mention, however, is that there are umpteen companies—including Yardley and Faberge; who do not test their cosmetics and toiletries on animals. They use only natural ingredients and test them on human volunteers.

Professor Paton uses very similar arguments in an attempt to justify the use of animals in smoking experiments. Apparently it has led to 'safer' cigarettes (meaning less tar) and the development of 'tobacco substitutes which could lower the risks of smoking'. This opinion is not shared by the *British Medical Journal* which asserts: 'In its futile pursuit of a safe cigarette the tobacco industry is chasing a will o' the wisp'. If the industry cared so much about the health of its consumers it would stop producing cigarettes and switch to other socially-useful forms of production. But the author quotes Sir Richard Doll as saying: 'It is unrealistic to think that a habit that has become so commonplace and involves to many financial interests can be eliminated overnight'. This is a perfect example of scientific tunnel vision; the problem of smoking, like alcohol abuse, will never be solved in the laboratory, only by society at large. People smoke and drink themselves to death for a reason, and instead of trying to discover why, scientists allow big business to use them so they can plead concern, when all they are really interested in is profit.

It is this sort of blindness to reality which lies at the heart of Paton's book. The philosophy behind it seems to be that if only we can leave scientists alone in their laboratories and with animals to experiment on; then in the fullness of time they will find cures for all of society's ills. Vivisection, according to the author, "offers the prospect of less suffering in the future."

The belief that health would improve through advances in medical science may have been understandable in the 1940s and '50s when the development of sulphonamide drugs and penicillin promised to eradicate infectious diseases from society, but it is no longer tenable. The drugs developed since have never really fulfilled their early promise; for instance between 1950 and '70 the death rate from pneumonia in America rose slightly despite drug therapy being available for the first time. Worse still, in 1959 the first drug-resistant bacteria appeared and by the 1980s three quarters of staphylococci infections were unaffected by penicillin. In 1973, Henry Simmons, Director of the United States Food and Drug Administration, observed: 'The drugs age began to decline in 1956. There have been hardly any effective new drugs since then.'

The crucial mistake made throughout *Man and Mouse* is that the author treats medicine and the medical profession as if they were somehow separate from the rest of society. Most of the ill-health in society has a social or political origin—being caused by oppressive environments and lifestyles—which medical science can do little about. Moreover it is now recognised that much of the illness in society is iatrogenic—caused by medical intervention itself. In the book 'Limits to Medicine', published in 1976, Ivan Illich launched the strongest attack yet on the medical industry. "The medical establishment has become a major threat to health", is how he begins the Introduction, and he goes on to describe iatrogenic diseases as 'pandemic'. His approach is diametrically opposed to that of Professor Paton; instead of trying to insulate it, he places medicine within a wider societal context, and he analyses the social implications of medical intervention.

While Paton assumes that society is fundamentally healthy he has been contradicted by men such as Rene Dubos, who said: 'It is an illusion to proclaim the present state of health as the best ever, when increasing numbers of people depend on drugs and doctors to meet the ordinary problems of everyday life.' A genuinely healthy society would require a minimum of medical bureaucracy and intervention to sustain itself, yet we see a huge multi-national industry which tampers with every aspect of our lives from birth to death in order to make us conform to its norm of well-being. The fact that 18 per cent of men and 28 per cent of women in Britain are regularly taking some form of medication prescribed by a doctor should be a cause for concern.

As for the animals themselves, Professor Paton denies that they have any natural rights, but considers them "moral objects in respect of which humans may accept duties". The superiority of the human species he regards as based on its capacity 'to accumulate experience by spoken, written, and printed word, and all that flows from this.' His defence of vivisection would seem to be a debasement of those characteristics he apparently admires in the human species.

Paul Gravett

Letters

ECOLOGICAL SUCCESSION REHABILITATED

SOME RESPONSES

Dear Sir,

*I found your article on "Ecological Succession Rehabilitated" (*Ecologist *15 (3): 104-112) interesting though I think you pushed too far the argument that Clements's climax has been found unacceptable because it could be seen to suggest the undesirability of the trend of most economic development toward the pioneer stage. Clements's idea, in its simplest expression, does not always mesh with observed vegetational processes. It's common for exceptions to be found to a general theory. Perhaps not so many ecologists wholly reject succession as you imply; what they do often suggest is polyclimax rather than monoclimax. You might be interested in my argument over a decade ago that human communities would do well to imitate succession to climax (quotation enclosed).*

But my principal purpose in writing is to point out your remarkably wrong interpretation of Carl Sauer's work. To say, as you do on page 106, that Carl Sauer saw change as a panacea to every problem is absurd. It suggests that Sauer shared the view that all modern change was a desirable advance. Sauer's outlook on modern, industrial nations, especially his own USA, was bleak, for he saw those economies as ravaging their home resources and pillaging the rest of the world for irreplaceable minerals.

Rather than write further on Sauer's views, I will provide examples from his own writings that speak far more eloquently.

Yours faithfully'
William C. Clarke
Professor of Geography
University of the South Pacific

Modern Man, the inveterate Pioneer

In his potent effect on his environment and back on to himself, man has been compared to pioneer plants, which as they rapidly multiply and 'mine' resources in a newly occupied site so alter the site that it becomes unsuitable for further occupancy by themselves. Succeeding the pioneers come other species better fitted to the changed conditions. If no external forces intervene, there may eventually develop the mixed aggregation of organisms generally known as the climax community, which can exist for long periods in a seemingly stable condition supported by a cycling of materials—circulated through the organism/environment system with only a slight leakage—and a flowthrough of energy captured from sunlight by the photosynthetic members of the community. A principal cause of the longevity of the climax community is its low or non-existent net productivity, which means a low backflow of effect to the environment. The energy the community consumes is mostly used for maintenance; the materials are dynamically self-contained. Minimum productivity helps make possible maximum stability.

Although the comparison of human behaviour to stages of plant succession is flimsy, it has value as an illustration of alternative ways of living that have different consequences with regard to long-term survival. Most human communities either do or else want to exist in something like the state of pioneer plants: rapidly expanding in numbers while exponentially expending the environment's accumulated materials. Unlike plants, however, humans frequently import substances from outside their area of occupancy for use both as materials and as sources of energy. In this way industrial societies and western agricultural systems maintain themselves in a pioneer status with a biologically aberrant negative balance; they consume more energy and materials than they possess. This parasitism on other areas, which is coupled with the pollution of the common terrestrial environment, has been considered good because of a narrow notion of cost in which the earth is seen as a storehouse from which materials that can be acquired cheaply, when measured by money, are considered rightly available and usable. Bring the materials from there to here; increase the local output; return the waste to there or spread it so thinly everywhere that any damage from pollution can be said to be an external cost. Such a provincial operation is economically but not ecologically sensible for on spaceship earth, there and everywhere are here, and all costs are internal.

(Clarke, William (1973) The Dilemma of Development. In H.C. Brookfield (ed.), *The Pacific in Transition: Geographical Perspectives on Adaptation and Change.* Edward Arnold, pp. 282-283.)

A New Ethic

Since Columbus, the spread of European culture has been continuous and cumulative, borne by immediate selfinterest, as in mercantilist economy, but sustained also by a sense of civilising mission redefined from time to time. In the spirit of the present, this mission is to "develop the underdeveloped" parts of the world, material good and spiritual good now having become one. It is our current faith that the ways of the West are the ways that are best for the rest of the world. Our own every growing needs for raw materials have driven the search for metals and petroleum to the ends of the Earth in order to move them into the stream of world commerce. Some beneficial measure of industry and transport facility thereby accrues to distant places of origin. We also wish to be benefactors by increasing food supply where food is inadequate and by diverting people from rural to industrial life, because such is our way, to which we should like to bring others.

The road we are laying our for the world is paved with good intentions, but do we know where it leads? On the material side we are hastening the depletion of resources. Our programmes of agricultural aid pay little attention to native ways and products. Instead of going out to learn what their experiences and preferences are, we go forth and introduce our ways and consider backward what is not according to our pattern. Spade and hoe and mixed plantings are an affront to our faith in progress. We promote mechanisation. At the least, we hold, others should be taught to use steel plows that turn neat furrows, through we have no idea how long the soil will stay on well-ploughed slopes planted to annuals. We want more fields of maize, rice, beans of kinds familiar to us, products amenable to statistical determination and available for commerical distribution. To increase production, we prescribe dressing with commercial fertilisers. In unnoticed contrast to our own experience these are to be applied in large measure to lands of low productivity and perhaps of low effectiveness of fertilisers. Industrialisation is recommended to take care of the surplus populations. We present and recommend to the world a blueprint of what works well with us at the moment, heedless that we may be destroying wise and durable native systems of living with the land. The modern industrial mood (I hesitate to add intellectual mood) is insensitive to other ways and values.

For the present, living beyond one's means has become civic virtue, increase of "output" the goal of society. The prophets of a new world by material progress may be stopped by economic limits of physical matter. They may fail because people grow tired of getting and spending as measure and mode of living. They may be checked because men come to fear the requisite growing power of government over the individual and the community. The high moments of history have come not when man was most concerned with the comforts and displays of the flesh but when his spirit was moved to grow in grace. What we need more perhaps is an ethic and aesthetic under which man, practising the qualities of prudence and moderation, may indeed pass on to posterity a good Earth.

(Sauer, C.O. 1956. The Agency of Man on Earth. In William L. Thomas, Jr. (ed.) *Man's Role in Changing the Face of the Earth.* The University of Chicago Press.)

Dear Sirs,

Edward Goldsmith's article on succession in issue 15(3) reads tragically like a clinging to the indefensible old by one who simply does not understand the new. While I would not wish to enter here into a complete critique of his entire article, or indeed into preparation of a counter-article, I would like to highlight a number of actual misconceptions and—since he quotes my writings so extensively—to correct a number of gross misrepresentations or distortions of what I myself or others have written in the past. It cannot, I feel, be coincidence that my name is misspelt whenever quoted—(Ed:- We apologise for having called Putman, Putnam). Such hasty and inaccurate reporting is equally reflected in the academic content of the piece.

The tenor of Mr Goldsmith's piece is apparent from the outset when he claims in his first sentence that "ecosystems develop in a series of stages which must all occur in the right order" towards a climax state. Since no two successional sequences ever show exactly the same progression how can there to begin with be a "right" order? (as Gleason pointed out as early as 1910). Further, the supposition that there may be a right (and a wrong?) order equally suggests some predestination: that the system knows where it is going and follows a predetermined track. Goldsmith rightly tells his readers (p106) that Putman and Wratten refuse to see the development of an ecosystem and the achievement of a climax as the result of a long-term strategy: largely because we (or rather I, since I wrote the particular chapter quoted) find it hard to see how a complex system can (without a mind of its own) think and plan ahead. Predetermination assumes some "conscious" organisation and planning and I cannot see how systems may do this. More critically, applying Occam's Razor, I do not see that it is necessary to invoke such concepts, whether possible or not: it is not the simplest hypothesis.

Goldsmith then reveals his hand. His whole article is an attempt to validate (by rhetoric not analysis) ideas of determination versus random process throughout ecology, to call us back to descriptive intuitive ecology and to avoid actually testing our theories with quantification. (And here he commits another grossness by equating quantification with mathematical modelling.) His methods are those of the politician not the scientist: emphasising what he believes, arguing in generalities and studiously avoiding uncomfortable factual evidence, attacking opposing theories again by presenting them in superficial generality only, and frequently, whether through design or lack of understanding, misrepresenting their claim. Clear illustration of this approach is in use of the old polemic of inverting chronology. We are told (p108) that Odum in his Basic Ecology (1983) says such and such (used in support of Goldsmith's thesis) but that "in an earlier textbook (1963) he is even more explicit". Is it not possible that the reason he is less explicit in 1983 is that he has changed his view in the intervening 20 years? This reliance on older texts in support of his argument is disquieting. We are told that Loucks "points out that there have been few opportunities to date to view diversity and its associated ideas—stability and productivity—as time-based functions." But what we are not told is that Loucks in fact pointed this out in 1970—since which time 15 years of papers have examined just this topic.

Throughout, to my regret (for he has a wide readership and I feel should be more aware of the responsibility shared by all teachers and public speakers not to mislead those who listen or read), Goldsmith distorts, misrepresents, misquotes so that he may defend the indefensible. Rather than as a true scientist examining the evidence objectively with an open appraising mind, forming conclusions on the strength of that weighed evidence, he has made his mind up before he starts and thus must interpret the evidence (whether deliberately or unconsciously) with a jaundiced and prejudiced eye. He accuses "modern ecologists" (whoever they may be) of being ideologically committed to a random and atomised world. (Goldsmith, one presumes, is a man without bias?) In such condemnation I am honoured to be in the company of Gleason, Tansley, Ricklefs, Simberloff and Whittaker—far greater minds than mine, and indeed well-called "ecologists" (p107 middle column lines 14-16): at least they are objective scientists.

As I say, I have no wish here to defend in detail the stand of "modern ecologists" against Mr Goldsmith's viewpoint; there are others far more qualified to do this than am I. However I must set straight a number of misconceptions and misinterpretations included amongst his "evidence". First I have never "attempted to rationalise my ideological commitment to technological progress". I have no such commitment. I try honestly to evaluate all evidence available to me on all sides of a question. As quoted I actually wrote (apparently "magnanimously") "The biological explanations we have presented for the mechanism of the process (of succession) may prove no more than observation of how the statistical necessity is accommodated". But that "this does not mean (just because we can explain it by statistical necessity) that there is no biological reality about succession". It just means we should be more critical in our evaluation of such claims. Secondly, Goldsmith as I have noted, confuses quantification with modelling (p107 lines 19-20), and compounds the error by assuming that "Putman and Wratten, like other scientific ecologists, suppose that because someone has developed a mathematical model which simulates in a rudimentary manner some aspects of the real world, then it must be capable of simulating in a sophisticated manner, all aspects of the real world". Oh dear, what a case of hoist by one's own petard! Neither we, nor any other reputable ecologist has ever claimed such a thing: the presumption is Goldsmith's not ours. Let me set the record straight. Models may be used to simulate ecological processes, to try and investigate what is the effect of varying the "power" of different variables on the model system. We then return to the real world with a clearer idea of which factors may be most important in ordering real ecosystems and can investigate that empirically. In other words we use the models to create hypotheses to be tested in the real world. In this particular case all we claim is that because the various phenomena of succession can be shown to be mathematically necessary consequence, then all the complex biological explanations offered in the past may or may not be necessary/

valid/operational. We do not refute, we merely show that there is room for doubt.

Which last should surely be the aim of any real scientist, to question and question again, to set up theories—but not just accept them blindly and not be prepared to re-examine them in the light of later evidence, but to keep probing, keep testing. Goldsmith's blinkered deference to his oracle (Odum) and total refusal to examine the rest of the evidence is as helpful to the progress of ecology as a science, as is blind Fundamentalism to the progress of evolutionary study. What a pity, too, he was unable to attend the recent British Ecological Society Symposium on Succession in Southampton in July.

Yours faithfully,
R.J. Putman
Southampton

From Ecology to Geognosy

Dear Sir,

The Ecologist volume 15, no. 3 is an inspiration that should be required reading by all scientists and students who are in any way "ecologists". As a professional academic with profound ecological interests I may be even more cynical than you. Not only are earlier notions of ecology such as "succession" and "superorganism" irreconcilable with "the view of society as geared towards perpetual technological and scientific 'progress'" (15:91) but such notions fail to sell computers. The fear of the poisoned epithet "naturalist" runs deep amongst today's pseudomathematising professional ecologists who are under continuous pressure to show that they too belong to the intellectual front guard of the military industrial complex that pays (if indirectly) their salaries. Clements' concepts of ecological succession cannot be calculated with tables of random numbers. A superorganism cannot be approximated by differential equations. Furthermore, in the science of ecology just as in the public at large, one yearns for a single, simple, correct and permanent answer. The concepts of orderly succession to climax and "balance in nature" have been replaced by calculations of "frequency and density dependent fitnesses" at least in part because the latter not only sell computers but assuage us with reassuring, orderly and publishable answers.

For psychology, as Abram (15:96) points out and Ecology (15:104) as you so perceptibly indicate to survive as disciplines of knowledge Gaia must be recognised. Ecology via geophysiology (15:52) must become geognosy. We must know the earth. We must recognise we live in the air, we must perceive the fine chemical distinctions between the multitude of compounds in our surroundings, we must become conscious of the microcosm, admitting our bacterial ancestry. Life can no longer be considered as if it were composed of two kingdoms: animals and plants. Most of all, we must, as Nigel Calder insists (Timescale: An Atlas of the 4th Dimension, Viking, New York) become as good chronographers as we are cartographers. We must understand time.

Professional ecologists will not become geognostics if they cannot be swayed by the strength of intellectual arguments. Those like yourself (15: 4, 90, 104) Charles Hughes (15: 92) and Norman Myers (editor: Gaia: An Atlas of Planet Management 1984. Anchor/Doubleday NY) passionately committed to preserve the dazzling, subtle and sustaining biota in its intricasies from the onslaught by McDonalds, the Norwegian Whaling Fleet (15:113) and Datsuns, cannot convince professionals on these aesthetic grounds alone. Clements, Cowles, and even Odum (15: 104-108), as remarkable as their contributions are, were limited by more than an adversary political ambience. They, like today's "modern ecologists" did pre-Gaian ecology. They lack requisite scientific infra-structure.

Lovelock's concept of Gaia (15: 15, 95) emerges from his deep understanding of the gas production and removal processes of diverse populations of exponentially growing and abruptly dying organisms, primarily microbes. As Lovelock has aptly noted, Gaia is simply another name for the colligative (collective) properties of the biota as they have persisted over at least three thousand million years. Hughes criticism of Gaia working by "sentient feedback as a mechanism" (15: 93) is perfectly valid. I hope and doubt that these days even Jim Lovelock would use cybernetic terminology—which implies an outside "governor" achieving a predetermined set point by the use of positive and negative feedback—to describe Gaia.

Perhaps it is helpful to proffer our newer attempt at a verbalisation of Gaia. Gaia is the biota (the sum of the animals, plants, fungi, protoctista and monera) and its influence on the atmosphere, oceans and fresh water, soil and lithosphere over the course of earth history. Gaia, as a modulated planetary surface (extending primarily some 20 kilometres from the top of the troposphere to the bottom of the abyss) is a phenomenon so far exclusively found on the planet Earth. The Gaia hypothesis is the concept that the composition of the Earth's atmosphere with respect to the reaction gases (e.g. O_2, N_2, CO_2, CH_4 etc), the acidity-alkalinity and the oxidation state have been kept within livable bounds (actively modulated) by the growth and metabolic activities of the millions of interacting species that comprise the biota. The active modulation of these properties of the Earth's surface is a colligative property of the active modulation of the local environment by the autopoietic entities we recognise as cells. Cells, specifically bacterial cells, are the minimum autopoietic entities known. Autopoietic entities, in the concept of Chilean biologists Humberto Maturana and Francisco Varela, are self-organising, self-maintaining structures kept intact by the continual replacement of their parts—that is, by metabolism. These parts, primarily macromolecules composed of carbon, nitrogen, oxygen and hydrogen —are remade and replaced ultimately at the expense of solar energy. Autopoietic entities have natural boundaries which they actively maintain whether they be damp naked epidermis, cell membrane, waxy cuticle, scaly skin or the national border separating Spain from France.

Gaia, then, is a huge autopoietic entity with a great history, bounded by the top of the troposphere and the bottom of the abyss. Through Gaia flow elements like carbon, nitrogen, oxygen, hydrogen, sulphur and phosphorus much more rapidly and in different patterns than they would subject to abiotic geological forces alone. Furthermore the anomalous distribution in the Earth's crust of calcium

carbonate, aluminium, gold, iron and other substances that strongly interact with the biota can best be explained by the presence of Gaia. In the absence of Gaia these substances would show distributions like those of the rare earths. Gaia, as animated planetary patina is an emergent property of the biota. Gaia is not a cybernetic system governed from the outside.

A major mechanism of gaia is the exponential growth of one population which leads to changes in local environments which then favour the exponential growth of other different populations. One being's waste is another's food. Methanogenic parts of one population of bacteria are sweet fresh air for another, the methylotrophs. Ecological succession, indeed, is a manifestation of an aspect of gaian mechanisms as one population of organisms replaces another within a community. If local conditions change beyond certain limits of temperature, water, nutrients and so forth, entire communities are replaced with completely different ones.

Furthermore both Lovelock's statement and Hughes' criticism of it (15: 94) "Thanks to Gaia, our fears of pollution-extermination may be unfounded" fail to clearly distinguish Gaia from one of the 10 species that comprises her, namely Homo sapiens, Hughes (15:94) says, "Neither . . . can we ignore the fact that extermination following a nuclear holocaust is now a real possibility", following detonation of nuclear weapons extermination of "western culture" is a certainty, extinction of Homo sapiens by the destruction of our environment is a high likelihood but the continuity of Gaia will probably not be affected at all. Weedy, fast growing, habitat-threatening species have "bloomed" ever since the earliest biospheres of Earth. Such weeds, by destroying their habitat for themselves, prepare the immediate environment for others: carrion is replaced by maggots, oxygenic photosynthesisers are replaced by respirers, ash gives way to pine gives way to oak; hydrophytes trap sediment and give way to mesophytes. Whether or not an aesthetic principle for us, metabolic and species diversity is a Gaian imperative.

We delude ourselves if we believe that as 3 million year old punks we can threaten the 3500 million year old planetary patina in which we are embedded. However, that we can foul our nest, convert the garden of Babylon to the sands of the Sahara and even change the planetary albedo by felling tropical forest trees and paving over with cement (15:131)—in short, that we can make our habitat hideous for our children—is certain.

Gaia won't help us; we will simply exemplify another one of her modulating mechanisms as we grow and metabolise in a way that insures our own extinction as a species.

Yours faithfully,
Lynn Margulis
Boston, Mass, USA

Notes:

I am grateful to Dorion Sagan, Betsey Dyer, Gail Fleischaker, David Abram, Stuart Brown and Jim Lovelock for discussion of the ideas presented in this letter.

See Brown, S., Margulis, L., Ibarra, S. and Segueiros, D. 1985 Contamination and desiccation resistances as mechanism of Gaia *Bio Systems* 16 (in press).
Lovelock, J.E. & Margulis, L. 1986 Gaia and Geognosy: towards a science of the biosphere. In *Towards a Global Biology*, M.B. Rambler, ed. Jones and Bartlett Publishers, Boston (in press).
Sonea, S, and Panisett, M. 1984 A *New Bacteriology* Jones and Bartlett Publishers, Boston.

Dear Sir,

Thank you for sending the latest issue of your excellent journal The Ecologist (1985 Vol 3) and I am deeply impressed by your editorial "Whatever happened to Ecology?" Here you touch on what I have been feeling for many years: that "Ecology" has been suffering a creeping internal disintegration because of its failure to view the world of living organisms of which also man is part, as a complete unit. It reminded me of a talk I had with Professor Theodosius Dobzhanski some 30 years ago, when I still lived in the Amazon. I suggested that the different theories of evolution (the organism is a product of the environment versus organisms are products of "Bauplane" (construction plans) versus organisms are products of competition (survival of the fittest random variations) reflects political economic systems in different countries: Soviet Russia versus Germany (and most other European countries) versus the USA. Dobzhanski did not agree, but in your article I see a parallel: the original concept of Ecology (e.g. Thienemann, the lake is an organism of a higher order) was established mostly in Europe, whereas the disintegration you describe comes mostly from the USA which is not a "state" in the European sense but more like a "club" of members who randomly came together to make their living by competition. The holistic view, as you point out, implicitly recognises with respect that behind the visible phenomena of life lies something we do not understand. I am very happy in that recognition!

Yours faithfully,
Prof. Dr. Harald Sioli,
Max-Plank Institute of Limnology,
Kiel, W. Germany.

Cross-bred Livestock in Third World Countries: Agribusiness Rhetoric versus Reality

Dear Sir,

Bharat Dogra's "India's White Revolution: Another World Bank Financed Disaster" (Ecologist 15: 182-186) provides a valuable lesson in the problems of cross-bred livestock. However, the lesson is not new. Earlier fiascos were ignored by the World Bank. Inappropriate cross-breeding (as part of the export of agribusiness technology) threatens many uniquely adapted breeds of livestock, breeds which have evolved to survive local conditions of management, disease and trace element requirements.

In reviewing the literature on cross-bred livestock we have found it difficult to find adequately researched case histories, even for first and second world countries. However, such case histories as we could obtain reveal a number of examples of commercial catastrophe as well as some genuine successes. (These are reviewed in chapter 12 of Molecular Biology and the Origin of Species, 1970; additional examples are provided in C.M. Ann Baker and C. Manwell, chapter 15 in Red Blood Cells of Domestic Mammals, 1983, and Population Genetics, Molecular Markers and Gene Conservation of Bovine Breeds, volume 11 of Elsevier's World Animal Science, in press).

There are many biasing factors at work. There is a natural inclination to favour the publication of success stories rather than embarrassing failures—except for the occasional disaster which is so big it cannot be completely hushed up (e.g., the Gambia Hen project, an after-

thought of the ill-fated Groundnuts Scheme; one estimate of the economic efficiency of the Gambia Hen project was that it cost $50 to produce one egg!) Some of the other disasters have come to light only because a large amount of research money was spent in an effort to find a "quick technological fix" and the scientists involved needed some publications to account for their time and funding.

Animal breeding is big business. Millions are made by selling semen or bulls to "grade up" native cattle. Only rarely is there any attempt to measure the long term consequences of the "immigration genetic load", where the supposed increase in animal production is more than offset by increased susceptibility to disease.

Very roughly, one can distinguish two types of cross-breeding programmes which have been used in Third World countries and elsewhere':

1. Partial or complete "grading up". Exotic breeds (often introduced via a few stud animals or as semen) are used to introduce supposedly superior genes into native livestock. (Bharat Dogra should have mentioned some especially valuable research done by Indian scientists: Even for the very limited situation of ample feed, there was no real production advantage in "grading up" Indian cattle (zebus) with more than 50% Friesian genes. The Indian research that has been done on cross-breeding is superior to much that has been done by more lavishly financed scientists in first world countries.)

2. Production of hybrids. Two or more distinct lines or breeds are crossed to produce hybrids. It is hoped to capitalise on heterosis or "hybrid vigour". This form of cross-breeding is especially favoured by agribusiness—and for a reason not mentioned by Bharat Dogra: By keeping control of the parental lines or breeds, and by selling only the hybrid progeny, the commercial breeding firm retains a complete monopoly. (This monopolisation principle can also be seen in the current fight over plant varietal rights and the patenting of life forms modified by genetic engineering.) What is profitable for the hi-tech plant or animal breeding firm may not be good for either farmers or consumers.

Cross-breeding may sometimes be a useful option. After all, it was the ancient Sumerians who first recognised the value of crossing horses and asses to obtain the 'hybrid vigour" of the mule—and they did this some 4000 years before agribusiness. On occasion, local breeds may suffer from in-breeding depression; judicious crossing will restore both productivity and survival. However, "hybrid vigour" is often environmentally very labile. A change in conditions may result in formerly superior hybrids becoming worse than parental lines. Basically, Barry Commoner's use of an old expression is especially relevant here: "There are no free lunches". Hybrids with faster growth are often more vulnerable to poor quality feed.

After the success of "hybrid corn" (maize) in the U.S.A. in the 1930s-1950s, animal breeders attempted to repeat the success. Some of the big plant breeding firms moved into the production of hybrid animals. The sheer power of market control gave an aura of success which was often unwarranted. Now, a handful of firms produce most of the first world's chickens and turkeys. Large scale pig production is also dominated by cross-breeding, but cross-breeding has been less significant for other large livestock, especially dairy cattle and sheep.

Cross-breeding has become a mystique, marketed as part of the package of modern intensive agriculture, sometimes sold with spurious scientific claims. This package includes a variety of "quick technological fixes" to attempt to overcome the disadvantage of intensification, notably reduced performance from stress and from disease. The "quick technological fix" for infectious disease has been the routine addition of antibiotics to animal feed (or occasionally to drinking water or by direct injection). After thirty years of warnings, evidence published in 1984 in Science and in the New England Journal of Medicine has forced many to accept the fact that this widespread addition of antibiotics is a threat to the health of people. Despite the awesome power of the agribusiness interests and their captive bureaucracies, it appears that the American Congress may pass much stricter legislation to restrict the use of antibiotics in animal feed. In turn, this will tip the balance of profitability from intensive to extensive livestock husbandry. Consequent to such changes in first world agriculture, there will be further pressures on Third World countries: agribusiness firms will attempt to continue profit maximisation by shifting their attention even more into cross-breeding in Third World countries. This is the same pattern seen recently for both "ethical" drug companies and tobacco transnationals when confronted with increasing legislative controls at home: they shift more of their activities into less regulated markets.

Of particular concern is the acceleration of the loss of breeds and land-races of native livestock. In selling the cross-breeding package deal, there is the agribusiness tactic of denigrating, even ridiculing, the value of native breeds. A classic example is the disparaging and racist remarks made under the aegis of the Ford Foundation about the sacred cows in India. The refutation of that claim came not from agricultural scientists in the West but from a combination of an American anthropologist and several Indian experts (see, for example, Marvin Harris's article in Current Anthropology 7: 51-60, 1966, and subsequent discussions in that journal).

Especially dangerous is a new trend masquerading as "conservation genetics". For example, Sir Otto Frankel and Michael Soulé specifically complain that there are too many breeds of Indian cattle, e.g. "... do we need all the breeds of Zebu cattle?" (quoting from their Conservation and Evolution, p. 255). Elsewhere in their book they suggest that the 28 different breeds of Indian cattle (28 being the number described in an old reference) might be reduced to 9 breeds, allowing for three different purposes (milk, draught and dual purpose) and three different environments (humid tropics, dry tropics and montane conditions).

In fact, the very existence of the 28 breeds or land-races of zebus recognised by earlier researchers was evidence of the necessity for a multiplicity of types needed to cover the extreme climatic, cultural and geochemical variability of the Indian subcontinent. (In fact, Frankel and Soulé's consideration of draught as a single purpose fails to recognise the variety of different draught tasks, from the slow and steady plough ox to the speedier

"trotting ox", certain breeds of which were highly esteemed by the English military. Furthermore, the actual number of breeds or land-races of zebus is greater than the 28 mentioned by Frankel and Soulé, for some types have only recently been described in the scientific literature.)

What Sir Otto Frankel and Michael Soulé do not mention is that it was not all that long ago that Frankel's own organisation, the Commonwealth Scientific and Industrial Research Organisation of Australia (CSIRO), had been very grateful for the existence of a multiplicity of Indian cattle breeds so that they could choose especially docile varieties for Australian husbandry. First world countries have used a number of different breeds of zebus to improve their own cattle which are expected to live in sub-tropical conditions, e.g., the Brahman breed of indicus *cattle developed by American breeders, or the various* taurindicus *breeds, such as the Santa Gertrúdis, the Droughtmaster, or the Australian Milking Zebu.*

In other words, first world scientific organisations and commercial firms have at times been very grateful for the existence of esoteric breeds of livestock in Third World countries. If those breeds are occasionally recognised as useful by scientists in first world countries (despite the great deal of cattle chauvinism which exists), think of how much more useful those breeds probably are to the indigenous farmers who have consciously or unconsciously selected their animals for generations to fit specialised ecological and cultural niches.

In conclusion, the arrogance of agribusiness is leading to the loss of valuable genetic variation in native livestock.

Yours faithfully,

Clyde Manwell and C.M. Ann Baker
Department of Zoology
University of Adelaide
South Australia

Escape to Space?

Dear Sir,

When I read, in The Ecologist *Vol. 13 No. 5 the article "The Gaian Perspective on Ecology" and your own review of a book by Peter Russell, my first reaction was to marvel yet again that* The Ecologist *can maintain a place for fundamental thinking—a rare thing now that nearly all public thinking relates to technical objectives, such as economic growth or particular technological or welfare processes, treated as ends in themselves. Russell's views as you quote them seem to be old poppycock in a fashionable idiom. A working life-time in public administration taught me that the tasks confronting us do not lie in the farfetched notions of Russell, or of Sagan and Margulis. The "global village" based on modern mass media was always a phony concept, because the essence of a village is that all communication is two-way, or involves several people at once, all of them both giving out and taking in. The elements in a culture which lend themselves to one-way transmission cannot possibly take the place of a real village culture. Sagan and Margulis's last few lines about habitats in space is also cloud-cuckoo. In the real world it is, and is likely to remain, difficult enough to get people to co-operate in doing humdrum things even when it is obvious to nearly all of them that the things ought to be done, like putting as much effort into forestalling ill-health as in curing it, or managing a fishery so as to maximise the* sustainable *catch. Inventing new technical problems may be fun for Sagan and Margulis but just perpetuates the myth of the technical fix.*

However, that is digression to show that in disagreeing with you on one point, in what follows, I am by no means dissenting from your conclusions. The point in question is your view, on p.191, first and second paras, that the modern world of man-made artefacts is not a natural product of the evolutionary process. I think it is probably just that, though unlike the Gaians I derive no comfort from the belief.

Here is the reasoning as I see it. First, unless one believes in the possibility of intervention from outside—from a separate divine order of being—man must *be a product of evolution like other animals, and if there is a system which over a long period has operated so as to maintain and improve the life-carrying capacity of the earth, man must be part of it. However, the Gaian hypothesis as expounded by Sagan and Margulis does not appear to postulate a principle which makes it necessary that the activities of living things should continue to improve their environment; it simply demonstrates what seems to have happened and suggests a mechanism. If one can now suggest a mechanism for the recent destabilising developments (and I share your view that the reduction in ecological variety is likely, at best, to allow bigger swings before equilibrising forces can take effect and, at worst, could lead irreversibly to an eco-catastrophe) the Gaian view would not be invalidated as an insight on the past, only as a guide to the future. In considering a possible mechanism, I suggest that if living organisms have the ability to influence the environment to be more supportive, this ability must be subject to the same processes of natural selection as have affected adaptive qualities. An individual or species or group acting in an enviroment-improving way would have a competitive advantage over others. In considering how this might work it does not appear to matter whether a change originates from genetic mutation or cultural innovation. In either case, a change in behaviour might be harmful or favourable. (It might be argued that cultural innovations are more likely to be beneficial because purposively introduced, but it seems to me that in practice changes in behaviour start as fashion and are essentially random; in a healthy society the elements which turn out to be good —a small residue from a lot of experiment—become changes in established custom.) The less favourable would lead to a group degrading their environment, becoming weaker than competing groups, and being "selected out".*

I see no reason why these processes should not have continued to operate just as effectively in relation to changes in culture-regulated human behaviour prompted by new ideas as in relation to changes in genetically-regulated behaviour prompted by mutations so long as the groups in which a change occurred were relatively small and competing with other groups not affected by the change. This condition—necessary to give any workable analogy with genetic evolution—seems likely to have obtained in animal (meaning for the moment non-human) com-

munities, in which a degree of communication sufficient to maintain a culture-bound behaviour pattern could well exist within a group without there being sufficient communication with other groups to transmit it to them. The same could have been true of "primitive" human groups. So long as communication was limited by the range of human senses, communities behaving in a uniform way must have been relatively small so an innovation in behaviour would have had to face competition from neighbouring groups who had not adopted it. Thus with natural selection operating so as to eliminate environment-degrading innovations the overall result of environment improvement could be maintained. It may well be, of course, that sometimes the harm to the environment would have been recognised and the behaviour consciously changed, but the selective pressure would always have been there as a long stop.

Now mass communication has changed all that. Even in antiquity the ability to make written laws could bring widespread uniform behaviour, and result in short-term benefit followed by collapse of a system (as seems likely to have occurred with development and then decay of large irrigation systems). But the scale though large could not be global.

Now techno-culture is global, and the implications are alarming. If some feature of human behaviour which forms part of the economic/technical culture (which is in any case tending to absorb ever more fields of human acitivity) should tend towards a catastrophe, that behaviour can become immediately world-wide, and is likely to do so if short-term economics favour it. If we fail to see the danger and reverse the process by rational concerted action, the catastrophe too will be world-wide. There will be no tribe next door to fill the vacuum left by the failure. The world-wide nature of our techno-culture has abolished the long-stop.

The idea of an eco-catastrophe becoming quickly irreversible probably seems far-fetched to most people, if not to Ecologist *readers. It could, in my (entirely non-expert) view, arise in relation to the earth's fresh water management system. The amount of precipitation falling on land surfaces may not be sufficient to maintain a great deal of life if it drains quickly back to the sea as it does off bare rocks. But a great many life-forms tend to keep the water on the land. Rain-forest allows secondary transpiration to blow further inland and produce more rain. The flora of temperate moorland give it high water-retaining capacity, to keep rivers flowing through dry spells. Desert plants specialise in quick take-up and slow release, so in pursuing their own survival abate the extremes of aridity. Beavers and men build dams. These all seem to fit the Gaian framework. But much human activity tends the other way. Part of this is conscious and deliberate: when I was urging a water authority's officer not to dredge all the reeds out of a river he said all his training was to get the water away down-river and off to the sea as fast as possible. But most of the human impact may be side-effects, from the reduced transpiration where crops (followed by desert) replace trees to the micro-scale effect of paving a garden. In view of the positive feedback cycle less rainfall — less vegetation — less retention and transpiration—less rainfall, there is clearly a possiblity of irreversible drying up, and reafforestation schemes seem to me to be a more reliable form of insurance than Gaia.*

Unless stability of the ecosphere soon becomes a main aim of government policies, the implication may well be that the natural end of evolution, fairly soon after the development of instant mass communication, is a destruction of the life support system; and we may well discover Dawkins's dead planets to prove it, before we join them. I see no very convincing evidence that our genetic make-up, formed as it has been by evolution in a system which had a long stop to field the errors, has the necessary ingredients to enable conscious planning to take over. Our built-in restless inventiveness and adventurousness, renewed in every generation, seems ill-adapted to the task of planning to forgo all short-term advantage wherever necessary to avert the slightest risk of eco-catastrophe, and to keep it up for ever. I am not personally unduly depressed by this. The human situation is, as ever, to find something useful to do which is some kind of step in the right direction and hope. Politically, the task is to work out which steps in the right direction are feasible, or on the verge of becoming so, and press for them. Small groups controlling land use within a small area in which they live have a greater built-in tendency to stability, but the Ecology Party has not, I think, yet realised that State welfare and housing policies as well as multinational companies can weigh on the wrong side. Nor are they prepared to recognise that since the activities of a handful of people could destroy all of us, its no good relying on everyone individually doing the right things voluntarily: the sustainable society is going to be pretty conformist. But eco-politics will evolve, and there is some popular appeal in moving to a smaller scale.

One final point, in what is I hope not too tediously long a letter. Some people seem to think that this kind of analysis denies an ethical dimension—and then look for salvation in some sort of divine introduction of morality. This seems to me to be a fallacy. The ethical dimension—the capacity for altruism—is there in human nature, evolved along with the rest of us. In other animals' natures too. On this I have been more impressed with the commonsense acceptance of morality as part of our survival equipment, in Mary Midgley's 'Beast and Man', than with ethologists who appear to question the existence of the moral element in animals' natures because they can't postulate a genetic mechanism for it to have evolved. Human and animal natures are what we see them to be, and are not made different according to what we choose to believe about how they became what they are. Anyway it seems to me perfectly reasonable that a human or animal grouping in which individuals were prepared to make sacrifices for each other might well be more competitively successful than other less moral groups, even if the morality were gained at some cost in individual competitive excellence. Vietnam has no Olympic champions but they won their war!

Yours faithfully,
Roy Cattran
Penzance, Cornwall

Classified

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IRELAND'S RESPONSE TO THE NORTH/SOUTH CRISIS. Summer School, Westport, September 19-21, 1986. Papers invited on inequities/instabilities in world system, restoration of local and national economic self-determination, aid policies, small-scale/community enterprise. Draft agenda from: Douthwaite, Cloona, Westport, Co. Mayo, Ireland. Tel: (098) 25313.

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RADIOACTIVE WASTE MANAGEMENT: UK Policy examined. Two-day conference, 24 and 25 April 1986 at Royal Lancaster Hotel, Lancaster Gate, London W2. Details from Miss Fiona Spindlove, IBC Technical Services Ltd. 3rd Floor, Bath House, 56 Holborn Viaduct, London EC1A 2EX.

International Symposium on ECOLOGY AND MANAGEMENT OF WETLANDS. June 16-20, 1986, Charleston, South Carolina. Details from International Society of Anaerobiosis, 2730 Savannah Highway, Charleston, South Carolina 29407, USA.

SHORT RESIDENTIAL COURSES at the Centre for Alternative Technology, Llwyngwern Quarry, Machynlleth, Powys, Wales. Ask for detailed programme.

OIL POLLUTION CONTROL COURSE. 19-24 October 1986. Contact Caroline Little, Institute of Petroleum, 61 New Cavendish Street, London W1M 8AR, UK.

THE OTHER ECONOMIC SUMMIT (TOES) 1986. Rally on 17 April, One-day conference 18 April, Course 12-14 September. Details from TOES, 42 Warriner Gardens, London SW11 4DU, UK.

OIL INDUSTRY NURSES SYMPOSIUM. 24, 25, 26 September 1986 at Newnham College. Cambridge, UK. Details from Caroline Little, Institute of Petroleum, 61 New Cavendish Street, London W1M 8AR.

OPEN DAY 1986 at the RSPCA Field Study Centre. Sunday 31 August. Contact N. Ford, Mallydams Wood, Peter James Lane, Fairlight, Hastings, Sussex.

THE PACE OF CHANGE IN FARMING: The organic option? One Day Conference on 7 May 1986 at Lains Barn Nr Wantage, UK. Details from D.S. Stafford, 10 Highfield Close, Wokingham, Berks.

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PROGRAMME

TOES International Rally 1986
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For full details of all the above events and of TOES 1985 publications, contact TOES, 42 Warriner Gardens, London SW11 4DU, UK.

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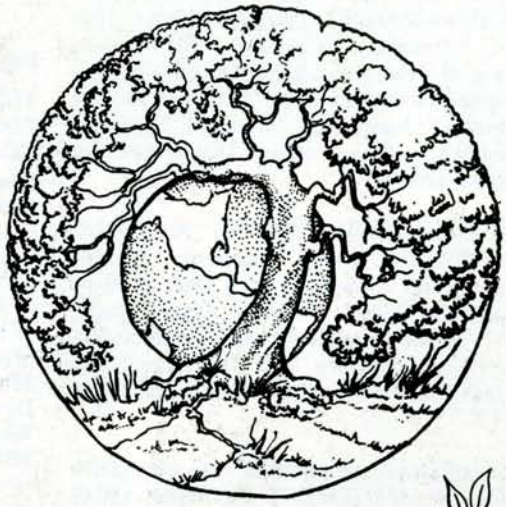

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