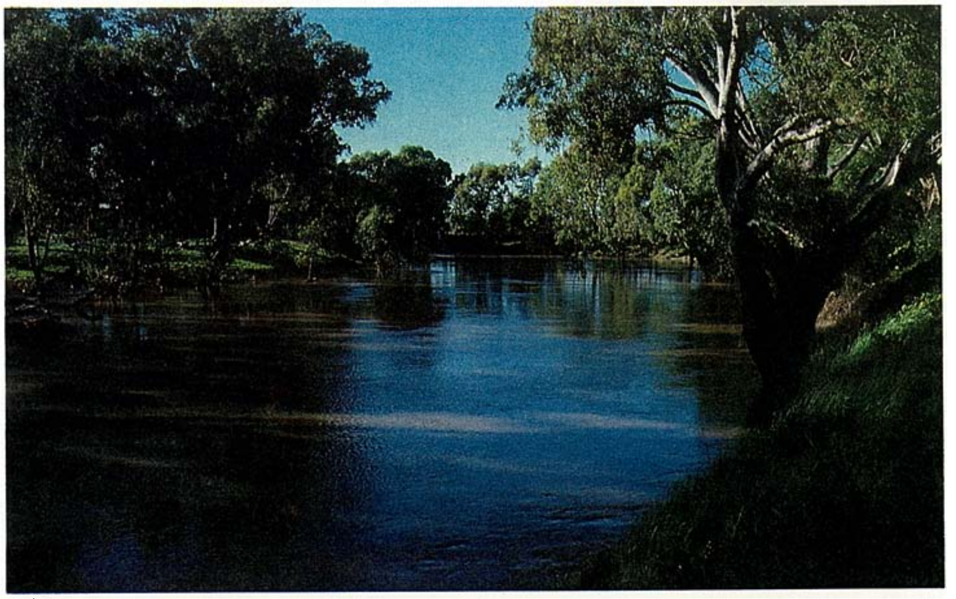
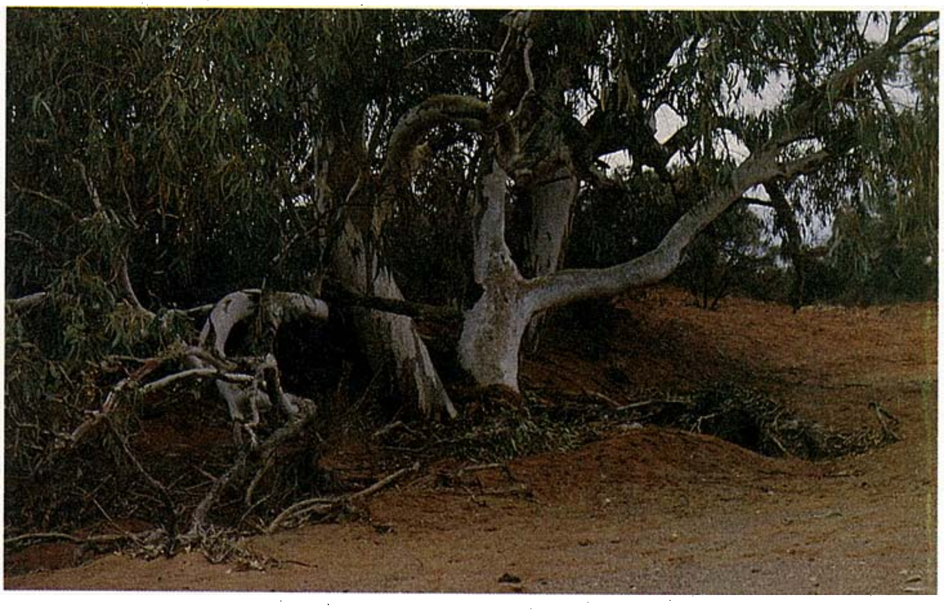


Conserving our genetic heritage



River red gum *(E. camaldulensis)* in two different environments—along the Macquarie River and beside a dry creek in arid country.

Australia is the land of eucalypts. From the tip of Cape York to southern Tasmania and from Cape Byron in the east to the westernmost point of Western Australia, these aromatic, evergreen trees dominate great tracts of our landscape and make it essentially Australian. We use them for timber and pulp, or merely gain pleasure from their just being there. Over the years many of the 'useless' species have been cleared to make way for grazing, crops, or development. Some now cover only a fraction of their former ranges.

The eucalypt is one of Australia's gifts to the world. Today many of the warmer countries grow eucalypts in plantations. Paradoxically, many of the species grown overseas are not the ones we use here. So the world has a use for some of our 'useless' species. Perhaps we owe it to ourselves and the world to maintain viable communities of such cultivated eucalypts in their natural state. Some States think so.

The Forests Commission of Victoria is considering establishing 'genetic' reserves to conserve communities not already protected in other reserves, and the Forestry Commission of New South Wales already has a system of forest preserves. Some other State forestry services have similar genetic conservation areas.

Individual trees within a natural population of any species vary greatly. The variability of each natural population reflects the large number of variable genes within it. Some of the eucalypt stands grown overseas derive from seed collected from only a few trees. So these plantations contain only the particular selection of genetic variation that existed in the parent trees, and they vary much less than the natural stands. Consequently they may be much less adaptable than their Australian kin, and a new selection of seeds imported from many more parts of the trees' natural range may well give better plantations.

Because of this, a number of countries are now approaching Australia for more seed of the particular species of interest to them. They may contact commercial seed companies or State Forestry Departments, but more often they approach the CSIRO Division of Forest Research (formerly the Forest Research Institute) since, with FAO help, this Division maintains a team that collects and tests eucalypt seed from all over the continent.

But Australia can only provide such seed if suitable stands of these eucalypts still remain. If the species has become rare, or possibly even extinct, the genetic resource will be severely depleted or even lost for ever.

Probably no eucalypt species has yet become extinct as a result of Man's interference. Nevertheless, local variants growing at sites with particular environments certainly have.

What about other cultivated plants? With the exception of the macadamia nut, no agricultural or horticultural crops came from wild plants in Australia. All our grains, vegetables, oil seeds, and fruit and nut trees were first domesticated elsewhere. All our improved pasture species have been introduced as well, sometimes by accident, but with these the situation differed slightly. Often, these species had not previously been used for agriculture, and Australia has domesticated wild plants.

Over the years the State Departments of Agriculture and CSIRO have sent staff overseas on collecting expeditions, both to augment the genetic variability within species already being grown here and to find new plants to bring into agricultural use. Plant breeders use the increased range of genetic variability in plants already being grown here for adapting them more closely to the Australian environment. All introductions are now coordinated through the Division of Plant Industry. Australia still depends on the stocks of plants growing overseas, just as the rest of the world depends on us for eucalypts.

'Primitive' crops lost

Since as early as the 1930s a few plant breeders have been warning that the world stocks of 'primitive' crop plants, which developed over the millenia through generations of human use, are vanishing. Ten years ago the International Biological Program of the International Council of Scientific Unions, and the Food and Agriculture Organization of the United Nations, took up the theme in earnest. Here in Australia, Sir Otto Frankel, a former Chief of the CSIRO Division of Plant Industry, has been a consultant to FAO for many years and has written prolifically on the subject.

The 'primitive' stocks represent a source of genetic variability that is of great value to plant breeders. But if we aren't careful, losing them could be one of the prices the world pays for the 'green revolution'.

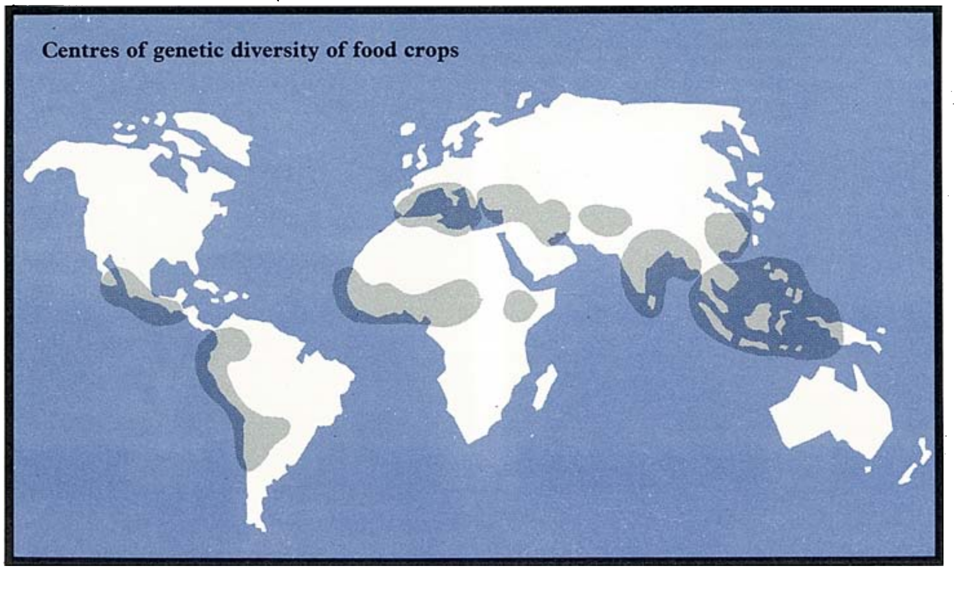
. . . the world's stocks of 'primitive' crop plants, which developed over the millenia through generations of human use, are vanishing.

We hear a lot about the great increases in grain production in developing countries brought about by the green revolution. Wheat, rice, and other crop varieties giving the great increases have been carefully bred to give the maximum yields. But they require a great deal of fertilizer. Also these varieties are genetically homogeneous—every individual plant is very similar to all the others—so the population is very uniform. Should circumstances change — if fertilizer becomes too expensive, or disease rampages through the crops — these very uniform varieties don't have the adaptability to be of further use.

To produce plants suitable for the new situation, plant breeders usually turn to the older crop plants of about 100 years ago, or (less often) to the more variable wild relatives, or to the primitive stocks—the ones that are being lost.

Until recently farmers in many of the poorer countries of the world were still planting many of these old lines. But when the new high-yielding wheats and rices came along they gave up planting the traditional types and went for the new ones instead. Thus during the 1950s and 1960s the traditional primitive stocks began dying out at an alarming rate, and with them goes one of the keys to solving the world's future food problems. It was this fact that stimulated the action from international agencies.

FAO and the International Board for Plant Genetic Resources are now encouraging scientific institutions in a number of countries to collect and store seeds of primitive and wild wheats, rices, and other agricultural plants, and thus to conserve this heritage of genetic variation in an international network of 'gene banks'. We are lucky indeed that tech-



Centres of genetic diversity of food crops

. . . with them goes one of the keys to solving the world's future food problems.

niques are now available that enable stored seeds to remain viable for many years.

Ancestral wheats

Wheat first became domesticated about 10 000 or more years ago. As the crop spread among the early civilizations, populations became isolated, and over the years the different primitive stocks or 'land races' developed in various parts of the Old World.

Probably we know more about the land races and wild relatives of wheat than those of any other crop. Much of this knowledge we owe to N. I. Vavilov, the great Russian botanist, who with his colleagues during the 1920s collected land races and wild wheats from many parts of the world. He identified 'centres of origin'—the places from which they originally came—and 'centres of diversity'—regions where particularly large numbers of land races had developed. The two types of centre do not necessarily coincide. Countries like Ethiopia, Turkey, Iran, Iraq, and Pakistan are centres of diversity. Many land races have developed in these countries.

Parts of Vavilov's collections have been preserved as viable seed to the present day. Thus his collections became the world's first example of a gene bank on which plant breeders could call.

Australia now has a national wheat collection of something over 14 000 different lines. Most of these are outdated types dating back not more than 150 years rather than the land races of old. So we stand to gain from the international efforts to preserve the land races. Our plant breeders have a continual task breeding new wheat strains to keep ahead of wheat rust diseases, for example, and it

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Man-made mutations – the other option?

Plant breeders need genetic variation to create new plants for cultivation. Conserving the variation of their primitive and wild relatives in gene banks is a way of making sure that this is available. But some plant breeders would maintain that the whole effort is unnecessary. They argue instead that all the genetic variation needed can be obtained by creating it in existing crop plants. These merely need to be treated with radiation or chemicals that make mutations happen. After all, more than a hundred crop varieties have now been developed using such techniques.

Perhaps these advocates are right. However, Dr Brock, a plant breeder with the Division of Plant Industry and an authority on inducing mutations, doubts it. He thinks that, for the present at least, both natural variation and induced mutations have their place. Induced mutations should be used as a supplement to naturally occurring variation.

As Dr Brock points out, plant-breeding programs can be regarded as consisting of three stages:

- selecting an adequate gene pool containing desirable genes
- manipulating the selected genes to generate more favourable combinations
- demonstrating the superiority of the new plants over existing ones

Inducing mutations increases the pool of genetic variability that can be used in the first two stages. Dr Brock believes it possible to induce any mutation that has occurred naturally (even though it may have been lost from existing plant populations) and probably also many that have never occurred spontaneously. However, if the required variability already exists in the plant population, then he considers that it will probably be simpler and cheaper to use it rather than to induce it anew.

Genes that control the form of a plant or animal are located along the length of chromosomes. When reproductive cells are being formed—during the process of meiosis—segments of the chromosomes become exchanged and mixed. Consequently the gene mix along the chromosomes becomes rearranged. Selection, by nature, by early farmers, or by plant breeders, picks out the combinations that are most favourable in the environment in which the plant grows—be it the natural one, primitive cultivation, or modern agriculture. When desirable combinations exist in natural plant populations it is certainly cheaper to use them than to attempt to create them artificially. However, Dr Brock points out that there is, as yet, little evidence that a combination of genes that is apparently desirable in a wild or primitive crop plant will necessarily be the best combination for plants grown in the very different situation of cultivation.

Chromosomes in a dividing cell—they carry the genes.

Early dreams of chemicals that would act on and change specific genes have yet to be realized. Any chemical mutagen will always affect several genes. So if such a chemical is used to try to change an existing crop plant by altering a specific gene, it is likely to affect the plant in other ways as well—which is a snag that always has to be borne in mind. Apart from providing variability where it cannot be found in the natural gene pool, induced mutations have played their greatest roles in vegetatively reproduced species such as fruit trees and in making small changes to highly productive crop varieties.

Other techniques of genetic engineering are becoming available for use in the future. For example, it has already proved possible to incorporate genetic material into crop plants from other species. Nevertheless, for the present, Dr Brock thinks that induced mutations are best regarded as supplements to the use of natural variation, rather than as the alternative.

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Some unusual types of wheat stored in the Australian Wheat Collection.

Two contrasting native *Glycine* species, relatives of the soybean—rare *G. latrobiana* (below), which was recently refound after not being seen for many years, and *G. canescens* from western New South Wales.

could well be that some of the ancient stocks have valuable features that could be bred into these new strains.

Native relatives of crops

We may not possess a comprehensive collection of ancient crop land races, but we do on the other hand have native wild relatives of a number of crops. By crossing, these too may give desirable new features to existing crop plants.

Australia has wild relatives of tobacco, soybean, rice, cotton, and sorghum. In fact, wild tobacco has already been used as a source of genes for commercial plants.

Blue mould is a disease of Australian wild tobaccos. When commercial tobacco-growing started, the mould quickly spread onto commercial crops, causing a great deal of damage. It subsequently spread to Europe. A chemical treatment developed to combat the disease was expensive and not entirely satisfactory.

In 1953, Mr Don Wark from the Division of Plant Industry began a successful program of breeding blue-mould-resistant types of tobacco for commercial use. To do this he crossed a good commercial tobacco with a wild blue-mould-resistant strain collected from near Port Augusta in South Australia. Commercial tobacco varieties resistant to blue mould, which were derived from this crossing with the wild species, are now in commercial use in Europe as well as here in Australia.

Nobody took much interest until recently in our native cottons and *Glycine* species. (The soybean is a *Glycine*.) However, Russian and American interest in these plants has prompted the Division of Plant Industry to collect, identify, and store them during the past 5 years.

Australia's introduced pasture plants have often proved to be of value to other countries with similar climates. Until a few years ago both CSIRO and the State Departments of Agriculture evaluated their introduced plants and only held on to the lines that looked promising. Often, they disposed of the rest on the assumption that they could always be collected again from their countries of origin. Consequently, by no means all of the 20 000-odd lines of plants introduced by CSIRO over the years now remain in store, and the situation is similar within the States. For example, the Division of Plant Industry has introduced some 200 samples of *Phalaris* pasture grass, but only 40–50 now remain in store. The Division has been storing seeds of all plants introduced since 1970.

Phalaris and subterranean clover are two pasture plants used in southern Australia that had not previously been in agricultural use overseas. Sub clover was unintentionally introduced. Both plants came from countries surrounding the Mediterranean Sea, where they occur on land that is heavily grazed by domestic stock. Sub clover at least has shown considerable genetic diversity in its new home. Many countries now look to Australia as a source of seed for the domesticated pasture phalaris or sub clover, rather than to the countries of the Mediterranean region. Proposals are afoot for setting up an Australian national sub clover collection.

Since 1959, the CSIRO Division of Tropical Agronomy has introduced many thousand tropical legumes and grasses for use in tropical improved pastures. Most of them came from South America or Africa. Samples of 9000 of these introductions remain in storage. As with countries needing Mediterranean plants, tropical countries are looking to Australia for seeds of domesticated tropical pasture plants. Several species in their cultivated form have found their way back to the countries they originally came from. The seed stored at the Division of Tropical Agronomy represents a gene pool that will be of great value to tropical countries.

The Division does not know whether any of the potentially useful species that it has brought in are in danger of extinction in their countries of origin. Probably, in fact, none are, even though a number came from densely populated developing countries where land is short.

Wild *Pinus radiata* threatened

The Monterey pine (*Pinus radiata*), which is grown so widely in plantations in southern Australia, is perhaps the best example of an important introduced plant that we do know is not safe in its native land. Huge areas are also planted with this species in New Zealand and Chile, while South Africa, Spain, Argentina, and Uruguay have smaller plantations. In fact at present greater areas in the world are probably planted with this tree than with any other single species. Yet California, where the Monterey pine grows wild, boasts only a few small plantations grown for use as Christmas trees.

Native stands of Monterey pine are restricted to three separate pockets on a strip of coast about 10 km wide and 200 km long south of San Francisco in central California. In all, the species covers about 6000 ha within these three areas. The land is under private ownership and some (especially around the city of Monterey) is being swallowed up for development. Thus the future of the species in California certainly cannot be regarded as secure. It may well in the future survive only outside the United States.

The CSIRO Division of Forest Research has accumulated a considerable collection of Monterey pine seed, which it is now evaluating in field trials. Nevertheless, like all collections, the Division's does not encompass all the variation to be found in the species.

In fact, Dr Ken Eidridge, who is in charge of the evaluation, doubts whether the parent seed even came from the most-suitable locations. On the inland side of the northern-most stand, near Point Ano Nuevo, trees grow on fertile soils up to an altitude of about 300 metres. No seed has been collected from the best trees in the best part of these stands. Nevertheless, trees from there may be even better suited to moist fertile sites in southern Australia than the type of Monterey pine grown on these sites now.

Who preserves the species?

The case of the Monterey pine raises the question: whose is the responsibility for preserving this species? Probably self-interest dictates that Australia and the other countries that grow the tree commercially should maintain as wide a sample of the natural genetic variation of the population as it can, as an insurance policy.

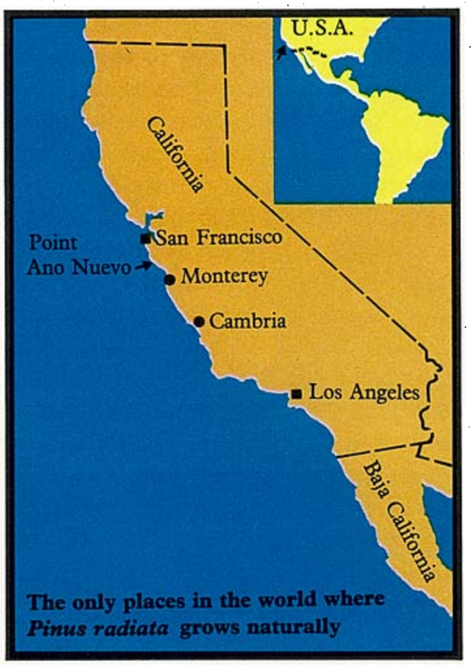
However, if we want to keep as many genes as possible, it would be best if the tree were preserved in its native habitats. The scattered population would then continue to be subject to the pressures of natural selection that first moulded its diversity. Stored seed or special conservation stands of the trees grown in foreign places must be replanted periodically and new generations grown. Each time, there is a chance that genes will be lost, so the stored genetic resource will slowly diminish.

This problem confronts us in Australia too with some of our eucalypts. About 500 species or subspecies of eucalypts grow here, and also a large number of hybrids. Two other species grow only on islands to the north of the continent, and a further half dozen are shared by Papua–New Guinea and northern Australia. So we are indeed the custodians of the gene resource from which huge eucalypt plantations have been established throughout the world. However, we have only recently started to study the variation patterns even in the major commercial species. So we don't yet have the knowledge needed to conserve our resources of genetic variation; indeed, we don't even know what they are.

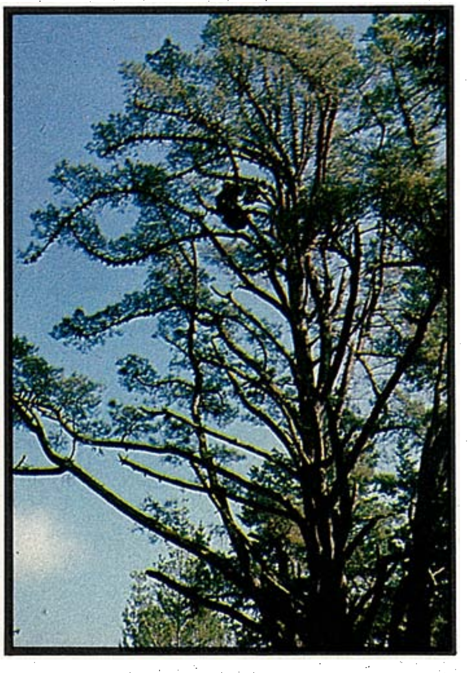
Eucalypt seed collected

Mr John Turnbull and his group at the Division of Forest Research have been systematically collecting eucalypt seeds since 1963. At present the group is concentrating on obtaining seed of species that are of commercial importance either

An unusual black-leaved sub clover from Western Australia.



The only places in the world where *Pinus radiata* grows naturally



An unusual type of Monterey pine that grows only at Point Ano Nuevo, California.

Natural stand of mature Monterey pine near Monterey, California.

Australian and Russian scientists during a recent seed-collecting mission in the Caucasus mountains.

New genes give better-adapted wheat crops.

to Australia or to other countries. FAO began giving financial assistance in 1966 because of the importance of this collecting to developing nations.

As with other plants, individual eucalypt species vary considerably from place to place. So collecting seeds of representative populations requires that samples be obtained from locations throughout the species' geographical ranges. Foresters refer to the trees growing at a specific site as a 'provenance'. Trees of each provenance tend to have a slightly different genetic make-up from others, since natural selection over many generations has adapted them to the specific conditions at each site.

Mr Turnbull and his colleagues collect seed of about 10 trees from each provenance. These are marked so that further seed can be collected if necessary. For a species like the river red gum (*Eucalyptus camaldulensis*), which occurs in both southern and northern Australia, obtaining seed from all provenances is a very big task indeed. For others with a restricted range, like Dundas mahogany (*E. brockwayi*), two or three collections have sufficed.

In 1975 Mr Turnbull's group supplied more than 2500 seed samples from known sources to 67 countries. The Division of Forest Research provides advice on which species to select, but usually relies on the countries supplied to test and confirm the suitability of the species and provenances for their forestry purposes.

In 1975, Dr Turnbull's group supplied more than 2500 eucalypt seed samples from known sources to 67 countries.

At present, few eucalypts are threatened with extinction. The small-leaved gum (*E. parvifolia*) is an exception. This small species occurs as a few scattered trees along the top of the coastal scarp of New South Wales in a narrow strip less than 100 km long by a kilometre or two wide. Most of the known trees occur on privately owned properties that vary between 500 and 1000 ha in size. They are devoted to sheep and cattle grazing. Some of the trees have been cleared to make way for rough pasture. Probably only a few hundred remain.

The species is important because it has a remarkable tolerance for low temperatures. This feature may well be incorporated in hybrids with other eucalypts to produce cold-resistant trees that could be planted for timber production in higher latitudes than is now possible. The species has been planted in the United Kingdom to form shelter belts—it is one of the few eucalypt species capable of surviving the cold British winters.

Should *E. parvifolia* be allowed to die out, taking with it the cold-resistant genes? Or should measures be taken to preserve it? We still have the choice.

More about the topic

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