WORKING WITH THE WORLD FOR PLANT IMPROVEMENT

FARRER ORATION 1983

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William James Farrer was a man of vision. He was one of the first to recognise the potential of hybridisation for the improvement of agricultural plants. He also saw the value of attributes to be found in plant varieties growing in far distant countries. From these ideas he conceived the goal of producing varieties of wheat which were productive, resistant to disease and of good grain quality, and also the means of achieving this goal by hybridising varieties of diverse geographic origin.

Farrer's work provided, indeed, an excellent example for the theme of the 1983 Oration, the value of international germplasm exchange in the improvement of agricultural plants in Australia.

Plant Introductions

The native flora of Australia supported a low density population for many thousands of years prior to the wave of new settlers that started to arrive in 1788. The native grasses also provided fodder for the animals which the settlers introduced, and their value as a foundation for the grazing industries continues to the present day. Apart from this, however, the contribution to the agricultural requirements of modern civilization has been relatively minor. Australia has given no important agricultural plant to the world, and although we have many species or sub-species related to important crops, the only example of these being successfully used as a parent in hybridisation is the production of 3 tobacco varieties with enhanced disease resistance (Marshall and Broue 1981) (Table 1).

Australian agriculture has therefore always been heavily reliant on plant introductions. Introductions can be of many different types. They may be accidental or deliberate, free or traded, legal or illegal, for use as a cultivar unchanged or as a breeding parent, obtained by posting a letter or the result of a hazardous collection expedition.

Germplasm Flow Models

One of the most important introductions subterranean clover (*Trifolium subterranean*) was an accidental one. This species was probably introduced on many occasions during last century (Cocks *et al.* 1980), and until recently it spread and evolved in Australia in relative isolation from the rest of the world. If these early introductions are considered as a single event, then this can be illustrated by the "Hive-off" model of Figure 1. In this model a sampling of the world gene pool leads to separate evolution of local varieties. The situation has however, changed a little in the last 20 years with the release of 2 cultivars incorporating genes from a Greek line of *Trifolium yanninicum*.

In contrast, a new species in Australian agriculture, triticale (*Triticum x Secale*), can be used as an example of the "Umbilical" model of Figure 2. In this model the world's germplasm is repeatedly sampled to provide varieties directly for Australian agriculture. Commencing in 1979, eight varieties of triticale have been registered in Australia (Table 2). All have been derived, with various degrees of local selection, from genetic material obtained directly from the International Maize and Wheat Improvement Centre (CIMMYT) in Mexico.

A more common model for important species for which there are well established breeding programs both in Australia and overseas is the "Booster" model of Figure 3. This involves a local breeding effort of intercrossing, selection and release, with introduced germplasm providing a periodic boost through the infusion of genes influencing desirable attributes.

Wheat

An example of this model is wheat. A significant improvement of Australian wheat varieties, which were initially based on those of Europe, occurred as the result of the introduction of Du Toit parental lines from South Africa in the 1880s (Table 3). These and later introductions of Indian varieties provided earlier maturity, thus allowing crops to mature before the onset of extreme summer heat and drought (Macindoe and Walkden Brown 1968).

Farrer was very interested in wheat quality and attempted to combine the earliness of Indian varieties, the baking quality of Fife wheats from Canada and the productivity of existing Australian material. He only partially realised this objective as his most popular variety, Federation, was not of good quality and the most popular of his good quality varieties, Florence, was not widely grown. However, it was his visionary concept, and his varieties which were later used as parents, which paved the way for others to realise this goal, for example in the variety Gabo released in 1945. Wrigley and Shepherd (1977) concluded that Gular, derived in part from Farrer's wheats, was probably the recurrent parent used in the breeding of Gabo.

The primary vision which drove Farrer on in his pioneering work was, however, the prospect of controlling the scourge of stem rust by breeding (Farrer 1898). In this he again forged the concept which others were to realise. It was the introduction, in the 1930s and later, of resistant parent lines from East Africa, North America and elsewhere that provided the raw material for men such as Waterhouse, Macindoe and Watson to use so successfully to control this disease.

The next major infusion of gemplasm commenced in the 1950s with the introduction of semidwarf wheats from USA and Mexico. These brought with them the genes for reduced height derived from the Japanese variety Norin 10, which were to be so valuable in eastern Australia and elsewhere in the world in controlling crop lodging and in increasing grain yield through raising the ratio of grain to straw in the plant. The flow of germplasm relating to semidwarf wheats in Australia is shown in Figure 4 and represents an outstanding example of the benefits derived from open international genetic exchange.

The increased yield achieved in some of the semidwarf Australian varieties has been documented in a previous Farrer Oration (Martin 1981). Figure 5 illustrates how these varieties were rapidly adoped by farmers in the eastern States. The reason why Western Australia should be such an exception remains unexplained. The most important of the semidwarf introductions was (LR64-N10B)An_E^3, numbered WW15 (Syme and Pugsley 1975), from which a suite of varieties with grain quality and disease resistance suited to Australain requirements and a wide range of maturities have been derived by various workers (Figure 6). Many of these varieties are currently grown widely and many are being used intensively as parents for varieties of the future.

Barley

A major improvement in Australian barley came with the selection of the variety Prior at the turn of the century (Table 4), although the geographic origin of this line is uncertain (Sparrow and Doolette 1975). Its main advantage lay in earlier maturity, and it was so successful with farmers that it dominated the Australian crop for many decades.

Good malting quality from English introductions was utilised to produce the variety Research and, later, the high successful variety Clipper. Other significant attributes introduced in overseas germplasm have been extra yield from Scandinavia and very early maturity, strong straw and increased yield from North Africa. Resistance to powdery mildew has been obtained recently from the Netherlands.

Sugar Cane

Collection expeditions to New Guinea late last century resulted in a significant improvement in yield with the importation of Noble canes and selection of the variety Badila (Table 5). Gumming disease became serious at this time and resistance was found in varieties from West Indies and, later, Indonesia. Another serious problem, Fiji disease, has been encountered with introduced varieties from India and USA in the 1930s, and again from USA in the 1950s. India has also been an important source of genetic material for increased yield, high sugar content and resistance of leaf scald.

Sorghum

A major improvement in Australian grain sorghums came from the reduced height of lines imported from USA in the 1930s. Varieties such as Wheatland, Alpha and Kalo resulted (Table 6). This was followed by the higher yielding hybrids based on cytoplasmic genetic male sterility introduced in the 1950's. Since then valuable disease and pest resistance has been found in material from India, Ethiopia and Natal and better standability in lines from Nigeria and USA.

Cotton

The cotton story is relatively simple. The modern industry has been based on the Deltapine Smooth Leaf variety, introduced from USA in the 1960s, followed by two later Deltapine introductions with increased yield potential (Table 7).

Rice

The rice industry of New South Wales was based for many years on the variety Caloro introduced from USA (Table 8). In the 1950s material with improved quality was introduced in medium and long grain types. This was used both directly and as parental germplasm in the breeding of local long grain varieties. More recently a semidwarf variety from USA, M7, has become important in NSW. In Queensland the industry has been based on two varieties from USA, Bluebonnet, and, since the 1960s, Starbonnet.

Tobacco

Introductions from USA have also been the foundation of the tobacco industry (Table 9). The variety Standard Hicks was grown for many years because of its quality and general disease tolerance. More recently, material with higher yield and with resistance to black shank and bacterial wilt has been important in improving this crop.

Sunflower

Sunflower introduced from Russia in the 1960s caused a revolution in this industry (Table 10). Varieties produced from this material were not only superior agronomically because they were shorter and matured earlier, they also had greatly increased oil content.

In the 1970s a second major change came with the production of hybrids from a combination of male sterile lines introduced from France and those with genes for fertility restoration from USA. The USA lines also provided useful resistance to rust.

Peanuts

The origin of the early varieties of peanut grown in Australia is obscure, but they were of the Red Spanish type. A major shift occurred in the 1920s when a high quality variety known as Virginia Bunch was introduced, probably from USA (Table 11) and this still forms the basis of this industry. A minor infusion of lines with improved kernel size distribution occurred in the 1960s. A White Spanish line originating from Israel has recently gained a small share of the market.

Maize

Hybrid maize varieties were first introduced to Australia from USA in the 1940s (Table 12). Improved hybrids followed, such as XL45 in the 1960s, with earlier maturity, disease resistance, shorter stature and higher yield. More recently, varieties such as XL81 with better resistance to lodging have been widely grown.

In Queensland the local breeding work has successfully utilised resistance to tropical rust and improved adaptation to the tropics obtained from material originating in Mexico and Columbia. Without this work the viability of maize production in North Queensland would have been in doubt.

Soybeans

The early soybean industry was based on the variety Semstar developed from the introduction of Chinese germplasm from USA (Table 13). Further material introduced in the 1950s provided a maturity type more suited to the tropics and more erect growth. A big change occurred with the introduction of determinate flowering from the USA in the 1960s. Together with improved yield and resistance to disease this has led, directly and through inter-crossing,to the current suite of varieties.

This brief review highlights only a few examples of the contribution of imported germplasm to agricultural production in this country. However, from the value of the crops covered, which approximates $4.5 billion annually, the importance of such germplasm to the Australian farming community and to the national economy is readily apparent.

Looking to the future, there is every reason to believe that Australian breeders will continue to exploit valuable material from overseas. As a single example, wheat breeders in Queensland are currently facing three new or newly-recognised disease and pest problems. Root-lesion nematode (*Pratylenchus thornei*) causes major yield loss on the Darling Downs (Thompson *et al*. 1983) and has forced many producers out of intensive wheat growing. Yellow spot (*Pyrenophora tritici-repentis*) is a serious obstacle to the adoption of stubble retention for the control of soil erosion as the disease is carried on stubble and current varieties are all susceptible (Rees and Platz 1983). Lastly, stripe rust (*Puccinia striiformis*) appeared in Queensland crops for the first time in 1983. Its rapid spread throughout eastern Australia and its noted capacity for race mutation suggests it is potentially one of the most damaging diseases to have been introduced to Australia in recent times. For each of these problems useful genetic resistance is being found in imported germplasm.

Exports of Australian Genetic Material

So far only one side of the story has been presented, the value of introduced material. If attention is now turned to exports of germplasm, some interesting examples of ways in which Australia has contributed to agricultural development in other countries are revealed.

Some of the best examples are in pasture species, where Australians have often recognised the potential of a species, popularised its production and then exported it successfully. Subterranean clover is a temperate species which has been widely grown for many years in areas of USA following introduction from Australia (Knight *et al*. 1982). Among the sub-tropical species a good example is the grass *Brachiaria decumbens*, a native of Uganda, which is now widely grown in Brazil as a result of Australian seed exports (Hopkinson, J. pers. comm.). Another is the legume Verano style (*Stylosanthes hamata*) originally from Venezuela, which through Australian efforts is now grown in parts of Thailand (Topark-Ngarm 1981) and southern India. A case of local breeding and dissemination is the legume Siratro (*Macroptilium atropurpureum*) which is grown in Eastern Africa.

In the crop species, both private and State breeding programmes have had an impact in other countries. With maize, private companies have exported to Thailand and the Phillipines and hybrids from the State programme in North Queensland have been the foundation of the industries developing in New Guinea and elsewhere in the Pacific. Sunflower hybrids have been exported successfully to Burma, Pakistan and Brazil and sorghums to Thailand, Phillipines, Argentina and Brazil.

Australian barley varieties have been important overseas both directly, as with the variety Clipper, which has been grown in at least 4 other countries, and indirectly as a source of early maturity in the European and Canadian breeding programmes. William Farrer's wheat varieties such as Federation and Bunyip, and others from Australia, played a major part in the developing wheat industry on the Pacific Coast of USA earlier this century (Suneson and Briggs 1941). Other varieties have been important in the CIMMYT program, mainly through their contribution of photoperiod insensitivity, but also as sources of high quality, white grain. Lately, Australian derivatives of CIMMYT wheats have been successfully grown in countries of the Middle East.

Interdependence Among Breeding Centres

There is therefore a further way in which the interdependence of plant improvement work in Australia and overseas can be described, the "Symbiotic" model of Figure 7. This diagram represents a continuing programe of breeding and selection in Australia, boosted occasionally from imported gemplasm, and the return of elite selections to the world community. Plant breeders using this model are truly working *with* the world for plant improvement, in a way which is beneficial to all parties.

We live in a highly competitive world which imposes its own pressures to restrict the interchange of germplasm. The recent expansion of commercial interests in the field of biotechnology has resulted in intense interest in the patenting of biological organisms and in many Centres it is inhibiting the free flow of material and information. Legislation for Plant Variety Rights operates in many countries to restrict the exchange of material and information. Nationalism is a factor inhibiting exchange in some countries and others would prefer to receive rather than to give.

A further factor retarding exchange is the imposition of quarantine restrictions. These may be necessary to exclude unwanted organisms, however it is important to realise the negative effect which excessive restrictions may have, and to develop efficient procedures for allowing breeders to have adequate access to germplasm from the rest of the world.

On the other hand, there are also forces operating to promote genetic exchange. One example is the creation of the International Centres, such as CIMMYT, which have taken on a responsibility to disseminate nurseries of selected breeding germplasm on a world-wide basis. The newly fromed Australian Council for International Agricultural Research (ACIAR) is concerned to promote co-operation and exchange between Australia and the developing countries of the Region. National and international germplasm banks are now receiving more support as their vital role in the collection, storage and distribution of genetic material has become more widely recognised. The Australian Wheat Collection has, for example, played a key role in this area for wheat breeders in Australia in recent years. Finally, the lower cost and greater ease of international travel promoted contact between people of different countries, and consequently encourages plant genetic exchange.

Conclusions

Germplasm introduction has played and will continue to play a vital role in the continuing improvement of agricultural plant species in Australia. It follows from this that those activities which have been mentioned as promoting genetic exchange should be supported. The enlightened policies of employers and other organisations, such as the Farrer Trust, which provide financial encouragement for students to study overseas should be applauded. For plant introduction to be successful, not only must the right source be identified, the receiver must also be receptive and able to recognise superior germplasm. Study tours and attendance at International Conferences are ways of increasing the likelihood of this fruitful "crossing-over". Personal contact is particularly important in a field such as plant breeding where many advances are made without written documentation.

Careful consideration must be given to the most appropriate breeding model for each agricultural species. For some which are less important, and in which another country is able to supply Australia's needs, the "Umbilical" model may be used. However, for most species of consequence the "Symbiotic" model is the most appropriate, a model in which Australian agriculture can receive, develop and give in return.

Agriculture has a proud tradition of open exchange between those concerned with plant improvement. This depends in part on continued public support for Government-funded breeding, but under any system it eventually comes down to the attitude of the individual scientist.

For inspiration in this regard one can return to William Farrer and quote from his letter written in 1886 to Mr. W. Lowrie of Roseworthy Agricultural College. Farrer had received small samples of seed from Professor Blount of Colorado, USA, and he wrote "I have very little myself, and what I have I have shared with you" (Russell 1949).

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Table 1

Use of Australian native flora in the improvement of agricultural plants.

Related crop	Species or sub-species	Varieties developed
Tobacco	21	Sirone Sirogo CSIRO 40T
Soybean	8	-
Cotton	11	-
Rice	2	-
Sorghum	10	-

Table 2

Triticale varieties in Australia

Year of release	Name	Genetic source
1977	Gro-Quick	U.S.A.
1979	Dua	Mexico (CIMMYT)
	Satu	Mexico (CIMMYT)
	Tyalla	Mexico (CIMMYT)
1980	Coorong	Mexico (CIMMYT)
1981	Ninghadu	Mexico (CIMMYT)
	Venus	Mexico (CIMMYT)
	Towan	Mexico (CIMMYT)
1983	Currency	Mexico (CIMMYT)

Table 3.

Germplasm infusion – Wheat

Introduced	Source	Attribute	Resulting variety
1880s	Sth Africa	Early maturity	Gluyas Early →
			Nabawa →
			Steinwedel →
1890s	India	Early maturity	Federation →
	Canada	Baking quality	Florence →
1910s	India	Early maturity	Ranee →
			Ghurka →
1930s – 1960s	Kenya		Eureka →
	Palestine	Resistance to	Gabo →
	U.S.A	stem rust	Timgalen →
	Canada		Eagle →
1960s –	Mexico (CIMMYT)	Semidwarf features	Condor →
			Egret →
		Resistance to stem, leaf and stripe rusts	Songlen →
			Millewa etc...

→ Indicates useful progeny arising from this variety.

Table 4.

Germplasm infusion - Barley.

Introduced	Source	Attribute	Resulting variety
1900s	England	Earlier maturity	Prior →
1920s	England	Malting quality	Research →
1950s	England	Malting quality	Clipper →
	Scandinavia	Yield	Bussell →
			Lara
	Nth Africa	Earlier maturity	Corvette
		Straw strength	Schooner
		Yield	
1960s	Netherlands	Resistance to powdery mildew	Grimmett

Table 5.

Germplasm infusion - Sugar cane

Introduced	Source	Attribute	Resulting variety
1890s	New Guinea	Yield	Badila →
	West Indies	Resistance to gumming disease	D.1135
1930s	Indonesia	Resistance to gumming disease	P.O.J.2878 →
	India	Resistance to	Co.290 →
	U.S.A	Fiji disease	C.P.29-116 →
1940s	India via Sth Africa	Yield, high sugar	N.Co.310 →
1950s	India	High sugar, vigour, resistance to leaf scald.	Co.475 →
	U.S.A.	Resistance to Fiji disease.	C.P.44-101 →

Table 6.

Germplasm infusion - Grain sorghum

Introduced	Source	Attribute	Resulting variety
1930s	U.S.A.	Reduced height (3 dwarf)	Wheatland ➤ Alpha Kalo ➤ Early Kalo Caprock, Martin
1950s	U.S.A.	Cytoplasmic genetic male sterility.	Texas 610
1960s	India	Resistance to: sugar cane mosiac virus sorghum downy mildew	QL 1, QL 21 QL 22
	Nigeria	Better standing	QL6, QL12
	U.S.A.	Better standing, yield	E57
1970s	Ethiopia Natal	Resistance to: head smut, downy mildew, midge	SC170, SC120, QL23
	U.S.A.	Better standing, yield Better standing, early maturity	Pride Goldrush

Table 7.

Germplasm infusion - Cotton.

Introduced	Source	Attribute	Resulting Variety
1960s	U.S.A.	Adaptation and quality.	Deltapine Smooth Leaf
1970s	U.S.A.	Yield	Deltapine 16
1980s	U.S.A.	Yield	Deltapine 61

Table 8.

Germplasm infusion - Rice.

Introduced	Source	Attribute	Resulting Variety
1920s	U.S.A.	Adaptation	Caloro →
1950s	U.S.A.	Yield, medium grain quality	Calrose →
			Bluebonnet 50 →
		Long grain quality	Kulu, Inga Pelde
1960s	U.S.A.	Resistance to lodging	Starbonnet (Nth Qld)
1970s	U.S.A.	Semidwarf habit	M7

Table 9.

Germplasm infusion - Tobacco.

Introduced	Source	Attribute	Resulting Variety
1940s	U.S.A.	Quality	Standard Hicks
		Disease tolerance	
1960s - 1970s	U.S.A.	Yield	Hicks Q46
		Resistance to:	NC2326
		Black shank	NC95
		Bacterial wilt	ZZ100

Table 10.

Germplasm infusion - Sunflower.

Introduced	Source	Attribute	Resulting Variety
1960s	Russia	Short Earlier maturity High oil content	Sunfola 68
1970s	France	Male sterility (cytoplasmic)	Hysun 31 Sunking,
	U.S.A.	Fertility restoration Rust resistance	Suncross 52 etc ...

Table 11.

Germplasm infusion - Peanuts.

Introduced	Source	Attribute	Resulting variety
1870s	?	Basic adaptation	Red Spanish
1920s	U.S.A.?	Superior quality	Virginia Bunch
1960s	U.S.A.	Better kernel size distribution	Infused into Virginia Bunch
1970s	Israel via India	High yield	White Spanish

Table 12.

Germplasm infusion - Maize.

Introduced	Source	Attribute	Resulting variety
1940s	U.S.A.	Hybrid vigour	DS28, etc...
1960s	U.S.A.	Earlier maturity Resistance to various diseases Shorter stature Yield	XL45, etc...
	Mexico and Columbia	Resistance to tropical rust Tropical adaption	QK lines, Nth Qld
1970s	U.S.A.	Resistance to lodging	XL81, etc...

<u>Table 13.</u>

Germplasm infusion - Soybean.

Introduced	Source	Attribute	Resulting variety
1930s	China,	Maturity suited to the sub-tropics	Semstar →
1950s	China, U.S.A.	Maturity suited to the tropics Erect growth	Ross
1960s	U.S.A.	Determinate flowering Yield Resistance to: Phytophthera root rot Bacterial pustule disease	Davis → Bragg → Lee → Fitzroy Forrest Dodds Dickie
1970s	Brazil	Tropical adaptation Yield	Canapolis

FIGURES

FIGURE 1. The "Hive-off" model. After a single introduction period local varieties are developed in isolation from the world gene-pool.

FIGURE 2. The "Umbilical" model. Repeated introductions from the world gene-pool are used directly to provide new local varieties.

FIGURE 3. The "Booster" model. The development of varieties from local intercrossing and selection is supplemented by the occasional injection of an introduction with desirable attributes.

FIGURE 4. Germplasm flow relating to Australian semidwarf wheats. The exploitation of the semidwarf habit has been facilitated by the free exchange of germplasm between Japan, Washington State, Mexico, Australia and New Zealand.

FIGURE 5. Semidwarf wheat varieties have been rapidly adopted by farmers in most States of Australia.

FIGURE 6. Progeny of the semidward wheat WW15 developed in Australia. Other parents used in developing these varieties are shown in lower case.

FIGURE 7. The "Symbiotic" model. In addition to the processes of the "Booster model" (Figure 3), elite germplasm is distributed to the world collections and interested researchers.

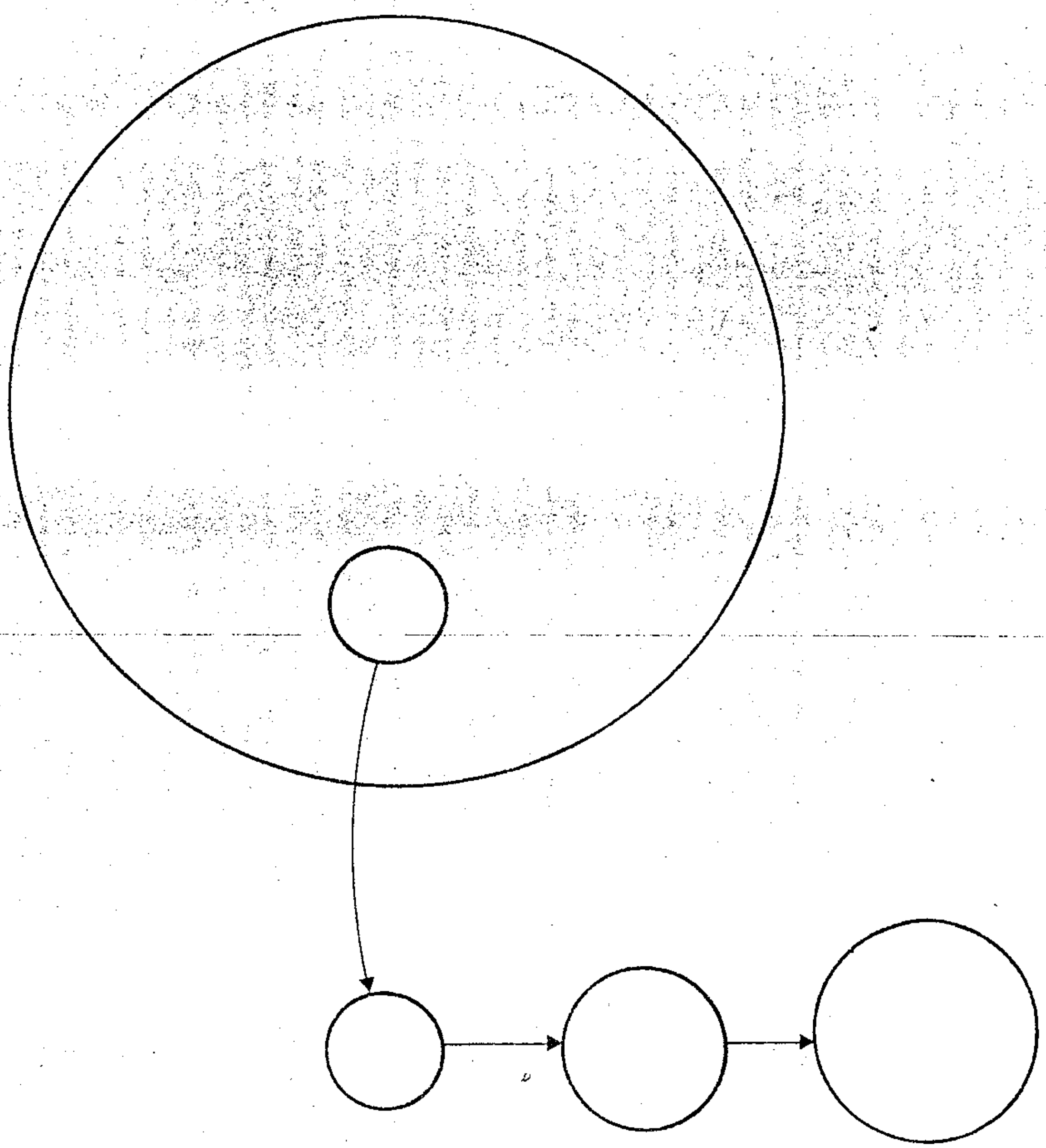

FIGURE 1.

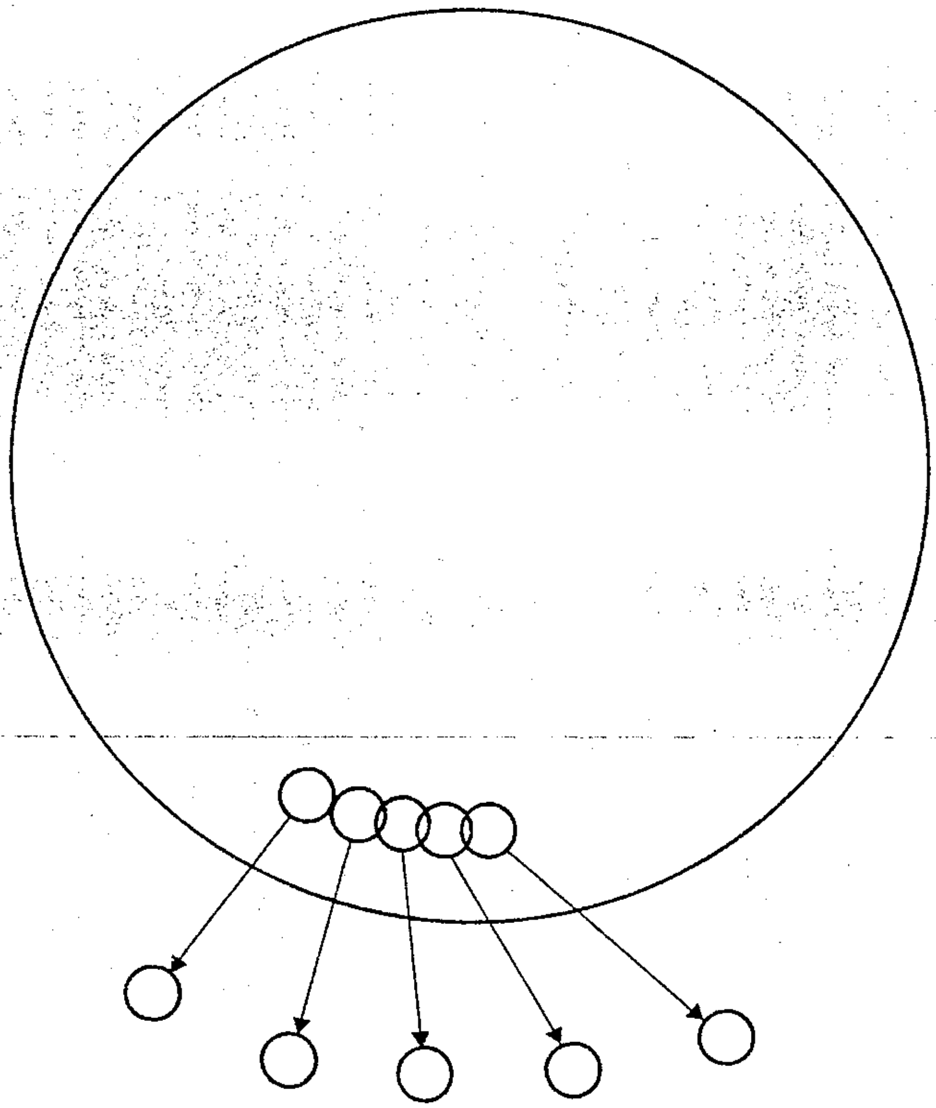

FIGURE 2.

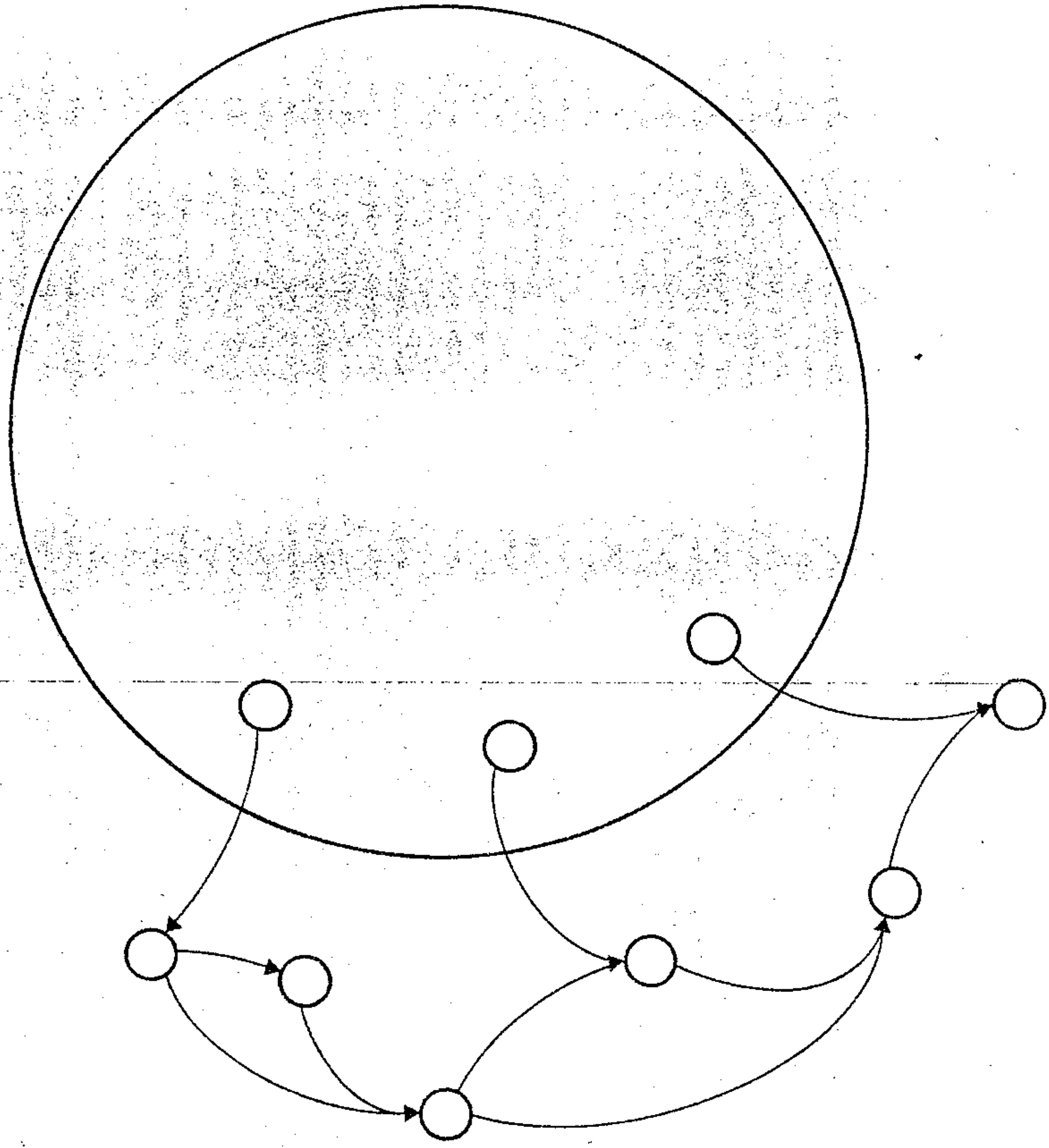

FIGURE 3.

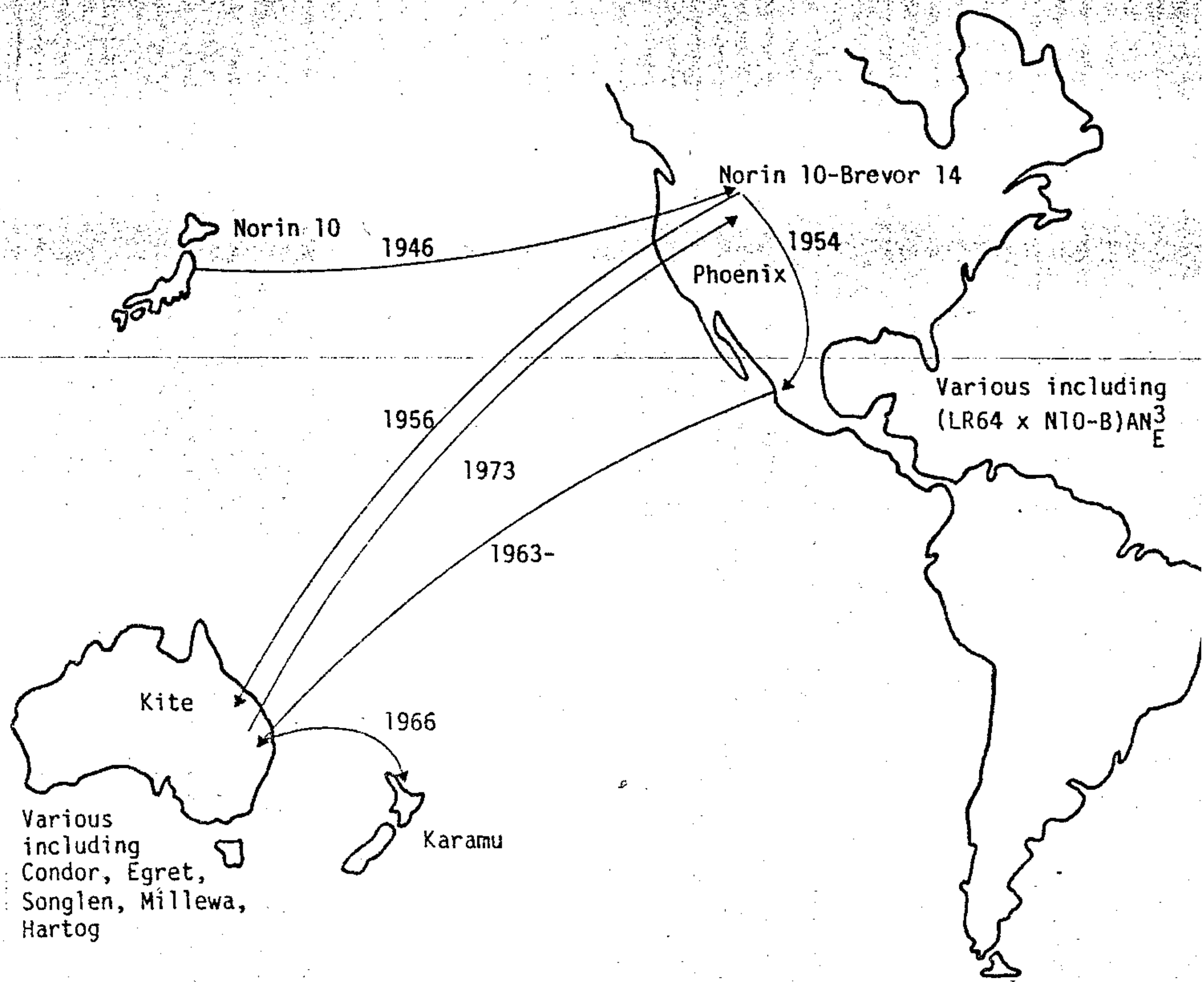
Norin 10
1946
Norin 10-Brevor 14
1954
Phoenix
Various including
(LR64 x N10-B)AN$^{3}_{E}$
1956
1973
1963-
Kite
1966
Karamu
Various
including
Condor, Egret,
Songlen, Millewa,
Hartog

FIGURE 4.

PERCENT OF TOTAL WHEAT PRODUCTION FROM SEMIDWARF VARIETIES

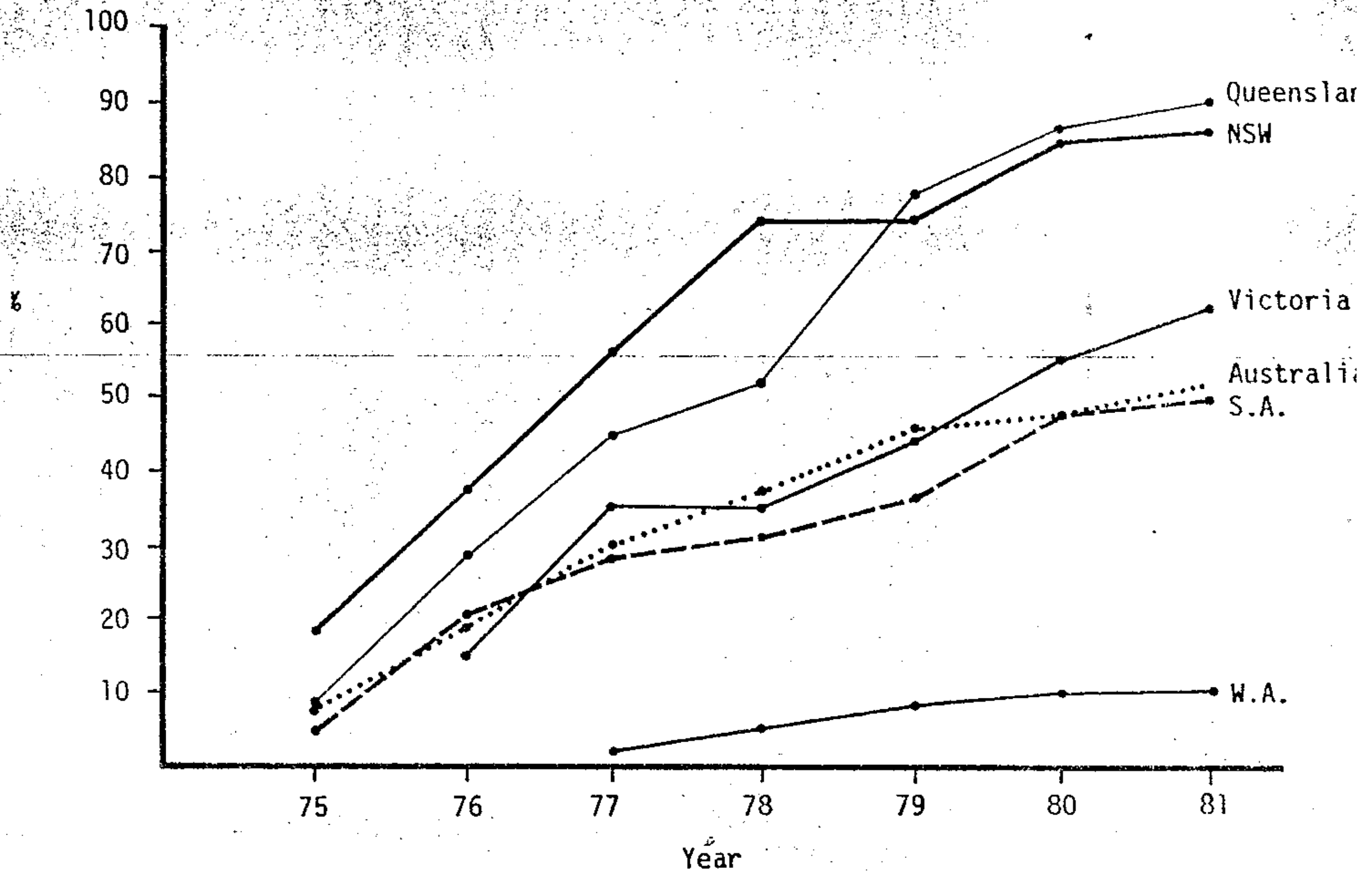

FIGURE 5.

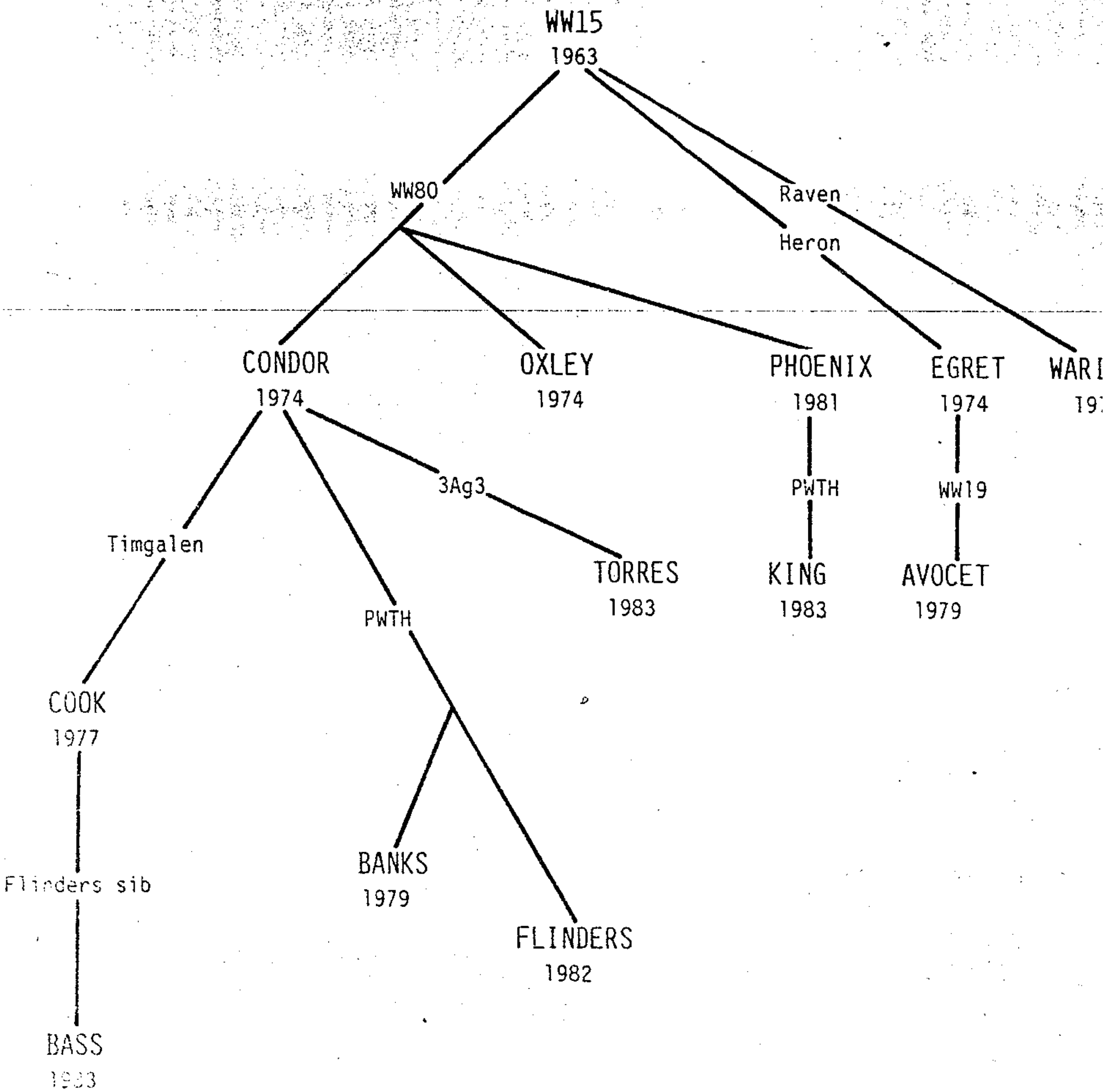
WW15
1963
WW80
Raven
Heron
CONDOR
1974
OXLEY
1974
PHOENIX
1981
EGRET
1974
WARI
Timgalen
3Ag3
PWTH
WW19
TORRES
1983
KING
1983
AVOCET
1979
PWTH
COOK
1977
Flinders sib
BANKS
1979
FLINDERS
1982
BASS

FIGURE 6.

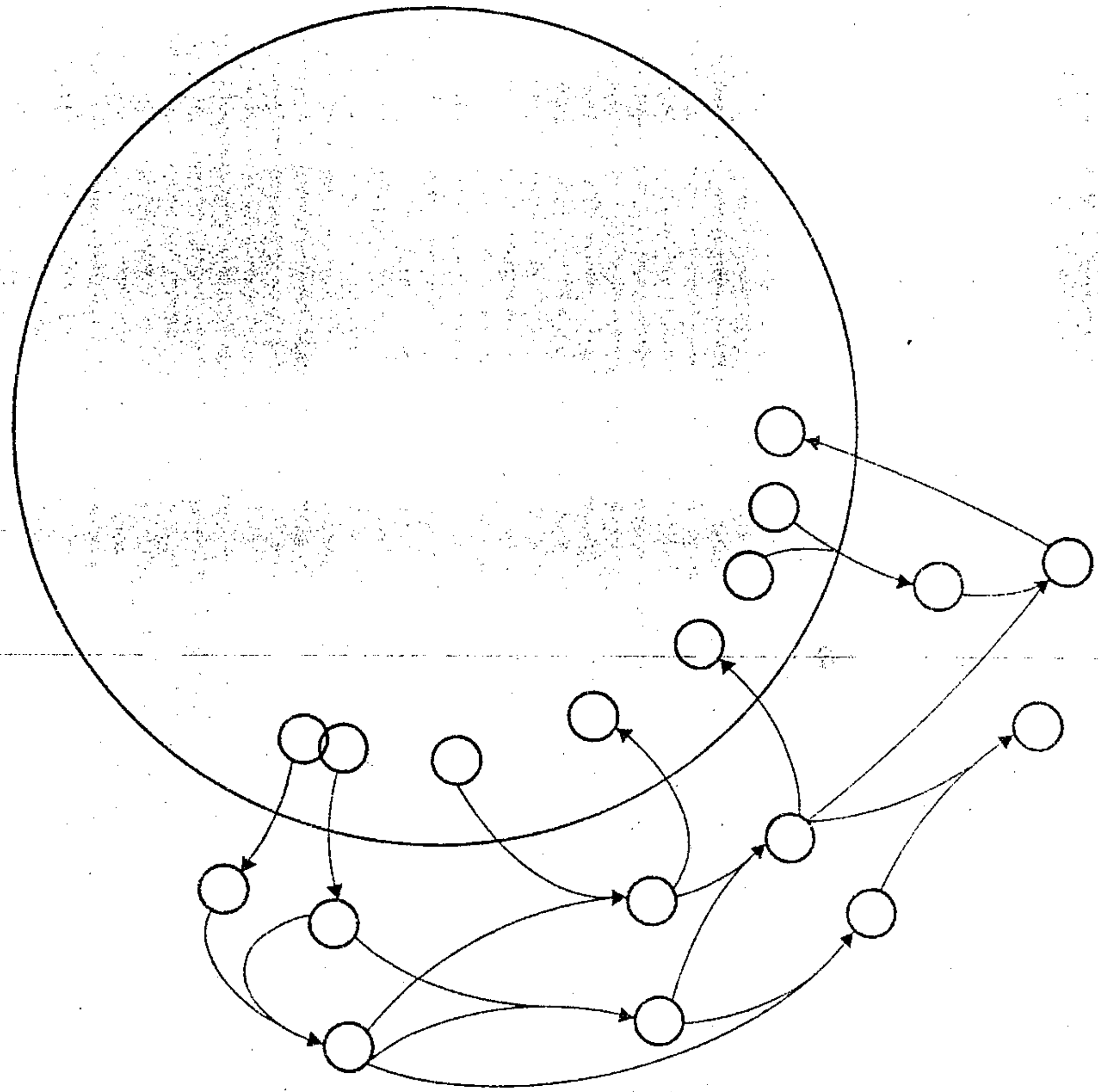

FIGURE 9