PRESIDENTIAL ADDRESS

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Part I. GENERAL.

Dr. E. H. Booth in his presidential address last year stated that a feature of the Society's meetings had been the large number of papers read. This year there is an increase of twelve papers to report, bringing the total up to fifty, which is the largest number in the past twenty years, and indeed in the history of the Society, so far as can be ascertained.

The amount set aside for publication of the volume this year was £380. Although so many papers have been published, this amount will not be exceeded, partly because a number of them are short, and partly because special financial arrangements were made to cover the cost of others.

The Council decided to continue the Clarke Memorial Lectures, and the lecture for 1938, which created great interest, was delivered by Dr. C. T. Madigan to a large and appreciative audience, on a subject on which he is one of the authorities, namely " The Simpson Desert and its Borders ".

The Clarke Memorial Medal for 1938 was awarded to Professor H. C. Richards D.Sc., of the University of Queensland, who, during the past twenty-five years, has made important contributions to our knowledge of the geology of Queensland.

The Annual Dinner this year was held at the Restaurant Annexe of Messrs. Farmer and Company Ltd., the guest of honour being Sir George Julius. All the arrangements were well carried out, and the comfort and enjoyment of the members and guests were assured.

A notable function in which members of the Society took part was the unveiling of the portrait of the late Sir Edgeworth David, which was hung in the Hall of Science

House. The ceremony of unveiling the portrait was carried out by Lady David, and the portrait was formally handed over to Science House by Dr. C. Anderson, as Chairman of the Portrait Fund Committee, and accepted by Mr. A. R. Penfold on behalf of the Science House Management Committee. A very representative gathering attended the ceremony. The portrait, which is an excellent likeness, was painted by Mr. Norman Carter, to whom high praise is due for the faithful portrayal, from drawings and photographs, of our honoured colleague.

It is a matter for gratification that, while there are still some arrears of subscriptions outstanding, the total amount of arrears has been further substantially reduced by the efforts of the Honorary Treasurer.

The Balance Sheet shows the position of the Society to be financially sound. It is very pleasing indeed to be able to report that, on the recommendation of the Minister for Education, the Honourable D. H. Drummond, the subsidy from the Government of New South Wales has been restored to £400 per annum.

The library is being further improved by the addition of the stack of shelves for current periodicals which was authorised last year, and these should prove a convenience to members wishing to consult the latest accessions. The arrangements made with Messrs. Tyrrell and Co. for the disposal of a number of superfluous volumes will leave room on the shelves for the current scientific journals, which arrive at the rate of about 300 a month.

It is with regret that I have to record the deaths of the following members:

Charles William Davey Conacher, died on 30th December, 1937, at the age of 57. Mr. Conacher was a Victorian by birth, but was educated in Edinburgh, returning to Australia in 1916 as General Manager of the North Australia Meat Company and of properties in the north controlled by Vestey's Limited. In 1920 he was transferred to Sydney, and he became, in 1934, General Manager of the Blue Star Steamship Line. Mr. Conacher lived in the Northern Territory for some years, and was considered an authority on its problems. He had a great belief in the future of the Territory, and was keenly interested in all schemes for the improvement of living conditions for the people of the inland, such as the Australian Aerial Medical Services and the Australian Inland Mission. In commercial life Mr. Conacher was highly esteemed by his colleagues for his wide knowledge of commercial, shipping, and pastoral matters, as well as for the sincerity and integrity of his character. He joined the Society as a life member only last year.

GEORGE ROBERT COWDERY, died on 15th May, 1937, at the age of 77. Mr. Cowdery was born at Glenlee, where his father was engineer-in-charge of the main southern line of N.S. Wales, and came of a railway pioneering family, his grandfather having been associated with George Stephenson in the early days of railways. Mr. Cowdery himself joined the railway service at the age of sixteen, as an apprentice in the locomotive workshops. In 1885 he became the engineer-in-charge of the duplication of the Parramatta to Penrith line, and in 1889, when the railways and tramways became separate departments, he became engineer for tramways, a post which he held for thirty-eight years. He served the two departments for a total period of over fifty-one years, and retired in 1927. When he took charge of the tramways, there were thirty street miles only, laid down in the Sydney system, which was worked by steam traction, with 228 employees. On his retirement the department had 1,547 employees, and the system, which was by that time almost entirely electric, covered 225 street miles—equivalent to 360 miles of single track. Mr. Cowdery had been a member of the Royal Society since 1892.

Two of our very distinguished Honorary Members died during the year.

WALTER HOWCHIN, F.G.S., died at his home in Adelaide on 27th November, 1937, at the age of 91. For more than half a century, Professor Howchin held an important place in the scientific life of South Australia, and the story of his career as a geologist is a romantic one. Born at Norwich in 1845, the son of a Primitive Methodist minister, he received his first schooling at the Academy of King's Lynn, and began work as a clerk in London at the age of twelve years, receiving a salary of two shillings per week, in addition to board and lodging. Later he was apprenticed to a printer, but studied for the ministry, was ordained at the age of twenty, and spent the next sixteen years in places within the Tyne Valley, where the geological features aroused his keen interest in geology. In particular, an abundant glacial till at Haltwhistle led him to a study of glacial action which ultimately resulted in his great discoveries of evidences of glaciation in Australia. Howchin published a number of geological papers during the years of his ministry in England, and at thirty-three became a Fellow of the Geological Society of London. Ill-health caused him to relinquish his work in the Church, and he came to Australia in the hope of arresting the serious lung trouble which threatened him. He was hardly expected to survive the long sea voyage, and was carried ashore on arrival. On being welcomed by his fellow churchmen of South Australia he referred to the blow that had broken his life at its beginning. A review of his achievements shows that, far from his active life being ended at thirty-six, his most productive period of scientific work was between the ages of sixty and eighty, and his output continued until within a short time of his death.

In 1883 Howchin became a member of the Royal Society of South Australia, and editor of its journal. In 1886, having completely recovered his health, he filled the position of secretary to the Children's Hospital, and later of Lecturer in Mineralogy at the Adelaide School of Mines and at Gawler, at the same time carrying on his studies in the geology, palæontology and mineralogy of South Australia. During his holidays Mr. Howchin visited his friends in the Methodist Ministry, often preaching for them on Sundays, and spending the rest of his time geologising in the surrounding districts. He was always a great walker, even until a few years before his death, and walked long distances collecting specimens and carrying out field observations. In 1902, at the age of fifty-seven, Howchin was appointed Lecturer in Geology and Palæontology at the University of Adelaide, and in the ensuing years he produced a large number of scientific papers, as well as seven books on geography, geology and anthropology. In 1908 he was appointed Honorary Professor of the University of Adelaide, which position he held until his retirement in 1920. It is interesting to record that in his ninetieth year he presented Part I of a new series of geological papers for publication in the Journal of the Royal Society of South Australia.

Among his other activities Professor Howchin was for over twenty years the representative of the Royal Society of South Australia on the Board of the Public Library, Art Gallery and Museum, and later became Honorary Palæontologist to the Museum.

He received the following honours from various societies for his scientific work :

Medal of Royal Society of N.S.W. ..	1907
Mueller Medal of Australasian Assoc. for Advancement of Science	1913
Geological Society of London, Moiety of Lyell Fund	1914
Sir J. Verco Medal of Royal Society of South Australia	1929
Lyell Medal of London Geological Society ..	1934

He was elected an Honorary Member of this Society in 1934.

Professor Howchin's greatest contribution to scientific knowledge is comprised in his series of papers on the existence of glacial rocks in the Adelaide Series of the Mount Lofty Ranges. In many of his researches, particularly those on glacial action, he was closely associated over a period of forty years with the late Sir Edgeworth David, with whom he had much in common.

Australia, and particularly South Australia, owes much to the enthusiasm and unceasing search after knowledge which were characteristic of Professor Howchin throughout his life.

David Orme Masson, K.B.E., F.R.S., M.A., D.Sc., LL.D., F.I.C., died on 10th August, 1937, in his eightieth year. He was born in Scotland and educated at the Edinburgh Academy, and at the University of Edinburgh. Among his teachers were Crum Brown, and Wöhler of Gottingen. He became assistant to Professor William Ramsay at the Bristol University, and from there returned to Edinburgh University as research fellow in chemistry. In 1886, at the age of twenty-eight, having already distinguished himself by his researches in organic chemistry, he was appointed to the new Chair of Chemistry in the University of Melbourne. The Department of Chemistry went ahead rapidly under his leadership ; his outstanding ability as a teacher soon began to be acknowledged, and research became a recognised part of the work of his school. The Chemistry Department of the University of Melbourne was looked upon as a model, and many of its graduates have had distinguished careers in Australia and abroad, five of them having reached the rank of professor.

Sir David Masson's work did not end in the Department of Organic Chemistry : his wisdom and knowledge were always available in matters of administration or of service within or without the University. He was President of the Australasian Association for the Advancement of Science from 1912 to 1915, and was one of those responsible for the visit to Australia of the British Association in 1914, and for the holding of the second Pan-Pacific Congress in Australia in 1923. He was closely associated with the Federal Munitions Committees during the Great War, and was one of a group of Melbourne University scientists who designed and tested a respirator for defence against gas, many of the features of which were adopted by the British War Office.

In 1912 Sir David was offered the Chair of Chemistry at University College, London, but elected to remain in Australia, retiring from the Chair at Melbourne in 1923, after serving the University for thirty-seven years. In 1923 he was created K.B.E.

Sir David Masson was keenly interested in the exploration of Antarctica, and was a very active member of the organizing committees of the expeditions. He was asked by the Prime Minister to become chairman of the committee formed to advise the Government on the founding of the Institute of Science and Industry (now the C.S.I.R.), and was one of the founders of the Australian National Research Council, of which he was president from 1922 to 1926. He also founded the Melbourne University Chemical Society, and was a founder and first president of the Society of Chemical Industry of Victoria, as well as founder of the Australian Chemical Institute in 1917. On the incorporation of the last-named society by Royal Charter, Sir David became its first president. Sir David's lectures in chemistry were looked upon as models in their simplicity, clearness, and cultured phraseology. He stood for all that was best in the eyes of his students and his colleagues; and there are many who owe to him the inspiration for their life's work. By the death of Sir David Orme Masson the scientific world has lost one of its most distinguished and cultured minds, whose work and influence have spread far beyond the borders of the Australian Commonwealth. Sir David had been an Honorary Member of this Society since 1930.

Part II.

SOME ASPECTS OF PROBLEMS IN BREEDING FOR RUST RESISTANCE IN CEREALS.

Introduction.

In addressing you tonight, I recall that so recently as 1935, Dr. R. J. Noble, in his Presidential Address, dealt with certain aspects of plant disease problems. This had previously been done to a limited extent by Professor R. D. Watt, our President in 1926. Thus in the past twelve years there will have been three of these addresses dealing with agricultural topics.

And yet in a country like Australia, whose wealth is so largely dependent upon its primary products, scientific endeavour may well be directed to the elucidation of some of the many problems in this sphere.

This year we have celebrated the 150th anniversary of the establishment of our colony. The progress made in this period has been stupendous, and brings home forcibly to us the great debt we owe to our pioneers. A continent which was sparsely inhabited by a native race now carries a population of nearly seven millions and produces wealth estimated to amount to £350,000,000 per annum. Without the benefits conferred by science, and particularly in its application to primary production, these tremendous advances would not have been possible. Yet whilst so much has been accomplished by science in the past, much still remains to be done.

Tonight it is my intention to depart somewhat from the general treatment of agricultural problems given by these two past-Presidents, and to deal with certain aspects of the subject of breeding for disease resistance, and more especially rust resistance in cereals. These are days when intense specialisation is a feature in research work, as in other spheres of human activity, and for some time it has fallen to my lot to be concerned with this problem. I hope it may be of interest to you if I review some phases of the work that have been receiving attention, and particularly those dealing with the organisms which cause rust.

Acknowledgments.

In carrying out the work a great deal of help has been forthcoming from many sources, and I gladly acknowledge my indebtedness and gratitude to numerous friends; it would be impossible to enumerate all. Drs. E. C. Stakman and M. N. Levine of Minnesota, and Dr. H. B. Humphrey of Washington have been instant in season and out of season in giving help. Officers of the State Departments of Agriculture in Australia and the Council for Scientific and Industrial Research at Canberra have constantly helped, and more particularly those of our own N. S. Wales Department. Of these it is perhaps not invidious to mention especially the generous assistance given continuously by Principal E. A. Southee of Hawkesbury Agricultural College and his officers. Loyal and efficient service has been rendered throughout by Messrs. J. H. Kaye and J. Bolin of the Sydney University attendant staff. Generous financial assistance from the Trustees of the Science and Industry Endowment Fund has been given over a period of years, without which it would have been impossible to carry on the investigations. Grants last year from the Carnegie Research Fund and the Commonwealth Research Fund have enabled much extra work to be done.

Historical.

Plant breeding goes back to very early days in the history of man. The exact place where man first began to cultivate plants is not known, but it seems certain that Iraq, the site of the traditional Garden of Eden, was one of the earliest homes of civilised man. Here, some thousands of years before the present era, plant improvement was actually practised. It took the form of hand-pollination of the date palm, a procedure which is clearly recorded in certain Babylonian and Assyrian monuments.

Even in those remote times when animals were first domesticated, it was probably recognised that sex lay at the basis of improvement. "Breeding" meant the use of superior animals for mating. Now the fact of sex in plants is less evident than in animals, because in most plants both sexes are present in one and the same plant. In the date palm, however, the sexes occur separately as in domesticated animals. The existence of two sorts of dates was recognised in the early days, viz. sterile and fruit-bearing. Yet the product of the "sterile" male tree was known to be essential for fruit production by the fertile female tree.

Now the seeds from a date palm give rise to male and female trees in about equal numbers. Under cultivation, the growing of such large numbers of " sterile " male trees would be very wasteful of the land. It was early found that if hand-pollination were practised, only a small number of male trees was necessary for the fertilization of a large number of female trees.

Furthermore, it was soon discovered that the offspring could not be depended upon to produce fruit the same as the parent. The fact of variation, which is the basis of plant-improvement work, was thus early recognised.

Mainly by reason of the absence from these regions of such annual crop plants as maize, the fact was lost sight of that all crop plants possess sex, and that wide improvement can be effected by breeding, as with animals. After a long lapse of time, Greek and Roman writers like Aristotle, Herodotus, Pliny, and Theophrastus speculated upon the existence of sex in plants, but made no experiments to determine the facts.

Rudolph Jacob Camerarius in 1694 seems to have been the first to demonstrate by actual experimentation that pollen is indispensable to fertilisation. He further sensed the possibilities in the field of hybridisation, as shown by his comments on his experiments. " The difficult question, which is also a new one, is whether a female plant can be fertilised by a male of another kind, the female hemp by the male hops ; the castor bean from which one has removed the staminate flowers, through pollination with the Turkish wheat (maize) ; and whether, and in what degree altered, a seedling will arise therefrom."

Following upon the establishment of the fact that sex occurs in plants, Linnæus, Kölreuter, Knight, and other hybridists made numerous successful crosses and effected improvements in plants. But the real progress that has been made dates from the commencement of this century, when Mendel's paper, originally published in 1866, was rediscovered. The advances since this time have been tremendous and far-reaching. From haphazard efforts, plant breeding has come to be placed upon a sound scientific basis.

Perhaps in no sphere of plant improvement has greater progress been made than in the work of breeding for resistance to disease. That this is so is a fortunate circumstance for primary producers, faced as they are with a growing host of diseases to combat. The increasing introduction to Australia of varieties of crop plants from overseas has been responsible for bringing to these shores many serious diseases. This applies with special emphasis to recent times.

Losses Caused by Plant Disease.

It is perhaps not amiss to remind you that the losses occasioned by plant diseases are often stupendous. The incidence of disease becomes a limiting factor in crop production in many cases. It has been estimated by Dr. R. J. Noble that plant diseases in Australia cause an annual average loss of £12,000,000. Many records of rust losses in cereal crops have recently been published,(58) but one or two of them may be repeated here.

For example, in North America the 1935 losses caused by rust in wheat exceeded £60,000,000. Even greater damage, totalling £75,000,000, had been done in 1916. Russian losses in 1934 from the same cause amounted to £32,500,000. Wheat losses in N.S. Wales from rust in 1916 totalled £2,000,000. From the records available it is clear that the ravages of rust in N.S. Wales have caused losses amounting to an average amount of £250,000 per annum during the past twenty years.

History of Rust Control.

Various attempts to control rust have been made since early times. Biffen(7) has reviewed some of these in a recent address. Of the Greeks, Theophrastus (370-286 B.C.) offers notable remarks upon differences in the susceptibility of different cereals to rust. Amongst the Romans, offerings were made at the festival of Rubigalia to ensure rust-free crops. Pliny recommended the early sowing of grain in order that the crops might escape rust. Even in those days it was recognised that climatic conditions played a part in the occurrence of rust epidemics, and that dew settling on the ears was a very important factor in the causation of rust.

Similar philosophies were current in the 17th century. As Biffen reminds us, Worlidge in 1620 suggested the prevention of the noxious dew by the use of smudge fires, or its early removal by two men dragging a cord stretched between them over the uppermost leaves and ears. At this period also, the possibilities were explored of making the crop obnoxious to the " distemper " by placing in it woollen rags steeped in a solution of salt of tartar, in white wine vinegar, or treated with pepper.

No definite progress was made until a century later. By the middle of the 18th century, farmers had come to recognise that there was some mysterious connection between the barberry and rust epidemics. This led to scattered attempts to eradicate the barberry. It was at this period, also, that there was recognition of the fact that some sorts of wheat were not so seriously affected as were others.

In 1800 an interesting observation was made by Peter Sers in England that spring wheat on his farm was not attacked by rust, although his winter wheat was destroyed. For two decades spring wheats were largely grown, but then they were dropped, probably because of their generally lower yield than winter wheats. Some resistant varieties which were found at this time, e.g. " Little's Anti-mildew ", were still in cultivation in parts of England at the beginning of this century.

The discovery of the value of Bordeaux Mixture as a fungicide towards the end of last century did not help the wheat grower in combating rust, although in recent times other protectants like finely ground sulphur scattered from aeroplanes have proved of real value in controlling the disease.

Early Australian Records of Resistance.

In the history of cropping in Australia there are not wanting references to varietal resistance to rust and other diseases. Taking into account the heavy losses that were sustained, this is hardly surprising. It may be of interest to review a few of the records.

As early as 1807 Governor Bligh wrote in a dispatch[21] dealing with the young colony's crops, " Indian corn is not so liable to the blight and other casualties as attend English grain ".

Following upon records of severe rust losses in the wheat crops, it is stated in the *Sydney Gazette* of 1832,[48] " A new variety which has been introduced by Mr. Cobb has been found to be particularly hardy, and was not affected by smut, although it was grown by the side of Red Lammas, which was much injured by the disease ".

Mackellar in 1865,[31] after calling attention to the fact that indigenous grasses were affected by rust, recorded that so far as wheats were concerned, " Egyptian seven-eared " and "Egyptian bearded" wheats were not subject to rust.

In the same year a report by Baron F. von Müller was quoted by Schomburgk[40] to the commission appointed to inquire into the cause of rust in cereals, in the following terms: "Next in importance is the choice of early-ripening varieties and those armed with the strongest coating of an epidermal siliceous deposit, and which are otherwise distinguished for their hardihood". In the same document appears this further statement: "Tuscan wheat imported from Gumeracka, Sth. Australia, turned out very soft and ruined by rust, whilst in the same fields, the English pedigree, Spaldings, red and rough chaff white wheat, remained perfectly free from disease. This singular fact clearly demonstrates that the occurrence of rust is not dependent on climatic conditions alone, but more likely on the effect and reaction of a variety of causes and circumstances, none of them in themselves, perhaps, sufficient to produce the disease. It would point also to an innate susceptibility of certain varieties to suffer from the devastation of the fungus."

Tepper,[49] in a report published in 1879, says: "At Mount Gambier it was noticed in 1862 that 'creeping wheat', the latest in ripening, was much less affected, if at all, than any other kind".

In Queensland, Tryon[50] in 1889 refers to the rust damage and states that hard wheats enjoy a comparative immunity from the attacks of the fungus. He believed this to be due to the high silica content of these wheats.

To cite one further reference to these earlier days, William James Farrer made outstanding contributions to the discussions on rust control. He affirmed that he had the greatest faith in the world that the solution to the rust problem could be found in the breeding of suitable varieties of wheat. His labours in this sphere later yielded results of the greatest value to Australia as well as to other wheat-growing countries.

The Use of Resistant Varieties.

Whilst certain remedial measures may be applied in many cases to combat parasites attacking plants, the most effective and most economical measure is to utilise varieties of crop plants which are capable of resisting the parasite. The plant breeder can render invaluable service in making these available. It is probably not too much to say that breeding for disease resistance is one of the most attractive fields of work in agriculture. This does not mean that correct cultural practices may be neglected. The use of resistant varieties should be supplementary to them.

The starting point in this work of breeding for resistance was the discovery that when a number of wheats were grown together their responses to rust attack were very different. Many proved to be highly susceptible, some moderately susceptible, and perhaps some resistant. Such a search for resistant sorts is often hindered by the fact that rust epidemics do not occur each year. It sometimes happens that a particular variety may mistakenly gain a reputation for resistance; but with the advent of an epidemic it goes down to rust. Rust nurseries in which "artificial epidemics" are produced have proved to be of the utmost value for testing work. And as will become apparent from later considerations, this work must be done locally.

But much more than mere resistance is required. There are many resistant wheats known, but usually they are not cultivated extensively. In addition to being resistant, a variety must have certain other characteristics which make it desirable commercially. For example, it must yield well and must yield a product that is marketable. It is just in this work of combining resistance with the other desired characteristics that the breeder has to play his part.

The next step in the work of controlling rust was the demonstration that resistance was not merely due to external conditions, but was an inherent property of the plant. In turn, this was followed by the epoch-making investigations of Biffen,[(6)] who was the first to demonstrate the application of Mendelian principles to breeding for resistance. In passing, it is not without interest to recall that a century previously, T. A. Knight, a pioneer in wheat breeding in England, actually suggested this possibility. Again, W. J. Farrer in Australia had been largely following this method. But Biffen, using almost ideal material in wheats subjected to attacks by the yellow stripe rust, established the fact that resistance and susceptibility were inherited in a simple Mendelian fashion. Further he showed that these were inherited independently of other plant characters, and thus it was possible to make combinations of different characteristics in plants, including resistance.

Consequent upon Biffen's work came a fuller realisation of the value of the Mendelian discovery, and intense activity in the development of resistant plants was the result. As Pearl puts it, " The plant breeder has made Mendelism the working tool of his craft ". An indication of the remarkable growth of the subject is shown by the fact cited by Clark[14] that in 1934 there were more than 10,000 publications dealing with plant genetics listed in the U.S.D.A. Library at Washington, D.C.

Contributions to Wealth from Resistant Varieties.

Remarkable contributions towards the control of plant diseases have been made by plant breeders. Coons[17] has recently called attention to some of these achievements. From a careful analysis of results with many crops, he considers that the use of resistant varieties which have been produced in U.S.A. is adding to farm wealth at least 60,000,000 to 70,000,000 dollars a year, and to national wealth a far greater amount.

In the absence of such facilities as are available in U.S.A. for the collection of data of this kind, no such estimate can be made for Australia. But an examination of some of the statistics of the wheat position in N.S. Wales is illuminating. It is only during the past twelve years that figures have been collected relative to the acreage sown with particular varieties of wheat, and hence the available data are rather scanty.

From the official records of the Government Statistician, the following table has been compiled, dealing with some of the best known wheat varieties grown in N.S. Wales.

It should be pointed out that the popularity of a variety depends not upon one thing but upon a number of factors. High productivity is of great importance, but is not the only consideration. Thus in recent years high milling quality has come to be a very needful characteristic in our wheats. Similarly, other features give special values to particular varieties. And it can scarcely be doubted that psychological considerations also enter largely in a number of cases to make a wheat popular.

Now referring to some of the varieties in the table, one can find clear evidence of the effects of successful work in breeding resistant varieties. " Federation " is perhaps the best known production of the late William James Farrer. It marked a wonderful improvement upon the

TABLE 1.

Areas in N.S.W. Sown with Specified Varieties of Wheat.

Varieties.	Season.					
	1925–1926.	1929–1930.	1932–1933.	1934–1935.	1935–1936.	1936–1937.
Baringa	—	—	—	38,400	139,619	287,474
Bencubbin	—	—	—	—	25,870	102,977
Canberra	474,797	236,399	91,263	24,947	19,813	16,099
Dundee	—	—	3,587	111,679	278,078	524,237
Federation	853,430	679,043	184,495	54,672	25,314	14,977
Ford	7	3,095	125,291	513,399	761,018	890,959
Hard Federation	158,027	122,946	49,544	20,631	13,547	10,126
Nabawa	155	203,217	1,619,915	1,135,719	997,317	879,688
Pusa 4	1,804	—	51,890	42,393	47,929	67,712
Turvey	190,094	281,556	168,727	62,927	50,991	37,644
Waratah	122,839	817,138	705,890	360,783	329,461	280,410
Yandilla King	182,410	431,512	433,807	200,790	150,612	103,267

wheats previously available. Only twelve years ago it was by far the most widely grown variety, occupying 30% of the total area sown. Since then it has steadily declined to a point at which the latest record shows that it was sown upon only one-third of one per cent. of the wheat area. This falling-off is largely due to the increasing damage done to "Federation" by diseases. The heavy toll taken from it by *Puccinia graminis Tritici* 34 in recent times is a factor of no inconsiderable importance, and its extreme susceptibility to flag smut and other diseases—with the exception of black chaff—has also made it fall into disfavour.

What has been said about "Federation" can be seen to apply to other varieties listed in the table, e.g. "Canberra" and "Hard Federation".

On the other hand there is striking evidence of the rise to popularity of wheats owing to disease resistance. Thus the Western Australian wheat known as "Nabawa", which was sown on a negligible area in 1925, came in seven years to be sown on 32% of the five million acres carrying wheat, and is still almost the most popular variety, occupying more than 20% of the wheat area. In a large measure "Nabawa" came into favour because of its high resistance to flag smut.

A phenomenal rise in popularity is also shown by the South Australian wheat "Ford". From seven golden acres in 1925, the acreage under "Ford" has rapidly mounted, until in the latest census it is found to be the most widely sown of all our varieties, occupying almost 21% of the total area. Here again disease resistance is partly responsible for the increased popularity. "Ford" is the only commercial variety grown which has any resistance of value to *P. graminis Tritici* 34 under conditions favouring rust development. In cases where other varieties have been ruined, "Ford" has given crops.

These illustrations serve to show the value that is placed upon resistant varieties. Results of the same general nature are to be found in crops other than wheat, and give evidence that the plant breeder has added largely to the wealth of our community. Success can be achieved in this work, and the wonder is that there is not a greater intensification of effort in this direction.

Causes of Disease.

In order to understand what is involved in breeding for resistance, it becomes necessary to enquire into the nature of disease. In general terms we may say that disease in a plant is anything that interferes with its normal functioning and development. Clearly there must be very numerous causes of disease. They include environmental (or non-parasitic) agents as well as living organisms like fungi which come up for our consideration tonight. Hence the scope of investigations is very wide and it becomes evident that " teamwork " is essential. The plant breeder should work in close cooperation with the plant pathologist and the plant physiologist—not to mention workers in other branches of science. Indeed there are probably few fields of research in which a greater need exists for " teamwork " in the investigations.

Taking first the case of a non-parasitic disease, two distinct factors are involved, viz. the host and its environment. Each necessitates full study, and the interactions of the two must be elucidated. Where, however, the disease is caused by a parasite, the problem becomes more complicated, for there are now three variable factors to be considered, viz. the plant, the environment, and the pathogen. And the interactions of these must be studied. It is seen that plant disease problems present features of great complexity. In ordinary breeding work designed to effect a particular improvement in a plant, the problem is usually straightforward. But in breeding for disease resistance the breeder has to consider not only the genetics of the host, but also the genetics of the pathogen, and these in their relations to each other and to their environments.

The Nature of Disease Resistance.

To determine exactly what constitutes resistance to disease is one of the ultimate aims of plant pathological endeavour. Much effort has been expended in work on the problem, but it must be admitted that we are still very much in the dark as to its real nature. A full knowledge would aid the breeder materially in solving his problems of breeding for disease resistance.

I would remind you that resistance to disease in plants is different from that in animals. The animal body with its circulatory systems generally gives a pronounced general reaction to invasion by a parasite. In the plant, on the other hand, a parasite produces a reaction in an individual host cell or small group of cells. With viruses, of course, the position is different. There is therefore probably no scope for the development of a system of serum therapy in plants. Butler[12] has recently examined the position, and concludes that analogies between animal and plant diseases should be confined within the limits of cellular pathology. He considers that no evidence has yet been produced to show that in plants anti-parasitic action takes place at a distance remote from the immediate site of infection.

Turning, then, to disease resistance in plants, at the outset it should be pointed out that confusion sometimes exists between disease escape and disease resistance. From a grower's point of view, ability to escape attack by a pathogen is often of the utmost value. Thus the development by Saunders of " Marquis " wheat largely minimised rust losses in Canada and U.S.A. because this wheat matured more rapidly than other sorts that were in cultivation.

Taking an Australian example, one of Farrer's wheats, " Florence ", which was bred for resistance to bunt, has been listed as being resistant to *P. graminis Tritici* 34. The fact is that if sown at the right time, this wheat matures so rapidly that it often escapes the damage done to slower-maturing varieties. It has, of course, long been known that its resistance to bunt is due to this same capacity to mature rapidly and grow away from the invading bunt fungus within its tissues. But it has to be remembered that if " Florence " be sown out of season, or if the rate of growth be retarded, it is susceptible to these two parasites.

Resistance is different from escape. It means the possession by the plant of some quality or qualities by reason of which it is capable of resisting attack by the pathogen. It will be evident that such a characteristic is much more valuable than disease escape, and is actually what the plant breeder attempts to incorporate in the variety of crop plant he sets out to synthesise.

So far as the non-parasitic diseases are concerned, there are well-known cases of resistance to them. This also applies to certain of the virus diseases. Numerous instances of resistance to parasitic diseases have been established and some of them carefully investigated. It is clear that in those cases where disease is due to organisms which can be cultured *in vitro* (" facultative parasites ") the investigations are simplified. The metabolism of such parasites can be studied on media of known composition, and from these results information may be obtained which bears upon their capacities as parasites. Work with such organisms has yielded results of the highest value. Brown[11] has recently made an able review of the position with regard to them.

In the case of pathogens like cereal rusts (" obligate parasites ") which we cannot at present cultivate on any artificial medium, the difficulties are much greater. The living plant is the only known medium upon which such organisms can be grown, and, since such hosts are themselves subject to great variation, the complexities are increased. At the present time it would seem that before real progress can be made in determining the nature of disease resistance to such pathogens, methods will have to be devised of growing them in artificial media.

As a result of many investigations that have been made, it is now generally considered that there are three main types of resistance shown by plants to rust. These are somewhat arbitrary divisions to make, but a classification on this basis is probably helpful as lessening confusion of thought on the subject.

Morphological Resistance.

Morphological resistance was early postulated by Cobb,[15] who considered that tensile strength of the leaves, ratio of sclerenchyma to chlorenchyma, amount of waxy bloom, number and size of stomata, and number and length of leaf hairs, were all related to resistance. Farrer[19] stated that narrow erect leaves with a thick epidermis were important attributes of rust resistance. Ward[51] from extensive investigations upon morphological characters in *Bromus* spp. in their relation to resistance to *P. dispersa* concluded that no such correlation exists. Hursh[23] found that there are marked differences in the amounts and the distributions of sclerenchymatous and chlorenchymatous tissues in the stems of wheats, and, since the rust mycelium is confined to the latter, these anatomical differences formed the basis of the differences between the resistance and susceptibility shown by such wheats. As Hursh puts it, " Rust development is mechanically delimited within certain tissues of resistant wheats ". It is interesting that Stakman and Aamodt[43] found that fertilisers modified the development of these tissues and thus altered the resistance or susceptibility of the plants to rust.

Quite apart from the effects upon resistance of such anatomical differences in wheat stems, it has been shown that structural variations in the epidermis may be of importance. Thus varieties like " Kota " and " Webster " have a very thick and tough epidermis. This means that the rust pustules have greater difficulty in bursting through the epidermal layer. The incubation period of the rust is therefore lengthened, and in a given time fewer uredospores will be developed.

Functional Resistance.

Apart from morphological resistance, Hart[20] reported that there is functional resistance in some wheats. Since uredospores of rusts gain an entry into their hosts through the stomata, she investigated stomatal movement in relation to rust invasion. She concluded that the early morning habit of delayed opening of the stomata of some wheats, preventing rust entry until the moisture on the plant had evaporated, and the exposure of the delicate germ tubes to desiccation and death, constituted resistance in such wheats. Peterson[38] working with stem rust, and Caldwell and Stone[13] with leaf rust of wheat, consider that stomatal movement is not thus related to resistance. More recently Stakman and Hart[45] have emphasised that this functional resistance, due to stomatal movement, must not be considered as the only factor making for resistance. It does not apply to all varieties, all rusts, and all conditions. In some circumstances, however, it may be of great importance.

Allen[2] considered that the small size of the stomata of some wheats prevented invasion by the rust germ tubes. This would postulate a condition of morphological fixity in the fungus. It is of course well known that in some fungi, e.g. *Synchytrium* spp., naked protoplasm occurs. Brierley[9] recorded an interesting occurrence in *Botrytis cinerea*. The protoplasm was able, under certain conditions and for a period of time, to live and grow when part of its surface was in a free plasmodial state and only subsequently enclosed within a cell wall. He further states[10] that in another investigation, then being prepared for publication, it was found that certain of the hyphæ of *Botrytis cinerea* were in a naked condition, existing as free protoplasmic substance. This same parasite is known to puncture mechanically the cuticle of its host plant[8] by production of a very fine infection peg and thus gain an entry into the tissues. In *P. graminis Tritici* itself it has been shown[53] that invasion of the young barberry shoots is brought about by an extremely delicate infection style which punctures the cuticle; once inside the cells the hyphæ resume their normal size. Unpublished work by the author, dealing with *Ustilago hordei* attacking barley, shows exactly this same feature. In view of such cases in which plasticity of the fungus has been demonstrated, it would seem that there is probably some factor other than mere smallness of stomata which has to do with the failure of germ tubes to enter the stomata in these cases.

Physiological Resistance.

Physiological or protoplasmic resistance is the third type and is definitely established. Marshall Ward[52] studied the relationship between host and parasite and found that, whilst a rust fungus invaded both susceptible and resistant hosts, the mycelium failed to develop in the latter. This work has been fully confirmed and amplified by other investigators. Whilst such cytological observations can be made readily, their exact interpretation presents considerable difficulty. Many explanations of the apparent physiological incompatibility between host and parasite have been given, but it is probable, as has been pointed out already, that a clear understanding of the happenings awaits development of a satisfactory method of cultivating cereal rusts in artificial media.

Starvation of the hyphæ in the uncongenial host by reason of the death of the host cells was postulated early by Marshall Ward. [52] Later there were indications that resistance was independent of nourishment, and that antagonistic relations between host and parasite explained the happenings. On analogy with animal behaviour, it was supposed that toxins were developed. Comes[16] maintained that the acidity of the cell sap was the cause of the resistance, and Hursh produced evidence in support of this view. But Hurd[22] later demonstrated that the differences in resistance could not be related to differences in H ion concentration. Leach[29] suggested that the absence of the specific food requirements of a fungus in a resistant host leads to the death of the hyphæ, with consequent secretion of an enzyme injurious to the host cells. Allen[2] concluded that in some cases the stomata may shut out the majority of germ tubes from the uredospores, in other cases heavy contact walls may be laid down subsequent to fungal invasion and prevent further development, and in yet others true immunity from attack may be shown. Newton *et al*[35] found that eight wheats, differing widely in rust resistance, showed no corresponding differences in the physico-chemical properties of their expressed tissue-fluids. Newton and Anderson[36] demonstrated that phenolic substances, apparently yellow pigments of the flavone type, bear some relation to rust resistance in certain wheats. Later work by Kargopolova[26] showed a higher content of proto-catechuic phenols in resistant than in susceptible wheats. Newton and Brown[37] point out that the young rapidly growing parts of a wheat plant may be very susceptible to rust, while the older non-mature parts are highly resistant. Johnson and Johnson[26] in studies of this phenomenon found that there was no direct relation between sugar content and reaction to rust. Anderson,[3] from studies in the inhibitory effects of extracts of different wheats on growth of a rust fungus, concluded that there was no relation between such effects and rust resistance. Johnson and Johnson[25] demonstrated that the greater susceptibility of the younger tissues cannot be attributed to a higher organic N content. Anderson[4] investigated the chemical composition of wheats differing in their reactions to rust, but found no relation between these results and rust resistance. Dufrénoy[18] considers that the resistance is due not so much to pre-existence of phenolic compounds in healthy plants before attack, as to ability of the host to produce such substances as a result of stimulus of the invading fungus. According to recent work by Sukhorukoff and Ovčarov,[47] resistance to rust in wheats is a direct function of their ammonia content, which, moreover, is an hereditary character of wheat varieties, and is modified by environmental conditions. From work with *P. triticina*, Kargopolova[27] states that pyrocatechuic phenols in wheat, under the action of auto-oxidation and of oxidising enzymes, form persistent tannins, the increasing accumulation of which is considered to be one of the most important factors in resistance. Wei,[59] from studies of resistance of beans to rust, considers that both host and parasite play an active part in the antagonism and the priority of the death of the parasite, or that the host varies from case to case, depending upon the relative production of "toxin" and "antibody", and relative resistance of both the host and the parasite tissues.

Clearly there is difficulty in reconciling these results. There are undoubtedly a number of different phenomena involved, and, as still further work is done, it is probable that even more will come to light. No one simple explanation of resistance can be expected to cover all cases. It is significant that the plant physiologist and biochemist are working on this problem, and it is reasonable to expect results of the utmost value to a knowledge of rust resistance from workers in these fields. Investigations dealing with growth-promoting and growth-inhibiting substances in plants are opening up new fields.

Alterations in Resistance.

Some of the confusion and controversies that have arisen in classifying plants in regard to resistance have been due to failure to realise what a complex property this is in the plant. Omitting for the present all consideration of the extreme importance of specialisation of the pathogen in its bearing on resistance—a subject dealt with later in this address—some other factors may be referred to briefly.

Whilst it is helpful to consider the three types of resistance as separate qualities, it should be remembered that they may occur together in a particular variety, or one or more of them may be only partially shown. Again the degree of development of a type of resistance is subject to external influences. For example, by increasing temperature and light[(55)] it has been shown that physiological resistance may be changed to complete susceptibility in a plant.

It is important to realise that what we call " resistance " may be shown only within a certain range of environmental conditions. For example, if we consider the rust *P. graminis Tritici* 34, a variety like " Federation " is susceptible under practically all conditions. Within a restricted range of conditions, the variety " Ford " is resistant. This range is much wider for " Hope ", but nevertheless limited ; thus when grown out of season it has been rusted with this race. Certain of the Kenya wheats and some of our own crossbreds, on the other hand, have shown such a wide range of resistance that no susceptibility to *P. graminis Tritici* 34 has been exhibited by them to date, even under the most rust-favourable conditions.

A notable case of the effect of environment was recently shown at Hawkesbury Agricultural College, where a large number of wheats were under test. The rows happened to be running in a N.E. to S.W. direction, with the paths at right angles to this. In early October, when rather favourable moisture conditions prevailed but temperatures were a little low for full rust development, an inspection of rows from this S.W. end—where the labels were in position—showed hardly any rust. Looked at from the N.E. (sunny) end, the same rows showed heavy rust infection. Examination of individual stems showed striking rust production on the sunny side and absence of it on the shaded side. Later in the season the rust developed on all sides of the stem.

The 1937 season gave a striking illustration of the effect of climatic conditions upon rust development in coastal areas. October is to be regarded as a critical month in this respect. In this year the temperatures were lower than is often the case, although moisture was abundant in the form of heavy dews as well as rainfall. The attacks of *P. triticina* on wheat, and of *P. graminis Avenæ* and *P. coronata* on oats were so heavy as to completely ruin crops. These rusts are known to have a lower optimum temperature for development than *P. graminis Tritici.* Only when the warmer conditions prevailed did stem rust appear in the wheat crops.

The profound effect that reduction of light intensity in certain circumstances may have on rust development has but recently been realised. And again, the concomitant effects of simultaneous infection of the host by rust and by another pathogen have also been shown to lead to susceptibility being shown by wheats which were otherwise resistant.

The foregoing considerations indicate how difficult it is to make accurate observations on resistance, and how complex is the problem of determining what actually constitutes rust resistance in a plant under present limitations of our knowledge. Each case deserves individual study. There is a real need for fundamental studies to provide exact information on the subject, and only when such information is available will it be safe to generalise.

Studies of Rust Fungi.

In any disease investigation it is a matter of paramount importance to learn the cause of the disease. Fungi are the causal agents of rust. They are very highly specialised organisms having very complex life histories.

Apart from numerous rusts on grasses, the cereal rust fungi known to occur in Australia are the following:

Puccinia graminis Tritici E. and H., causing stem rust of wheat.

P. triticina Eriks., causing leaf rust of wheat.

P. graminis Avenæ E. and H., causing stem rust of oats.

P. coronata Avenæ (Cda.) E. and H., causing leaf rust of oats.

P. graminis Tritici E. and H., causing stem rust of barley.

P. anomala Rostr., causing leaf rust of barley.

P. graminis Tritici E. and H., causing stem rust of rye.

P. dispersa E. and H., causing leaf rust of rye.

It is noteworthy that the yellow stripe rust caused by *P. glumarum* (Schm.) E. and H. and the stem rust of rye, *P. graminis Secalis* E. and H., are not known to occur in Australia. This is but one of many illustrations of the fact that the Australian rust problems demand local study.

In general the stem rusts cause more damage than the leaf rusts, although evidence is accumulating that the latter are much more serious than is often supposed; whilst they do not lead to such obvious pinching of the grain as do stem rusts, they reduce the number of grains set and so diminish productivity.

1. Stem Rust of Wheat.

Stem rust of wheat is the most important of the group and calls for most attention. In Australia it has been shown[55] that it is present in the uredospore stage throughout the year, occurring on "volunteer" wheat plants and grasses in between the wheat-growing seasons. It is with us always.

Apart from this uredospore attack of the wheat host, it must be remembered that, despite oft-expressed statements to the contrary, the Australian rust does attack the barberry. That is to say it goes through its complete life history here at least on some occasions.[57] The grave importance of this lies largely in the fact that new physiological races have been shown to originate on the barberry by hybridisation and segregation.[56]

Physiological Specialisation.

The occurrence of physiological races is a feature of the utmost importance. Physiological specialisation has been known for many years, but its direct bearing upon problems of breeding for disease resistance is sometimes overlooked. Aamodt[1] has aptly said, " To produce new varieties that are not resistant to all the races of the pathogen that are present in the region in which the variety is to be grown is to acquiesce, at least, to only temporary or partial success ". The truth of this has been amply confirmed in Australian experience, as will be described later in this address. Many otherwise inexplicable happenings in the work of breeding for rust resistance become perfectly plain when the facts of specialisation are known.

More recently Stakman[46] has put it this way : " That racial specialisation is important is generally recognised, but how important it is is not universally appreciated. The more the problem is investigated, the stronger becomes the conviction that its importance can scarcely be over-estimated." And again, " The extremists who assert that physiologic specialisation foredooms to failure the breeding of resistant varieties, and those who assume that it is of no consequence, are both likely to impede progress ".

A clear illustration of the far-reaching effects of rust specialisation was given in last year's severe epidemic in U.S.A. Dr. Stakman has recorded that this was unusual, in that it had its origin in Southern Mexico. Barberries are common there, and the unusual races found in U.S.A. in this season doubtless were derived from aecidal infections of these plants. The variety " Ceres ", which had always been resistant prior to 1935, was again so severely damaged that it will probably go right out of cultivation. The susceptibility is due to the prevalence of race 56, which first had been recorded in 1928 as a barberry derivative in U.S.A. (Parenthetically it should be remarked that this is one of the races recorded in Australia in 1929[56] as a direct derivative from a barberry inoculated with race 34, and that to date this race has not been found under natural conditions in Australia. Nevertheless natural infections of barberries here by race 34 may well lead to its occurrence in our crops.) The variety " Thatcher " which has been so widely acclaimed for its rust resistance, performed well and is superseding " Ceres ", but Dr. Stakman states that even " Thatcher " showed definite signs of serious rust damage, despite the absence of race 36, and that a more resistant variety than "Thatcher" must be developed.

Determination of Specialisation.

Specialisation is a phenomenon of wide occurrence in many groups of the fungi. The identification of physiological races can be made by several methods, e.g. by the pathogenicity shown by particular host plants, by cultural characteristics on artificial culture media, by physico-chemical reactions, and by biometrical studies.

Amongst the rusts, specialisation can best be demonstrated by the differences shown in their parasitic capabilities on certain selected host plants. Dr. E. C. Stakman of Minnesota is outstanding amongst workers in this sphere, and has been largely responsible for the developments that have taken place. It would be difficult to overestimate the value of his work.

To take an illustration of specialisation, stem rust occurs on wheat and on oats, but the rust on wheat does not attack oats and *vice versa*. Both attack the barberry, but nevertheless retain their identity when reinoculated on to their gramineous hosts. They may thus be regarded as two distinct sub-species. The first has been named *Puccinia graminis Tritici* and the second *P. graminis Avenæ*. In all, eight sub-species of *P. graminis* have so far been recorded, and it seems certain that an additional one occurs in Australia. Work on this is not quite complete, but it will probably be recorded as *P. graminis Lolii*.

Now, within these sub-species further separations of different groups may be made. This is best done by culturing each rust on seedlings of a selected set of varieties of the particular cereal host—a so-called "differential set". The wheat stem rust differentials selected by Stakman and Levine[42] number twelve, those for oats three, for rye five, and so on. The reactions given by each member of the differential set are recorded. Certain varieties in the set may be resistant to one rust and others susceptible. The tabulation of these results gives a means of identifying that particular rust. It is designated by a number which is written in Arabic numerals after the sub-specific title. Thus *P. graminis Tritici* 34 refers to Physiological Race No. 34 of *Puccinia graminis Tritici*. The differential set has of course been selected empirically. In our work a number of instances have been found in which the addition of yet other varieties to the set makes it possible to separate two otherwise similar races into different entities.

Now a second series of inoculations of the same differential set with another rust may yield the same results. This shows that the same physiological race is concerned. On the other hand, a different reaction on one or more of the differential varieties connotes a different physiological race whose identity in turn is fixed by this means.

Work of this nature, carried out in various countries, has resulted in the identification of about 150 physiological races of wheat stem rust, 10 of oat stem rust and 60 of wheat leaf rust.[44] It is clear that if results of such work are to be comparable, all steps in the procedure must be standardised. There is still much to be done in this direction if world results are to be of real value for comparative purposes. A good deal of evidence points to the fact that some of the races recorded at present as being different are really identical with others whose behaviour has been worked out under different environmental conditions. Purity of the differentials and maintenance of the proper environmental conditions during the development of the rust are prime essentials. But if the methods are standardised, the determination of physiological races can be made quite definite and precise.

A question of great importance is whether these physiological races retain their identity. Much work has been done to determine the point. It has been established that these races are constant entities. Mutation sometimes occurs in them, and there is the record by Roberts[39] of a race of *P. triticina* which appears to be unstable. But this is exceptional.

Specialisation in Relation to Breeding for Resistance.

It has sometimes been stated that determinations of physiological races in this way do not help the plant breeder who has to do with rust resistance in mature plants. The field is, of course, the final court of appeal in relation to disease resistance as well as to other crop characteristics. But it is clear that it would be extremely difficult to devise practicable methods for the accurate determination of physiological specialisation in the field. Apart from the time and space that would be required for growing the plants to maturity, the difficulties in the way of obtaining full control of the conditions for making the tests would seem to be insuperable.

Whatever method of determination is used, the fact is beyond dispute that the stem rust fungus of wheat is a complex of a number of entities. In breeding, or in any other work connected with a pathogen, it is essential to know just what entity is being dealt with. The accepted determination method—using seedlings—allows a worker to identify his organism, and if his work be breeding for resistance, then he knows to what organisms his plant is resistant. By reason of the fact that changes are known to take place from time to time in the physiological races present in a given region, it is imperative to know the extent of the resistance he has obtained.

There are many instances in which it has been reported that the resistance of a particular variety " broke down " in an altered environment. These are generally cases in which the real happening was that a different physiological race of the pathogen was present in the new environment, and the variety which was resistant to the first race was susceptible to this second one. The change was in the pathogen, not in the host, and was not due to environmental influences.

Again, if the race or races present in the area are known, breeding for resistance may be facilitated. Thus in the work in progress, stem rust of wheat generally is severe at Hawkesbury Agricultural College, although it may be slight in the wheat belt. At present when race 34 is the rust present in Australia, selections made for resistance at H.A. College will prove similarly resistant in the wheat belt. It is probably due to the fact that this race has been ubiquitous in Australia for such a number of seasons that a tendency has been shown in some quarters to decry specialisation studies.

For yet another reason these surveys of the races present are important. Where the resistance of the varieties to particular races is known, workers in other countries where these same races occur may call upon such varieties at once to contribute the resistance that they require.

There are, of course, many cases in which there is complete correlation between the results obtained from a study of seedling reactions and those observed in the field. For example, residues of material are still on hand of wheat differentials grown at H.A. College in 1924, i.e. prior to the advent of *P. gr. Tritici* 34. Races like 43 and 45 were those actually shown to be present in that area at the time. Straw of the varieties " Kanred " and " Kota " is clean and quite free from rust attack, whilst that of "Einkorn" is black with rust. In those days it was only with the utmost difficulty that sufficient grain could be obtained from the latter wheat in order to retain it in the differential set. At the present time, owing to the presence of race 34, the difficulty is to get grain from the now heavily rusted "Kanred" and "Kota"; on the other hand "Einkorn" ripens perfectly free of rust. This is in complete agreement with the seedling behaviour of these wheats.

Again, in the years prior to the occurrence of race 34 in Australia, it was usual at an area like the Cowra Experiment Farm to find on varieties like "Canberra" and "Thew" mature leaves bearing a mixture of susceptible pustules and flecks. Cultures from these varieties, subjected to the ordinary determination treatment, revealed the presence of races like 43 and 45, and these in turn on seedlings of the original host plants showed complete agreement with the field reactions.

There have been repeated examples of this same correlation in the case of varieties of oats showing differential resistance to *P. graminis Avenæ*. Thus certain oat varieties in the field at maturing stages have frequently shown both susceptible and resistant pustules of stem rust on the same leaves. Cultures derived from these two types of pustule, when used to inoculate seedlings of the original varieties, produce the expected susceptible and resistant reactions. Again, a rusted plant of "Richland" oats collected at Cowra in 1936 yielded cultures of *P. graminis Avenæ* 8. This race is characterised by the susceptible seedling reaction on "Richland" oats.

Levine and Smith[30] in a recent important paper report the results of extensive investigations dealing with the possible correlations between seedling and mature plant reactions. Using all ten known races of *P. graminis Avenæ* to inoculate a number of oat varieties, they found that in no case was a variety resistant or susceptible as a seedling or adult plant without a corresponding reaction in the other phase tested. They conclude that seedling reaction is a reliable index of reaction of adult plants to specific physiological races of oat stem rust.

Studies dealing with the leaf rusts of wheat, oats, and barley have given similar results.

Küderling[28] with *P. glumarum Tritici*, Murphy[34] working with *P. coronata* and Asuyama[5] with *P. triticina*, have recorded similar concordance between seedling reaction in the plant-house and field behaviour of the nature plant. Myers[33] in recent work with rust of flax showed that the same gene conditions immunity in the field and glasshouse.

The general interpretation would seem to be that this type of resistance is protoplasmic. Cells of such plants at all stages of development possess the desired quality of resistance.

In contrast with such cases there are others in which there is not the same clear correlation between seedling and mature plant reactions. So far back as 1914, Stakman[41] called attention to the strong susceptibility of Iumillo and Einkorn wheats, in the seedling stage, to certain races of stem rust, and their extreme resistance in the mature stage in the field. Other workers have since observed cases in which there is also lack of correlation between seedling and mature plant reactions. Such have come to light in our own work. Thus the differential variety "Acme" gives a susceptible seedling reaction to race 34 under some conditions in the plant house, whilst it is resistant as a mature plant in the field. Other varieties behave in a similar way. It should be pointed out that such varieties usually show chlorotic—and often nerotic—areas around pustules on seedling leaves under certain plant house conditions. At least in part this difference between seedling and mature plant behaviour is to be explained on the basis of the development in the mature plant of structural (or morphological) resistance, a type of resistance which obviously cannot be present in a seedling.

Physiological Races Present in Australia and New Zealand.

Adopting the generally accepted methods of determining specialisation, nine races of wheat stem rust have been found in the investigations of Australian and New Zealand material which commenced in 1921 and are still in progress. Their identities are set out in Table 2.

It has been pointed out before and is again emphasised that one group of three races, viz. 43, 44 and 54 show many similarities, and a second group comprising races 45, 46 and 55 are also similar. Both groups differ greatly from each other and from the other races 11, 34 and 59.

For purposes of comparison the relative frequencies with which these races have occurred are shown in Table 3, together with their origin. They do not include a large number of determinations of material received from New Zealand in 1935, which are to be reported upon separately.

The distribution of these races over the period of years that has elapsed since the inception of the work is shown in Table 4.

The change in the rust flora commencing in the 1926 season is a striking feature in these determinations. It is interesting to notice that, in general, happenings in Australia and New Zealand are parallel. In view of the usual W. to E. air movement and such an observation as the deposition of dust from Australia upon snow of the Southern Alps of New Zealand, it is to be expected that transport of uredospores may also take place across the Tasman Sea.

Such a change is, of course, not unique. Where continuous determination work has been in progress over a period of years in other countries, similar changes in the races present have been recorded. It is just such a change in the causal organism which complicates the work of breeding for disease resistance and makes necessary the continuous determinations of the races that are present in the locality concerned.

The origin of the race 34 in this case is difficult to explain. In other cases where barberries are regularly infected, the appearance of new races can readily be accounted for. The occurrence of race 11 in New South Wales in the 1935 season has been fully accounted for on this basis, since natural infections of barberries with race 34 had been found in 1933, and race 34 is known to be heterozygous and to produce race 11 as one of its segregates. But the appearance of race 34 in 1926 cannot be satisfactorily explained at the present time.

That it has had a profound influence upon our rust problem cannot be doubted. Apart from extended host range, in cultural studies under controlled conditions it is very striking to find how very rapidly new uredosori of race 34 are produced in comparison with the time taken for such races as 43 and 45. Field evidence indicates that rust damage in varieties which formerly were not severely attacked has become severe in recent times.

TABLE 2.

Typical Reactions of the naturally-occurring Physiological Races of Puccinia graminis Tritici *in Australia and New Zealand.*

Physiological Race.	Little Club C.I. 4066.	Marquis C.I. 3641.	Kanred C.I. 5146.	Kota. C.I. 5278.	Ar-nautka C.I. 4072.	Mindum C.I. 5296.	Spel-mars C.I. 6236.	Ku-banka C.I. 2094.	Acme C.I. 5284.	Ein-korn C.I. 2433.	Vernal Emmer C.I. 3686.	Khapli C.I. 4013.
	Type of Reaction on Differential Wheat Variety.											
11	4	4	3++	3++	4	4	4	3++	3++	3	0;	1=
34	4	4	3++	3++	4	4	4	3++	3++	1=	0;	1=
43	4	3++	0	0;	0;	0;	0;	×	1	3	1	0;
44	4	3++	0	0;	0;	0;	0;	3+	3+	3	1	0;
45	4	2	0	2−	4	4	4	×	×	3	3	1
46	4	3++	0	2−	4	4	4	1	1	3	3	1
54	4	3++	0	0;	0;	0;	0;	1	3	3	1	0;
55	4	4	0	2−	4	4	4	×	×	3	3	1
59	4	2	0	0	1	1	1	×	3	3	1	0

TABLE 3.

Summary of the Number of Isolations of Physiological Races of P. graminis Tritici *grouped according to their Origin.*

Physiological Race.	Origin of Material. A.C.T.	N.S.W.	Vict.	Qland.	S. Aust.	W. Aust.	Tas.	N.Z.	Totals.
11	2	14	—	—	—	—	—	1	17
34	63	1,381	118	88	105	49	32	67	1,903
43	—	130	7	17	3	2	1	—	160
44	—	39	—	4	2	—	1	—	46
45	1	33	3	—	7	—	2	3	49
46	—	43	4	3	1	—	9	2	62
54	—	4	—	—	1	—	—	—	5
55	—	9	—	1	—	—	—	—	10
59	—	—	—	1	—	—	—	—	1
Totals . .	66	1,653	132	114	119	51	45	73	2,253

TABLE 4.

Summary of the Number of Isolations of the naturally-occurring Physiological Races of P. graminis Tritici *in Australia and New Zealand in the various years.*

Physiological Race.	Season of Isolation ending 31st March of the year stated.																	Totals.
	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938*	
11	—	—	—	—	—	—	—	—	—	—	—	—	—	3	5	2	7	17
34	—	—	—	—	4	18	152	156	90	181	139	143	93	220	189	304	214	1,903
43	20	10	10	55	15	14	21	—	—	—	10	1	—	4	—	—	—	160
44	2	4	—	1	3	30	6	—	—	—	—	—	—	—	—	—	—	46
45	3	—	—	15	5	17	5	—	—	—	—	—	—	—	4	—	—	49
46	14	—	15	24	1	6	2	—	—	—	—	—	—	—	—	—	—	62
54	—	1	—	—	—	3	1	—	—	—	—	—	—	—	—	—	—	5
55	2	—	—	5	—	1	2	—	—	—	—	—	—	—	—	—	—	10
59	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	1
Totals	41	15	25	100	28	89	189	156	90	181	149	144	93	227	199	306	221	2,253

* The record for 1938 extends only to 1st January.

Varietal Resistance to Known Physiological Races.

In the early stages of the work when only these six races were known, extensive varietal tests were made with them. It is of value to set out these results which were obtained while these particular races were present in our crops.

This shows that the varieties tested fall into fourteen groups. The groups are set out in order depending upon the reactions exhibited by the varieties to the six races of rust. The latter are not arranged in their numerical sequence. It has been pointed out previously that there are affinities between races 43, 44, and 54 and also between races 45, 46, and 55, as determined by their behaviour on the differentials, so this arrangement of the races has been adopted here. This arrangement is further justified by the groupings set out below.

Group 1.

Varieties susceptible to all six races, giving the following results :

Race ..	43	44	54	45	46	55
Reaction	S.	S.	S.	S.	S.	S.

A 88, Akagomughi, Alaska Branched, Allies, Alpha, American Club, American 8, Autel White, Bald Knob, Baldry, Bandon, Barooga, Baroota Wonder, Bathurst 7, Bathurst 9, Bathurst 10, Bayah, Bearded Gluyas, Biffen's 60/29, Billy Hughes, Black Beardless Emmer, Black Winter Emmer, Blue Wave, Boonoo, Booran, Braemar Velvet, Cadia, Cairo 1, Cairo 2, Californian Club, Canimbla, Carinda, Cawnpur 13, Ceres, Chilian, Chinese White, Club E.A.S., Clubhead, College Purple, Comara, Comeback, Coreen, Correll's 8, Cowra 28, Cowra 31, Cowra 36, Cowra 39, Cowra 42, Cuballing, Cunana, Currawa, Dart's Imperial, Dauno III, Defiance, Early Defiance, Einkorn, Emperor, Etawah, Farmer's Friend, Federation, Fenman, Forelock, From Texas 3015-106, Fulcaster, Fultz, Gallipoli, Géant de Milanais, Glen Innes 2, Golden Drop, Gresley, Gwalior C 14, Hard Federation, Hatif Inversable, Hoof's Imperial, Hudson's Early Purple Straw, Hurst's 9, Improved Steinwedel, Indian 12, Indian 24, Indian F, Indian F× Telford's, Indian Dwarf Beardless, Indian Dwarf Semi-bearded, Indian Dwarf C.I. 4534, Indiana Swamp, Japanese 108, Japan Bearded, Japan Bearded U.S.A., John Brown, Jonathan, Jones' Fife, King's Early, King's Red, King's White, Little Club, Little Joss, Lott's White, Lotz, Mac's

White, Maharajah, Majestic, Major, Mammoth Amber, Martin Amber, Masolino, Mesopotamia T 45, Mesopotamia T 54, Minister, Nandero, Nangeenan, Narrogin, Narrogin 8, Newman's Early, Niloc, Nungarin, No. 6, No. 24, No. 76, No. 137, Ojirua, Onas, Peace Hybrid, Penny, Polish (England), Polish (U.S.A.), Polish (Short Glumes), Poole, Punjab 8 A, Punjab 11, Pusa 4, Pusa 6, Pusa 107, Quality, Radilla, Rajah, Rattling Jack, Red May, Red Rock, Red Wave, Red Wing, Ruby, Russian C.I. 4453, Russian C.I. 4454, Russian C.I. 4455, Russian C.I. 4456, Russian C.I. 4457, Russian C.I. 4459, Russian C.I. 4460, Russian C.I. 4462, Russian C.I. 4463, Russian C.I. 4464, Russian C.I. 4465, Rymer, Salt Wheat, Sands, Sanger's Prolific, Solid Straw Tuscan, Sonora, Spelt C.I. 3039, Stanley Brown, Stanley White, Steinwedel, Sun × Dawson, Sunset, Synthetic Wild, Talgai, Tregorco Mendel, *Triticum orientale ensigne*, True Wild, Turvey, Union, Union 17, Union 28, Vac, Wallace, Waratah, Warden, White Federation, White Fife, White Odessa, White Tuscan, Wickepin, Wilfred, Wilhelmina, Yandilla, Yeoman C., Zaff, Zealand, Zealand Blue.

Group 2.

Varieties resistant to three and susceptible to three races as follows:

Race ..	43	44	54	45	46	55
Reaction	R.	R.	R.	S.	S.	S.

Anvil, Barletta, Bena, Booral, Bunge, Cad, Cadet, Canberra, Caliph, College Eclipse, Cowra 40, Cowra 41, Droophead, Duri, Early Bird, Early May, Early Purple Straw, Early Red Chief, Ensign, Equator, Exquisite, Farrer's Durum, Forge, Fortune, Gluyas, Graham, Gullen, Hamell, Hurst's 3, Indian F. × Federation, Italy × Bobs, Italian Spring C 4413, Marshall's No. 3, Pinet, Power's Fife, President, Prize-taker, Purple Straw, Riverina, Roseworthy, Russian C 4461, Silver Baart, Spelt Black Bearded, Spelt White Beardless, Stanley × Yandilla King, Sultan, Theiss, Triumph, Warrah, Yandilla King.

Group 3.

Varieties resistant to three and susceptible to three races as follows:

Race ..	43	44	54	45	46	55
Reaction	S.	S.	S.	R.	R.	R.

Basil, Binya, Bobs, Bobs × Federation, Bonus, Dindiloa, Hornblende, Nevertire, Pusa 31, Pusa 45, Red Bobs, Thew.

Group 4.

Varieties resistant to only one of the six races as follows :

Race ..	43	44	54	45	46	55
Reaction	S.	S.	S.	R.	S.	S.

Bomen, Cedar, Fane, Firbank, Florence, Ford, Geeralying, Haynes' Blue Stem, Haywood's, Hornbill, Kitchener, Narrogin 9, No. 1, Nyngan 3, Plowman's No. 2, Plowman's No. 3, Polish E.A.S., Quantity, Red Fife, Redit, S.H.J., Wagga 13.

Group 5.

Varieties resistant to only one of the six races as follows :

Race ..	43	44	54	45	46	55
Reaction	R.	S.	S.	S.	S.	S.

Cargo, Cleveland, Cudgen, Red Russian, Yuna.

Group 6.

Varieties resistant to two of the six races as follows :

Race ..	43	44	54	45	46	55
Reaction	S.	S.	S.	R.	R.	S.

Bathurst, Blount's Lambrigg, Bobin, Bunyip, Carrabin, Cowra 38, Eden.

Group 7.

Varieties resistant to two of the six races as follows :

Race ..	43	44	54	45	46	55
Reaction	S.	S.	S.	R.	S.	R.

Cowra 29, Hurst's 11.

Group 8.

Variety resistant to two of the six races as follows :

Race ..	43	44	54	45	46	55
Reaction	R.	S.	S.	S.	R.	S.

Felix.

Group 9.

Variety resistant to three of the six races as follows :

Race ..	43	44	54	45	46	55
Reaction	R.	R.	S.	S.	R.	S.

Imperial Amber.

Group 10.

Varieties resistant to four of the six races as follows :

Race ..	43	44	54	45	46	55
Reaction	R.	R.	R.	R.	S.	S.

Aussie, Cowra 30, Queen Fan, Union 66.

Group 11.

Varieties resistant to four of the six races as follows :

Race ..	43	44	54	45	46	55
Reaction	R.	R.	R.	S.	R.	S.

Italian Spring C 4411, Wandilla.

Group 12.

Variety resistant to four of the six races as follows :

Race ..	43	44	54	45	46	55
Reaction	R.	S.	S.	R.	R.	R.

Turkey Red.

Group 13.

Varieties resistant to five of the six races as follows :

Race ..	43	44	54	45	46	55
Reaction	R.	R.	R.	R.	R.	S.

Canaan, Nabawa.

Group 14.

Varieties resistant to all six races as follows :

Race ..	43	44	54	45	46	55
Reaction	R.	R.	R.	R.	R.	R.

Abyssinian, Alberta Red, Barwang, Clarendon, Emma, Euston, Galgalos, Galgalos E.A.S., Gaza, Kanred, Kota, Kharkov, Maem, Mentana, P 762, P 1066, P 1068, Persian Black, Preston, Rieti, Warren.

By far the greatest number of varieties fall into the first group characterised by susceptibility to all six races. Then there are two large groups in which the behaviour to races 43, 44, and 54 is similar, as it is also to races 45, 46, and 55. These in turn are followed by groups of varieties with resistance to one or more of the races, ending with the group in which resistance is shown to all six races.

Such a method of grouping serves to show what the opportunities are of combining desired resistances by crossing. At the same time it indicates that a number of varieties other than those of the accepted differential set may be used in the determination of the rust races concerned.

When race 34 appeared, the same varieties were tested with it in a search for resistance to this rust.

Of them, the only ones to show resistance were the following:
Abyssinian, Alberta Red, Einkorn (two strains), Emma, Gaza, Italian Spring C 4413, Maem, Persian Black, Pinet, Russian C 4458, Spelt Black Bearded, Trigo Africano.

Several hundred other varieties have been tested subsequently with race 34. The resistant ones were the following:
Abou Fashi, Acme, *Ægilotrichum triuncialis durum*, Africano, Akathistiko, Akrona (2 strains), Aleppo, Alicante 4, Aziziah, Bansi × Khapli 568 (3 strains), Beladi (9 strains), Bianrollo, Covèlle, Crete 9, Cyprus (4 strains), Damascus (3 strains), Doubbi, Duro 34, D.5, Egypt (23 strains), Fedweb (several strains), Greece (8 strains), Greek 10, Haurani, Heiti, Hofed (many strains), Hope, Hope × Marquis × Yaroslav, H44-24 × Marquis, Iraq 11, Italian durum C 3430, Italian Spring, Iumillo, Joppa, Joppa Stranger, Kambouriko, Kawvale, Kenya Crossbred (20 strains), Khapli (3 strains), Margerito, Mahon de Teumara, Malakoff, Marouani, Marquis × Emmer, Marquis × Emmer Beardless, Marquis × Kanred × Marquillo, Marquis × Vernal Emma 20 (6 strains), Marquillo (2 strains), Mindum, Morocco (4 strains), Nodak (2 strains), Navarre 18, Pacific, Palestine (4 strains), Palestine durum 2650, Pentad × Marquis (5 strains), Persian Black, Pinet, Poona (6 strains), Portugal (14 strains), Russian (9 strains), Russian hordeiforme (2 strains), Salonica 17, Seville 19, Sinai (4 strains), Solid Straw durum, *T. Timopheevi* (2 strains), *T. durum leucomelon*, Vernal Emmer × Iumillo (2 strains), Vernal Emmer × Marquis × No. 138 (2 strains), Webfed 1/1, Webster (4 strains).

It is notable that amongst the latter, very few are vulgare wheats. The group of vulgares obtained from Kenya by the N.S. Wales Department of Agriculture are the most valuable of them. In the absence of precise information regarding the pedigrees of these wheats, Macindoe[32] has suggested that durum wheats have been used in their breeding. There are many durums in the list which are fully resistant to race 34. Breeding work with some of these has shown that the transference of their resistance to vulgare types does not present any real difficulty.

Of the varieties resistant to race 34, none has any commercial value under rust epidemic conditions in Australia. But they give the needed starting point in the breeding of useful types for our conditions.

It is interesting to compare the rust situation as shown by the occurrence of the nine races recorded in Australia with that revealed by determinations of rusts present in Britain. This work has involved the use of teleutospores sent by Dr. Alan Smith, Mr. W. Buddin and others from British areas. In no case have uredospores survived the journey from England. Inoculations of barberries have yielded æcidial cultures which have been multiplied in the uredospore stage and then used in the determination work. It is obvious that some of the races thus determined may be segregates of other uredospore races which are themselves heterozygous. Nevertheless the British rusts are seen to be totally different from ours.

From work extending over several seasons, the following races have been determined, viz. 23, 24, 27, 33, 35, 51, 53, 69, 83, 109, 117, and 122. In addition, at least 4 other races which are not recorded in the latest list(44) have been determined.

Again, it may be pointed out that whereas *P. graminis Secalis* has not yet been found in Australia, æcidial cultures derived from teleutospores on *Agropyron repens* sent by Dr. Alan Smith from Rothamsted, England, showed that this rust was the cause of the attack. As determined on the usual differential varieties, it was race 3. But when inoculated on to rye plants which had been continuously inbred for eight generations in another investigation that is in progress, both " 4 " and " 1 " pustules were produced side by side on the same leaves of certain of the plants. Obviously two races were present on this basis, although each would normally be recorded as *P. graminis Secalis* 3.

In all the many determinations of the stem rust attacking rye collected in the various Australian States, *P. graminis Tritici* of one of the known races has been present. Our rye rust problem is clearly quite different from that in England.

2. Leaf Rust of Wheat.

For many years it has been emphasised that leaf rusts do much more damage than is generally realised.(54) Investigations have been in progress for some time dealing with the causal organism, *P. triticina*. In the specialisation studies in Australia, two races have been found. As pointed out elsewhere(55) they are not separable on the usually accepted set of differential varieties, but by using the variety " Thew " (a number of other Australian varieties serve the same purpose) the two races may be sharply differentiated. On this basis they are designated races 16 and 26 by Stakman[44] in his series of 58 races. They have been called "Aust. 1" and "Aust. 2" respectively in previous writings.

The determinations of the races present were commenced in 1926, and the results obtained since then are summarised in the following tables, the first showing their distribution in time and the second their distribution in space.

It will be seen that the two races are widespread in both senses. There has been a good deal of evidence to indicate that race 16 occurs more frequently in the early part of the rust season than does race 26. From New Zealand material the same two races have been determined many times, but in addition to them, several other races have been found.

It is clear that any control programme must take both races into account. As was done in the case of stem rust, more than 600 varieties of wheat were tested with them. The results showed that by far the greatest number of wheats are susceptible to both races. Those resistant are arranged in groups as under, in which it will be seen that a number of varieties are resistant to race 16 only, only one to race 26 alone, and a number to both the races. Amongst the last-named, vulgare wheats are rare.

Group 1.

Resistant to *P. triticina* 16.

Alberta Red, Basil, Bonus, Damascus (3 strains), Egypt 44, Euston, Fulcaster, Fedweb (several strains), H44-24 × Marquis (2 strains), Hofed (several strains), Japanese Bearded, Joppa Stranger, Kenya Crossbred C 6041, Leon 4, Malta 4, Palestine 3, Pentad × Marquis C 5981, Persian Black (2 strains), Poona 808, Portugal (2 strains). Russian 60, Stanley Brown, Stanley × Yandilla King, Thew, Webster (4 strains).

Group 2.

Resistant to *P. triticina* 26.

Early May.

Group 3.

Resistant to *P. triticina* 16 and 26.

Africano, Aleppo 4, Alicante (2 strains), Aziziah, Beladi (8 strains), Chinese White (2 strains), Cyprus (2

TABLE 5.

Summary of the Number of Isolations of the Physiological Races of P. triticina *from Australia and New Zealand in the Various Years.*

Physiological Race.	Season of Isolation, ending 31st March of the year stated.												Totals.
	1927.	1928.	1929.	1930.	1931.	1932.	1933.	1934.	1935.	1936.	1937.	1938.*	
16	3	52	60	20	35	63	58	54	107	87	75	41	655
26	3	70	71	20	34	50	56	45	80	63	54	19	565
Totals ..	6	122	131	40	69	113	114	99	187	150	129	60	1,220

* The record for 1938 extends only up to 1st January.

TABLE 6.

Summary of the Number of Isolations of the Two Australian Physiological Races of P. triticina *according to their Origin.*

Physiological Race.	Origin of Material.								Totals.
	A.C.T.	N.S.W.	Vict.	Qland.	S. Aust.	W. Aust.	Tas.	N.Z.	
16	22	513	33	24	37	9	2	15	655
26	11	460	25	15	38	5	1	10	565
Totals ..	33	973	58	39	75	14	3	25	1,220

strains), Damascus, Democrat (2 strains), Egypt (5 strains), Einkorn (2 strains), Gaza, H44-24 × Marquis (5 strains), Hope, Hofed (several strains), Italian Spring, Iumillo, Joppa, Kawvale (2 strains), Malakoff (2 strains), Mediterranean, Norka, Pentad × Marquis, Pinet (2 strains), Portugal (3 strains), Red May, Russian C 4461, Salonica 17, Salt Wheat, Spelt White Beardless, T. Timopheevi (2 strains), Tunis 24, Valencia 1.

3. Stem Rust of Oats.

Of the ten races of *P. graminis Avenæ* that are known,[44] six have been found in Australia. Their identities are set out in the table which follows. It has been pointed out elsewhere that certain of the host reactions are subject to considerable fluctuation, particularly with changing temperatures. For example, without adequate temperature control it becomes impossible to separate races 1 and 2, and also races 3 and 7. Hence these two pairs of races are grouped in later tables.

Table 7.

Typical Reactions of the Naturally-occurring Physiological Races of P. graminis Avenæ *in Australia.*

Physiological Race.	Type of Reaction on Oat Variety.		
	White Tartar.	Richland.	Joanette.
1	2	2 –	1
2	2	2 –	3 +
3	4	2	1
6	4	4	3 +
7	4	2 –	3 +
8	2	4	3 +

The distribution of these races is shown in the following tables in regard to both time and space.

It is clear that the complex of races 1 and/or 2 is the most widespread. A striking feature relating to races 3 and/or 7 is that in general they do not show up early in the rust season. They characteristically attack the " side " oats, and most of these are late-maturing types. There

TABLE 8.

Summary of the Number of Isolations of the Physiological Races of P. graminis Avenæ *from Australia and New Zealand in the various years.*

Physiological Race.	Season of Isolation, ending 31st March of the year stated.														Totals.
	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938*	
1 and/or 2	30	3	21	38	39	38	62	54	48	34	72	66	55	38	598
6	—	—	—	2	6	—	—	—	—	—	—	—	—	—	8
3 and/or 7	—	—	—	7	4	2	13	5	6	5	5	8	9	25	89
8	—	—	—	—	—	—	—	—	—	—	—	—	1	1	2
Totals	30	3	21	47	49	40	75	59	54	39	77	74	65	64	697

* The record for 1938 extends only to 1st January.

TABLE 9.

Summary of the Number of Isolations of Physiological Races of P. graminis Avenæ *grouped according to their Origin.*

Physiological Race.	Origin of Material.								Totals.
	A.C.T.	N.S.W.	Vict.	Qland.	S. Aust.	W. Aust.	Tas.	N.Z.	
1 and/or 2	17	470	24	32	31	8	8	8	598
6	—	6	2	—	—	—	—	—	8
3 and/or 7	3	73	4	2	—	—	6	1	89
8	—	2	—	—	—	—	—	—	2
Totals ..	20	551	30	34	31	8	14	9	697

would seem to be an interesting connection here between the rust and the developmental phases in these oats. The other two races, viz. 6 and 8, have occurred but rarely. It is of interest to note that the latter has quite recently been found as one of the several races obtained from æcidia on a barberry produced by inoculating it with viable teleutospores on oat straw sent from England. This culture has a characteristic, noted in certain other British races, of producing teleutospores on seedling leaves very soon after the initial inoculation.

The behaviour of numerous varieties of oats when inoculated with particular races has been determined. In this work race 6 was lost before the varietal tests were completed, and this incomplete set of reactions has therefore not been incorporated in these records. The results are summarised by grouping the varieties according to their reactions to the several races.

Group 1.

Varieties susceptible to all 5 races, giving reactions as follows :

Race	1	2	3	7	8
Reaction ..	S.	S.	S.	S.	S.

Abundance, Algerian, Algerian Tartar, *Avena barbata*, *A. brevis* (two strains), *A. byzantina*, *A. fatua suburnifolia*, *A. nudibrevis*, *A. sterilis Ludoviciana*, *A. sterilis polystachya*, *A. strigosa*, *A. strigosa glabrescens*, *A. strigosa orcadensis*, *A. strigosa pilosa*, *A. Wiestii*, Banner, Belar, Black Danish, Black Mesdag, Black Tartar 3552, Buddah, Budgery, Burt's Early, Calcutta, Chinese Skinless, Custes, Dun, Fergusson Navarro, Forward, Fulghum (six strains), Gidgee, Glen Innes No. 1, Guyra, Haver III, Kanota (two strains), Kelsall's, Kherson, Kurri, Lachlan, Lee, Ligowa, Lubra, Lubra Selection, Markton (two strains), Mulga, Myall, Nortex, No. 8, No. 15, No. 33, No. 35, No. 61, O.A.C. 3, Palestine, Quandong, Red Rust Proof (three strains), Red Rust Proof × Scotch Potato, Ruakura, Scotch Grey, South African Skinless, Stakman's Oats, Stark's Hooimaker, Sunrise, Trisperma Cu 110-2, Victoria, Victory, Warrigal, White Giant, Wilga, Yarran.

Group 2.

Variety resistant to 1 of the 5 races as follows :

Race	1	2	3	7	8
Reaction ..	S.	S.	S.	S.	R.

Bimbi.

Group 3.

Variety resistant (at low temperatures) to 3 of the 5 races as follows:

Race ..	.. 1	2	3	7	8
Reaction	.. R.	S.	R.	S.	R.

Joanette.

Group 4.

Varieties resistant to 3 of the 5 races as follows:

Race ..	.. 1	2	3	7	8
Reaction	.. R.	R.	S.	S.	R.

Advocate, Abr. × Victory × Reid's (two strains), Barker's Tartarian, Birdwood, Bradley (two strains), Burdett, Green Mountain, Iogold (one strain), Lampton, Minn. II, 22-70, Minn. II, 22-132, Minn. II, 22-177, Minn. II, 22-178, Minn. II, 22-183, Minn. II, 22-219, Reid's, Sun × Reid's (two strains), Weston, White Russian, White Tartar (two strains).

Group 5.

Varieties resistant to 4 of the 5 races as follows:

Race ..	.. 1	2	3	7	8
Reaction	.. R.	R.	R.	R.	S.

Minn. II 22-177 (one strain), Black Tartarian.

Group 6.

Varieties resistant to 4 of the 5 races as follows:

Race ..	.. 1	2	3	7	8
Reaction	.. R.	R.	R.	R.	S.

Burke (two strains), Early Kherson, Iogold (one strain), Laggan, Richland.

4. Leaf Rust of Oats.

In our coastal areas particularly, this rust does much damage. Last season gave a striking example of devastation of oats by *P. coronata*, as well as by *P. graminis Avenæ*.

Over a period of years it has been noticed that a particular leaf of an oat plant in the field may show both susceptible and resistant pustules of leaf rust on it. This has been frequent in our Sydney University experimental plot. Only in recent years has the accepted set of differential varieties been available, but already five races of the rust have been sorted out. It has been found that the host reactions are very liable to vary with fluctuations in the temperature at which the plants are maintained. Nevertheless races can be identified with certainty under standardised conditions. Those determined are as follows: 3, 6, 7, 40, 47.

It is not considered fair at this stage of the work to tabulate the distributions of the races. When more determinations in time and in space have been carried out, this will be done.

Many varieties have been tested, but the work is incomplete and no attempt is made at this juncture to group them. Suffice to say that a few are resistant to all the races. These include three strains of oats belonging to *Avena strigosa*, and therefore of little value in a crossing programme, together with the varieties "Victoria", "Bond", and "Klein 69B". These, of course, give a definite starting point in the breeding of resistant varieties suitable for our conditions.

5. Leaf Rust of Barley.

In addition to stem rust, caused by races of *P. graminis Tritici*, the leaf rust causal organism, *P. anomala*, has been isolated from many sources. With one exception, these isolates have not shown any differences in the tests that have been possible. The differential varieties used by German workers have not been obtainable, hence no comparisons with races recorded overseas have been possible. The exceptional case just mentioned has the interesting characteristic of producing the resistant "2" reaction on "Kinver" barley, the variety always used throughout this work for culturing isolates because of its extreme susceptibility. Further work with this unusual race will probably bring to light other differences, but at present it is clear that at least two races of the rust occur.

Numerous varietal tests have been made and a number of resistant varieties determined. Lack of space prevents a tabulation of them here.

6. Leaf Rust of Rye.

Rye is not of great importance in Australia, but the rusts attacking it have been investigated. The stem rust present has invariably been one or other of the established races of *P. graminis Tritici*. Two seasons ago the first evidence of specialisation in its leaf rust, *P. dispersa*, was found. On the leaves of plants in the field were many cases in which both susceptible and resistant pustules were present. A very few completely resistant plants were also present. Cultures were obtained from both types of pustule, and appropriate host plants selected and selfed. The difficulty in determining accurately from differential varieties what the two rusts are arises from the habit of cross-pollination in rye. Selfing of the resistant selections and of other plants chosen has led to complete sterility being manifested in most cases. Nevertheless efforts are still being made to carry this work through to its completion. Tests with a number of fertile strains of rye that have been inbred for eight generations have not yet brought to light any resistant types, but as more work is done, varieties suitable as differentials may become available.

7. Grass Rusts.

Already it has been recorded[55] that certain grasses in Australia are important hosts of cereal rusts. *Hordeum murinum* and *Agropyron scabrum* are notable examples. From one collection of the former, both oat and wheat stem rusts have been isolated, and sometimes more than one race of each of these rusts have been present. There have been very numerous instances of one race only being present on the grass examined. Clearly such grasses are important in the cereal rust work.

But there are other grass rusts which are not able to infect cereals. Some of them are important, causing considerable damage to the grasses attacked. No intensive work on the specialisation of these rusts has yet been undertaken, but there have been clear indications that physiological races occur in some of them. Thus in the case of *Lolium perenne* there have been instances of strongly resistant plants occurring in fields where most plants have been susceptible, and yet other plants have shown both resistant and susceptible pustules of *P. coronata* on the same leaves. This gives evidence of the presence of at least two races of this rust in that locality. Observations in other grass rusts will probably show similar evidence of specialisation. In breeding programmes designed to lead to the production of rust resistant strains of grasses, therefore, specialisation will have to be taken into account.

Conclusion.

Time and space will not permit of a description and consideration here of the actual results obtained in the breeding work that has been undertaken. Many controlled investigations have been made, using material from crosses between parents differing in their resistance to particular races of stem and leaf rusts of known identity. These apply to wheat, oats, barley, and rye. Results of considerable genetical interest have been forthcoming, as well as of practical importance through the production of resistant types of agronomic value.

Looking now to the future, from what has been set out it it apparent that specialisation is to be expected in each of the cereal rusts. And it must not be forgotten that changes in the physiological races present may be looked for as time goes on. Any breeding programme designed to give control of rust should take fully into account this phenomenon of specialisation. The occurrence of " mature plant resistance " does not rule out the need for this.

It is to be expected that further results of outstanding value will be forthcoming from wide crosses, involving not only interspecific but also intergeneric hybridization. Our own work involving such wide crosses is giving valuable results. The cytogeneticist can make contributions of the greatest value in this sphere of the work.

A much fuller coordination of effort on the part of workers in many lands seems to be needed. Even within a single country there have been many evidences of wastage that would have been avoided by a pooling of knowledge and material.

But above all it seems to me that we need very much more fundamental research into the many problems connected with this subject. A great deal more exact knowledge on basic matters is needed if we are to go ahead confidently in this work of gaining control through the breeding of resistant varieties. And to this end I believe that this Society is making a useful contribution, and will do so in even fuller measure in the future.

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