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Australian Academy of Science - Science education
Interview with Dr Douglas Waterhouse

Contents

Dr Douglas Waterhouse, a former chief of the CSIRO's Division of Entomology, was interviewed for the Australian Academy of Science's *Video Histories of Australian Scientists* program in September 1993. The interview was conducted by Dr Max Blythe of the Medical Sciences Video-archive of the Royal College of Physicians and Oxford Brookes University in the United Kingdom. Here is an edited extract.

You can order the videotape from us for $59.95, or borrow it from Cinemedia.

Early imprinting

You were born in Sydney in 1916, into a very interesting, supportive family. I have a feeling that you may have been imprinted with natural history quite early.

Well, my mother used to relate that, because I was fairly sickly as a young child, she took her complaining second son out in a pram to try and get him to sleep one day. She stopped to get a pebble out of her shoe, and all of a sudden I stopped complaining. She looked up, and there the pram had stopped just opposite a low wattle tree. I had put out my hand and picked a weevil off a wattle branch. Normally you would expect an insect to be crushed in the tight little hand, but this armour-plated insect survived and I went to sleep. Subsequently, when we went out my mother would collect one of these beetles and let me hold it.

That weevil was called *Chrysolobus spectabilis* and happens to have been one of the first insects that Sir Joseph Banks collected when he landed in Botany Bay on 29 April 1770. The specimen that he collected is now in a drawer in the British Museum of Natural History, in London. And with that weevil I too started my collecting.

Tell me about your parents. I think they were linguists.

My mother was born in Kilmarnock, Scotland. She graduated from Glasgow University in French and German and then taught both languages at Dundee. During vacations she went to the Continent – at that time, for a woman to have such Continental travel and training in languages was rather unusual. Dad had graduated from Sydney University with first-class honours in English, French and German, and also had taught for several years at schools in Sydney. When he went over to the Continent to study phonetics and become more fluent in French, German and Italian, he met my mother in a house run by the Mott family in Seine, France, where a number of people were studying phonetics to improve their pronunciation.

Dad then came back to Australia and they had a long correspondence courtship. They eventually married in Scotland in 1912, had a honeymoon on the Continent, and settled back in Sydney. I was the second of their four sons, and it so happened that my mother was the middle of her mother's three children and my father was the middle of three sons.

Your father had a phenomenal success story, receiving awards for his linguistic work and eventually becoming Professor at Sydney, didn't he?

Yes. He was recognised in France, he got the Goethe Gold Medal from Germany and he was knighted by King Umberto of Italy for the contributions that he had made to teaching Italian in Sydney University.

Professor Eben Gowrie Waterhouse, CMG and Janet Frew Waterhouse.

I think that on the Continent he met and dealt with both Hitler and Mussolini.

Correct, yes, both in 1934. He was in Berlin at the time of the *Putsch* and had half an hour or more with Hitler, which he has recorded in some detail in his memoirs.

From his language career your father turned to plants and horticulture, and popularised camellias worldwide, I believe.

He had always had a hobby interest in landscape architecture. When he retired, he started to look into means of propagation of camellias, which were one of the plants which had a very effective form. He looked into the origin of camellias, which come from South-East Asia and China, and he looked into the nomenclature, bred a number of varieties, wrote widely about them and stimulated a renewed interest in them.

He died at 96½ and, up to a couple of months before he died, he was still very active and writing half a dozen letters a day by hand, and was then the president of an international camellia research society. I hope to emulate him.

Tell me more about your mother. I think she was an equally exciting person, and closer to you when you were a boy.

Very much so. She devoted her time to her four children, helped us with our homework, gave us wise sayings like, 'Only the best is good enough.' But if you were having a tough time with maths or something like this in your homework, she would say, 'Plodders win through.' She motivated us in an extremely good way. It was only when we all left home that she had time to take up her own interest in simple flower arrangements. Under the influence of a grand master of *ikebana*, a Japanese form of floral arrangement, she became the first president of the *ikebana* group that was established in Sydney.

DW (centre) with two of his three brothers.
(Photograph taken by Harold Cazneaux in the summer of 1920-21.)

Beginning entomology

Let's go on to the link with your uncle, who was a very distinguished writer on Australian butterflies.

Uncle Athol was Dad's older brother, and he and Dad used to help their mother, my grandmother, to collect shells on Sydney Harbour. They both got from her an interest in bush rambles and in nature, and in 1903 at the age of about 25 Athol published the first comprehensive list of Australian butterflies. At that time he was an engineer-chemist in the Sydney Mint, but when the Mint changed from Sydney to Melbourne he got early retirement and could then work full-time on his hobby of butterflies. For his very interesting early work on natural hybridisation in the field of butterflies he got a Doctor of Science from Sydney University.

My uncle encouraged me early on to look at insects, but when I was eight or nine he started to take a more active interest in my hobby, giving me a glass-fronted case with butterflies in it. This stimulated me further and I put more beetles in bottles and even stuck ordinary household pins through insects.

This probably horrified him, because he then gave me a cyanide killing bottle and a folding cane butterfly net to collect insects. And my parents, at my next birthday, gave me fine entomological pins, forceps, pinning boards and various other equipment. This I am sure got me afloat.

DW (back row, third from right) at Rosny Preparatory School, Gordon, in the mid-1920s.

During your preparatory school years, living in Gordon, you continued your love of natural history and went out regularly into the Hawkesbury sandstone bush, collecting. Were you on your own?

We went out ourselves, but particularly with our father on Sunday mornings. Gordon, on the North Shore line, is in the middle of the Hawkesbury sandstone, and in those days there was still an enormous amount of bushland around us. It contained very varied and fascinating flora and fauna, and in particular it was rich in wildflowers. Our father showed us different sorts of boronias, orchids and flannel flowers, and two of the plants that are influenced greatly by insects – the trigger plant, which lets off a trigger when an insect comes and uses this for pollination, and a sticky plant called *Drosera*, which traps insects and digests them to obtain their nitrogen supplies.

But in your teens you were plucked from spending a lot of time in that wonderful environment to become more and more taxed with schooling.

Yes. When Turramurra College folded up, I did my last half year of primary schooling and then all my secondary schooling at Shore. I was a reasonable pupil there but not very good at sport, so I didn't enjoy school. In those days you had to be in the First VIII of rowing or the First XV of football or the First XI of cricket. I could play tennis reasonably well, but that was regarded as pretty sissy in those days. Some of us did, however, manage to encourage a master to set up a natural history society and then we could go out occasionally on various trips.

On one occasion when I was secretary of the Natural History Society, I offered to arrange for the New South Wales government entomologist, named Gurney, to come to speak. We were all waiting in the school library at about 7 o'clock on the appointed evening for him to turn up and show us some interesting specimens, and nothing happened. By a quarter past, the boys were saying, 'Oh, you blew it. You organised him to come at the wrong time,' and even the master was getting a bit cross with me. So I rang the man's home, where his wife said, 'Well, he had dinner early and went upstairs to change, but he forgot where he was going and got into bed. I thought it was funny that he hadn't said goodbye to me.' When he did turn up at school – and gave an interesting talk – I knew from his head (which seemed to be half as large as usual) and his somewhat vague look that he must be a great scientist. Most of the other boys said it confirmed their opinion that entomologists were a bit crazy.

At Shore you became friends with Max Day, who is also a Fellow of the Academy, who has told me that he has vivid recollections of happy meetings and bushwalking and collecting with you in those days, and he went to university at the same time as you. Your careers have paralleled quite a lot.

Yes, even to this day, and he lives 100 metres from where I do now. We met in our first year in high school, and when my Uncle Athol invited me to go out collecting I suggested that Max, who lived closer to Uncle Athol than I did, should come along. He was a regular collecting companion with Athol, but also he and I used to go collecting together. If we got anything particularly interesting, though, Athol would say he thought he might have that for his collection, all of which has ended up in the Australian Museum, in Sydney.

University days

Doug, you passed your school leaving exams well enough to get an Exhibition scholarship and go to Sydney University.

The Exhibition was useful because it provided free education. My school subjects were somewhat restricted. I did four languages – English, French, Latin and German – and maths I and maths II, but I couldn't do more than one science subject, either chemistry or physics, and there was no biology, because that was only in girls' schools. When I went to Sydney University I did chemistry, which was good, and then physics, botany and zoology. Zoology in particular was a great stimulation and of very great interest.

What was it like when you and Max Day went to Sydney University?

My father was a professor at the university and so at home I had already met some of the university professors, including the head of the Zoology Department, Professor Dakin. Max and I were able to go on a very important Rover Scout expedition to Mungo, about 100 kilometres or so north of Newcastle on the Myall Lakes, to study a patch of brush rainforest there. The university Rover Scout group was at that time led by the Professor of Botany, Professor Osborn, who was a charming person with an extraordinary way of speaking when he was lecturing. Many others of the 25 or 30 people there became firm friends, including Sir Rutherford (Bob) Robertson. Max and I were there during our September vacation as probably the only first-years present, with half a dozen professors and a range of people from zoology, botany, geography, geology and so on. Getting to know them under those circumstances made all the difference, because we were invited into the senior student and staff tea room, which was a little common room behind the zoology museum. This meant that the Zoology Department became our spiritual home; we met visitors there and we managed to talk to the staff on informal terms. I'm sure it made an enormous difference to us.

Your course unfolded with great success, with you going on to entomology and an honours project in your fourth year. Tell me about Woodhill in that regard.

Tony Woodhill was the senior lecturer in entomology, who probably hasn't been given due credit for his contributions to teaching at Sydney University, where he spent almost all of his career. He was a rather quiet, shy person, very kindly, with a pleasant smile. His lectures were full of meat but he wasn't flamboyant and didn't give rise to stories that could be told about him as they could about all of the other staff. But he stimulated and taught all of the entomologists that were required by the Commonwealth and by New South Wales over a very long period, something like 1930 to 1955.

Our group included Max Day and also Margaret Cumpston, who has continued in malaria work since then. The group was a very stimulating one and there were several more advanced students who interacted with us extremely effectively. Woodhill encouraged us to select our own honours project, and I selected a primitive aquatic insect in the Megaloptera. This was a study of the larva, not only its morphology and fine structure – its histology – but also its respiration. It had some interesting lateral processes from its abdomen, and the question was whether these were gills or just ornamentation.

You completed your degree with first-class honours and a medal, but while you were still at university you'd made links with CSIR – which in about 1950 changed title to CSIRO. Perhaps you'd tell me about how that link accessed a future career for you.

At the end of our third year Max and I were invited to become what was called then 'student labourers'. You were given £2 a week and you had to find your way to the job, which for us was down in the Goulburn Valley, in central Victoria, helping to breed up parasites. One was *Macrocentrus ancylivora* and the other was a species of *Glypta*, and they were meant to help to control the peach-tip moth. You had to go out and collect the larvae of the peach-tip moth, put them into cages with the parasites and let the parasites attack them. We bred up lots of these parasites and they were liberated, but unfortunately they didn't become established. The moth can now be controlled by using its sex pheromone. The sex pheromone of the female, which takes the males in to where the females are, can be synthesised and put out in little tubes, one per tree, when the trees are pruned. When the males emerge, the tubes keep on putting out the pheromone into the air and so the scent is everywhere and the males are confused. They don't find the females, the females aren't mated, and only sterile eggs are laid. This is a very effective method of control.

Hindering the sheep blowfly

Our work in the Goulburn Valley led to us being invited again in the next vacation, this time to Canberra. Max became involved with termites, which he had studied for his honours, and I was assigned to the blowfly section, under Dr Ian Mackerras. He was deputy at that stage to Dr Nicholson, who was Chief of the Division of Entomology and had himself spent several years on sheep blowfly work. Because my initial period was only going to be for six or eight weeks, I was given a piece of equipment called an olfactometer, to test out the way in which the sheep blowfly, *Lucilia cuprina*, was attracted to materials. However, when the person who had been doing this work in CSIR suddenly resigned and the position was advertised, Ian Mackerras suggested that I might apply. Within a few weeks I was offered the job and accepted it – and having arrived on 2 January 1938 I was, in effect, there for the rest of my life, or at least until I retired in 1981 at 65. You might say that I am a stick-in-the-mud - but very happily so.

Your work on the Australian sheep blowfly is really a big story with quite a background. Economically, the sheep blowfly was an enormous problem.

Yes. It was estimated at that time to be causing losses of £4 million per annum, which was an enormous sum – equivalent now, after inflation, to at least two or three hundred million dollars.

If the sheep blowfly lays its eggs on the fleece or on the skin of a sheep, the eggs hatch and the young larvae abrade the surface of the skin with their mouth-parts. This causes serum to emerge, and the larvae feed on that and keep on scraping. If no further flies come to the wound, the temperature of the sheep rises, the wool stops growing and the larvae fall off when fully grown. When the wool starts growing again there is a thin area of fibre, termed a break, where it had stopped and that greatly reduces the value of the fleece. If more eggs are laid, the wound gets larger and larger. Often bacteria then come in, septicaemia sets in and the sheep dies. It is necessary to do something to prevent death or, if possible, catch the strike early enough so that a break won't occur.

What was the standard practice in 1938?

The standard practice was to cut the wool from over the strike wound and, using the back of garden shears, scrape out all the maggots, which would fall on the ground. You would then put on a dressing, which often contained an arsenical so that if a few larvae remained behind they would feed on that and be killed, or any further young larvae hatching would also get a stomach poison. But sometimes this caused necrotic wounds and so it wasn't very good.

However, I looked at what mechanism there was for absorption of poisons in the digestive tract. On the wound in the sheep, the pH is near neutral, sometimes alkaline, certainly no more acid than pH 6.5. By feeding larvae with indicators, however, you could show very clearly that in the centre of the digestive tract there is a very acid region, down to pH 3 to 3.5. The question then was what happened in absorption of anything, including poisons, as it went down through the digestive tract. By using histochemical reactions I could show iron in the cells of this acid region: this was the region where iron was absorbed. Then I looked at other metals, including copper because copper salts were sometimes used in these dressings. I found copper was also absorbed there, but by different cells.

Then the question arose: could one use an arsenical or other compound which would be soluble and absorbed in the acid region of the digestive tract, but not become soluble in the much more alkaline or neutral pH of the wound? The first experiments didn't show promise, but that particular line was then halted anyway by the discovery that borax and boric acid were very effective stomach poisons for the larvae. They were bland for all the wound tissues; they were bacteriostatic. In fact, we now know that they inhibit the proteolytic enzymes which the blowfly larvae use to digest the tissues. So, we had an effective stomach poison.

The next question then was: where did the main population of the sheep blowfly breed? If, as was assumed at the time, they bred largely in dead sheep and that was the main source, then it didn't matter if you scraped the maggots out of the wound onto the ground. If they were more than half grown they could produce fertile flies. But some experiments that I did then showed that, from each of the wounds on an average, you would get perhaps 1200 adult flies, whereas if you put dead sheep out on trays and collected all of the maggots you would sometimes get no sheep blowflies at all, just plenty of other blowflies. This was partly because they couldn't get enough food in competition with other species and partly because, when you get a heaving mass of maggots in a carcass, the temperature goes up and this affects many of the processes of *Lucilia cuprina* more than other species, so that they didn't survive. It became clear that the very time-consuming process of burying these carcasses or burning them (even though that might be good on other grounds), didn't have any effect on the sheep blowfly population. The population was almost entirely bred on the surface of the sheep.

The next thing then was to develop a contact poison, or a mixture of poisons, which would kill the maggots very quickly; and then to cut the fleece down to about an inch over the surface, put the dressing on and hope to kill all of those maggots. This was quite a challenge, although just at this time two people in Cambridge – Professor Wigglesworth and Dr Hurst – had done some very interesting work. The cuticle of an insect has got a lipid layer on the surface and then a thicker inner layer, which is protein but it is largely aqueous. What is necessary is to have something, perhaps a mixture, that will go through the lipid layer and then through the protein layer, but without being too damaging to the sheep.

Eventually a mixture of orthodichlorbenzene, kerosene and lysol – which sounds horrible – was found to have this effect. It could be put onto the sheep wound, and as soon as it got there the maggots would be killed and stand out dead, but the wound was not unduly affected. Into this witch's brew was put boric acid, and there was an inert clay carrier. This led to a dressing called BKB, which was widely used for quite a long time. After the war it was temporarily supplanted by DDT and other chlorinated hydrocarbons, until those were no longer permitted. But BKB did achieve the purpose at that particular time.

At war – against the mosquitoes

The war broke into your early years at CSIR.

Yes. Ian Mackerras enlisted the day that war was declared – he was NX18, the 18th person from New South Wales. Having a medical degree, he went overseas as a medical pathologist. When he came back to Australia he was asked to set up a series of malaria control units, because at that stage Japan had come into the war and it looked as if Australia would be involved to the near north or further north. I volunteered to join these and was accepted, but interestingly enough the Army decided that the CSIR facilities at Black Mountain were far more extensive and appropriate, so it would be better for me to remain out of uniform and do research there. But when there was anything to be tested in the field, I would don uniform, be called up, and go out and use Army facilities. I believe this was an extremely effective way of using my abilities.

To begin with, I was testing oils for spraying onto mosquito breeding grounds which are bodies of water – oils which would spread very effectively, even though there might be surface films there already. I also had to test materials which might be used for mosquito sprays and housefly sprays to stop transmission of diseases. It was thought that our pyrethrum supplies, which at that stage came from Kenya, might easily be cut off, so it was a matter of testing any possible alternatives. It was particularly important to get a good mosquito repellent. Citronella oil had a reputation from earlier use in World War I and at other times in the Middle East, but when we tried it against mosquitoes in New South Wales it had almost no effect at all – plenty of smell but a very short-lasting effect.

I tested essential oils from many of the Australian trees, and one which proved to be an extremely effective repellent was from Huon pine, which is particularly common in Tasmania. The oil of Huon pine contains methyl eugenol and was used at that stage during grinding of lenses for telescopes and other optical equipment. The next step was to test it out in the field, but to my great disappointment half of the army volunteers became nauseated within about 10 or 15 minutes after it was applied to their face. The other half, including me, were totally unaffected, but it had to be dropped.

For my tests I would sit in a large muslin cage in a room, along with a thousand or so mosquitoes, and have a substance on each leg, another one on an arm and so on. This work got into the press, and as a result we got many letters suggesting all sorts of materials and mixtures to be tested. As a matter of course I tested all of these and all of their ingredients.

The Standard Oil Company wrote to us about two preparations that they had used in oil exploration in South America. One was dimethyl phthalate and the other was diethyl phthalate, and the company had about 35 per cent of these materials in two separate repellents. It so happened that, within our limited capacity to manufacture chemicals in Australia at that time, we could manufacture the phthalates. A friend of mine in Sydney, Herman Slade – who now lives half his time in Vanuatu and half in Australia – had one of the first stainless steel kettles and was making dibutyl phthalate. This was used as a plasticiser for the fabric of aircraft wings, to make them smooth and glossy. He made a series for me of these phthalates – dimethyl, methylethyl, diethyl and all the way up to dibutyl.

I found that the diluted dimethyl phthalate was a good repellent but the pure dimethyl phthalate was quite outstanding. It gave protection against voracious mosquitoes for probably an hour and a half, under conditions as hot as you could get. So immediately I got in touch with a colleague, Captain Bob McCulloch, who tested it out under field conditions up near Newcastle, where there were hordes of mosquitoes, and it was equally effective. Major Mackerras dispatched us immediately up to Cairns, where at that time there was a lot of malaria transmission – it has since been cleared up. We found the repellent just as effective against those malaria mosquitoes.

The next stage was to test it out under conditions in Papua New Guinea which might be experienced if war came as close as that. So I was sent up to a little village at the mouth of the Lakekamu River, which is near the Fly River on the southern shores of New Guinea, where the malaria rate and the number of mosquitoes was the highest known at that stage in New Guinea. Most of the time, children there died from massive malaria mosquito bites; the inheritance of a degree of resistance from their mothers didn't protect them except for about four or five weeks at the end of the dry period each year, when they could survive. By day, resting on the jungle floor you would find it absolutely peppered with these mosquitoes and, if at dusk you stood and waved a mosquito net round, you could collect one or two hundred mosquitoes every minute. It was really an excellent place for this sort of work.

Outdoor field laboratory, Lalapipi, mouth of the Lakekamu River.

We didn't know at the time whether or not the strain of malaria was Atebrin resistant. Fortunately, I took half as much again Atebrin as I needed. I became as yellow as if I had had jaundice, and I remember hearing Tokyo Rose saying over the radio, 'Don't take your Atebrin. If you go home you'll not only be sterile but you'll be impotent!' (This was the sort of attempt made by Japan to discourage the Australian troops from taking their Atebrin.) Anyway, I was protected even though I had probably well over a thousand bites from these malaria-carrying mosquitoes. The malaria strain was clearly Atebrin sensitive.

The dimethyl phthalate, later called Mary, stood up under these conditions just as well as it had before, despite the 'mights' – it might not have worked or it might have caused nausea or we mightn't have been able to synthesise it.

Were you trying it with any of the troops you were involved with?

No, I did this myself. To expose yourself like this, there was a risk. There was a signal station on the other side of the river, but I was there with two entomological colleagues who had been doing work on malaria rates and who confirmed my experimental work. When I got back to Land Headquarters in Melbourne, Major-General Burston, who was the Director-General of Medical Services, Ian Mackerras and Bill Keogh, who was the Director of Pathology, were all sufficiently impressed that they gave very high priority to the production of this material. It then was used by the Australian forces, and I think later by some of the American forces, for the rest of the Pacific War, and it remains a very effective repellent.

What an unusual sight you must have been in New Guinea at that time, without rifles or other weapons, doing your experiments. You were a captain by then, weren't you?

Yes, and normally you would have an entourage, or at least a staff sergeant. To go up into these areas, normally there's nobody more senior than a lieutenant. Although at Headquarters captains were a hundred to a penny, out there a captain is really quite senior, and in the ship that I went on from Port Moresby to Lalapipi I found that I was by far the most senior officer. The captain of the ship was a warrant officer and they had some very battle-hardened troops from the Middle East, under the command of a sergeant. I remember we set off at midnight on a Saturday night and at 7 o'clock on the Sunday morning the captain asked me whether I was going to have a church service. I thought twice, beckoned the battle-hardened sergeant round the other side of the cabin and said, 'Look, you know more about this than I do. You're going to come and tell me what orders I have to give you.' So he went back and said, 'The Captain says we'll have a five-minute church service. Now get busy.' Later on, when they started on using their .303s to shoot sharks, I went round the back of the cabin and he came around to me; he didn't ask me anything but just went back and said, 'The Captain says you'd bloody-well better stop that.' So we got on extremely well.

But I didn't even have a staff sergeant. I didn't have kitbags – because I had bottles of this, that and the other, and pipettes and measuring cylinders. I went around these parts with two suitcases. This made me look a bit peculiar, but I guess I was sufficiently peculiar that the troops didn't mind me. In fact, after a while they got quite interested in what I was doing – even though it was clear that I didn't know much about fighting.

Happily married

You came back to CSIR in 1945, after the war. By then you were already married, with one child, so let's put your wife into the story. She was only 18 when you met and decided to get married, and you were quite senior by then.

Yes. She was stunning. She's always been terrific – very understanding and a great support – and she's had to put up with me going around the world, often without her. She doesn't like flying, but she has been around several times with me.

Captain Waterhouse and fiancée (Allison Dawn Calthorpe), Sydney 1943.

Your wife helped you in some of your research projects.

Yes, in the early days. In fact, I met her in one of the early blowfly experiments, before the war, when she had joined CSIR as an assistant while waiting to be admitted as a nurse. She came out in the field and helped with one of the experiments to measure the density of the flies in the field. Later on, she was a willing helper in allowing mosquitoes to feed on her arms when we were developing mosquito cultures and so on. She also later – but not with me – became involved in some moth-proofing operations when there were big stores of wool and there had to be a means of protecting these against clothes moths and carpet beetles.

And that's a marriage that still goes on very happily.

Yes – 50 years next March.

With Dawn and children in 1959. Jonathon (on floor), Douglas (on right) and Diana. A third son, Gowrie, was born in 1964.

Before you could get on with your work at CSIR, you had some time in England. Because of the economy at the time, your wife would have had to go for two years or not at all, so she didn't go with you. Would you like to explain that to me?

Because I was only going for a year, if she had come with me she would have had to stay on for a period because transport was very limited and she couldn't get any guarantee that she'd be able to return with me. So she stayed behind for almost a year, while I went to Cambridge and then had a most fascinating trip back through the United States and Canada, looking at quite a number of laboratories and meeting people who were to make or were already making extremely important developments and discoveries.

A Cambridge studentship: more blowflies

How was it that you went to Cambridge?

I was offered a one-year studentship overseas, which led me to go with a number of other trip-deferred students to England. In the same cabin aboard ship was David Craig (a Fellow of the Academy), on the bunk above me, and others on that ship included Gordon Ada (a Fellow of the Academy) and Ed Salpeter, a Corresponding Member of the Academy and an eminent physicist. We lectured to each other on the way over and worked quite hard during the six-week, fairly slow journey to England. We left from Sydney and didn't call at any other Australian port, and it was a month before we landed in Aden and Port Said as our only stops before England.

At Cambridge you worked in Wigglesworth's unit. Much earlier you had been fired up by some of Wigglesworth's publications on insect physiology, I think.

He is the father of insect physiology in the world. He had not only written a small Methuen book but later *Principles of Insect Physiology*, and stimulated work in all fields of insect physiology around the world. His group in Cambridge was supported by the Agricultural Research Council, and not surprisingly he had attracted to the group some of the brightest brains of the day. It was a particularly stimulating environment at the time. Any one of those that were there could be said to have had quite fascinating and original ideas and developments, and many were subsequently elected as Fellows of the Royal Society.

When you got there, you were going to do some research on peritrophic membranes?

Yes. It was a matter of selecting something which I could do in the time that I was there, but which enabled me to attend lectures and to visit other groups in the UK. It was more important to absorb the atmosphere and the interaction with other people than to write another paper, which could be done elsewhere. I still have the weekly letters I used to write back to the boys in the lab to share my experiences.

In the late 1940s.

Keilin and a whole range of other people were doing exciting things in Cambridge at that time, and this continued with the peritrophic membrane of the blowfly.

That's quite so. The peritrophic membrane is a cylinder, in the case of the blowfly, and is produced at the beginning of the midgut. There's a secretion ring which squeezes out, as it were, a plastic tube which fits all the way down and surrounds the food being passed down the gut. I was interested to know what function this had in permitting or preventing the passage of material from the food out into the surrounding epithelium, which is where things are absorbed and get into the body. Anything that is taken up by the cells has to pass through this first, and in some insects you have to know how parasites get through it. The malaria parasite, in the case of the mosquito, has to go through the peritrophic membrane before it can penetrate the cells. This membrane varies a bit from one insect group to another, but it has a very interesting structure and obviously has an important function.

Doug, the short time you were in Cambridge robbed you of a chance to do a PhD there, but a DSc would come a bit later, in 1952.

Fortunately, yes. Although a PhD would have been nice - at that stage there were no PhDs given in Australian universities and the people who had them had got them from overseas – there wasn't quite the same peer pressure. But really it was a question of what was more important, to get a degree or to get the experience which would enable me to do a wider range of research and to have stimulation. Although I guess it was sad that I couldn't spend two years there, it didn't worry me that much.

So you came back to CSIR and continued your blowfly work.

Yes. We thought that there were still improvements that we could make. I studied excretion in blowflies, and I also thought that perhaps we could do even better than boric acid, so I looked at the fine structure in the digestive system and a variety of other things like this.

Moth-proofing wool

But just as the '50s were approaching you diverted some of your energies to looking at wool storage problems.

After the war, rayon, nylon and other synthetic fibres became available in much larger quantities and were much cheaper. This was posing a particular threat to wool, and three divisions of CSIRO were set up to look at the properties of wool, particularly any which were disadvantageous. One of them was that wool would felt, so it was necessary to have a way to wash it more easily and even in washing machines. Another question was whether you could permanently pleat it. Also, the synthetics were not digestible by clothes moths and carpet beetles as wool was, and it was then that I got involved in wool digestion. Why was it that, of all animals, only insects could digest wool, and of these only a small group of clothes moths, carpet beetles and the lice that live on birds? This was a mere handful of the five or 10 million insects – perhaps a few hundred at most.

The principal protein of which wool is made is keratin, the material which is the main constituent of hair, fingernails, feathers and so on. It had been known from work by two Danish scientists that clothes moth larvae had very alkaline conditions in their digestive tract – a pH of 10 – and also very reducing conditions. It was a matter of knowing how important those two factors were, or what other factors there were that enabled these wool-digesting insects to do so, and whether the factors could be interfered with in some effective way to produce moth-proofing.

So their enzymes were operating in these amazing reducing conditions?

Yes. I found that the highly alkaline conditions were not really important, because they were characteristic of all lepidopterous larvae. For instance, you could chop up wool finely and put some cabbage juice with it, and the larva of the cabbage white butterfly would eat it quite happily. It would pass unchanged through the pH 10 or thereabouts in the digestive tract, so alkalinity by itself wasn't important.

It turned out that the very reducing conditions were what mattered. You could measure this by feeding dyes which changed colour according to the oxidation-reduction potential, and the value in the clothes moth larval midget was minus 300 millivolts. The reason this was important was that one of the main amino acids in keratin is cysteine, which has two sulfur groups which are joined together in an –SS– linkage. If you have reducing conditions, you can cleave that. Once that bond is cleaved, normally you get two –SH groups formed, and this cleaved wool then can be digested by many insects. It's interesting that, in permanent waving of hair, you cleave it in a similar fashion, put the hair into whatever position you want and oxidise it again to restore the linkage, but the linkages then are in a different spatial relationship and you get a permanent crimp. One of the things that we thought of was to put, in between the two –SH groups (ie, –S-X-S–), something which wouldn't be cleaved by the reducing conditions. We would then have a permanent moth-proofing. The insects' digestive system wouldn't work any more.

But quite apart from that, in the process we found that there was another enzyme which cut off the –SH groups. Consequently, if you put in things which would otherwise be poisonous, like mercury, lead and arsenic, they formed insoluble sulphides. You could see this happening, because lead and copper sulphides are black, arsenic red or yellow, and antimony red, and so on. So the insects have a built-in mechanism for protecting themselves against quite a number of the inorganic poisons. You could even get protection against fluorine, because they have calcium granules and can produce insoluble calcium fluoride. They also have a mechanism for protection against barium.

Anyway, it became clear that inorganic poisons were not going to be of any use; you would have either to go to organic poisons or alter the structure of the keratin molecule. But just at that time, empirical tests on a whole range of insecticides showed that dieldrin was a very effective moth-proofing agent. It was, in fact, used for the next 20 or so years until chlorinated hydrocarbons became unacceptable on environmental grounds.

So again your work was cut short, this time by dieldrin coming in. Let me now just mention the goblet cells in the intestine, which you looked at quite a lot. They were a storage repository for the kind of things that were being put into complexes.

Yes. Although you get insoluble sulphides, some of these can be rendered into colloidal form by the amino acids and polypeptides that are either in the digestive juices or released during digestion. We looked at how the colloidal materials were taken up in these special cells in the gut. You could get larvae which you'd fed on these poisons and tell what they'd fed on by looking through the semi-transparent cuticle at those accumulations. But when they moulted, those were cast off. So it is clearly a form of storage excretion.

Updating *Tillyard*

From about 1954 to 1960 you were Assistant Chief of the Entomology Division.

Yes. That broadened my interests. I had responsibility for insect physiology and toxicology and veterinary entomology and some responsibility also for biological control, which was quite important to my later career. The administrative chores weren't really as onerous as I thought they were then, and certainly not nearly as onerous as the enormous load of administration that is now on my successor.

The head of the Division was Nicholson, whom you'd started with.

Yes. He was an outstanding theoretician, particularly in population dynamics, and a very clear thinker. He was a very shy person, though, and he wasn't an empire builder – he was relatively loath to take the opportunities that were occurring at that time for getting more staff and facilities. Although there was a slight increase in support for the Division, there was not nearly as much as in the neighbouring Division of Plant Industry, where the Chief at that time was Dr Frankel, later Sir Otto Frankel, who took every opportunity that came his way and built up an extraordinarily effective and outstanding team of researchers in the Division of Plant Industry.

Did you feel a bit frustrated at that time, that opportunities were being missed?

No, not frustrated. There were so many things to do that I accepted the situation quite happily.

What about your wish at that time to update Tillyard's Insects of Australia and New Zealand*?*

That was one of the things that I had been keen on. Tillyard's *Insects of*

Australia and New Zealand was almost a bible to me. It was published in 1926, when I was just 10, and I was given a copy shortly afterwards and gradually understood more and more of it. But by the 1950s an enormous amount of additional information had been acquired, and in any case even in the '20s no one person could have accomplished an effective spread over the whole spectrum of entomological activities. I was very keen for the group of colleagues that we had to rewrite *Tillyard* and bring it up to date, but Nicholson didn't really feel that this was an appropriate thing for the Division to undertake and said he was pretty sure that the Executive wouldn't agree to it. So we didn't do it until later, after I became Chief.

One of the first things was to find a general editor. Ian Mackerras had left the Division shortly after the war to become the first Director of the Queensland Institute of Medical Research, but in the early '60s he was close to retirement and I managed to persuade him to come back to Canberra to be the general editor, which he did in a spectacularly thorough and effective way. Indeed, the Executive was quite happy to allow significant resources to be diverted to the Division. It took almost 10 years to amass the different contributions, by 30 contributors, mostly from within the Division but quite a number from elsewhere in Australia and even overseas. It proved to be a spectacularly effective textbook for Australia and was used widely overseas too.

CSIRO Entomology: so many challenges

That remarkable addition to the literature was published in about 1970. Let's return to your career in 1960, when you took over from Nicholson on his retirement. What were your main areas of interest in your years as Chief of the Entomology Division?

Perhaps I should start by saying that already in the middle to latish '50s there were many people, myself included, who were recognising that modern, synthetic, postwar insecticides weren't going to be the solution to all insect problems – that we would need to invoke all other possible methods for insect control and only use pesticides when it was highly advantageous to use them. The other methods were cultural methods – such as planting early to avoid pests or rotating crops in such a way that the pests of one crop couldn't continue with the next crop and therefore were likely to die out or to go down in numbers – or the use of resistant varieties of crops or, most importantly, the use of biological control, because all of our important agricultural crops in Australia are introduced and almost all of our weeds are introduced. Often the insect pests have come in without the natural enemies that keep them in control overseas. If you can bring in these natural enemies – after tests to show that it is safe – in what is called classical biological control, you can then expect the natural enemies to reduce the population below a level at which damage would occur. One example of biological control is the use of myxomatosis, which was studied by Frank Fenner and Max Day, and the biological control of prickly pear is well known.

Hard at work at the Division of Entomology, CSIRO, Canberra.

It was clear that a great deal more had to be learnt about our insect pests. My proposal, called 'New Perspectives in Insect Control', suggested something like 150 additional appointments to the staff of the Division, about 50 of them research people – there were at that stage only about 30 or 35 research people. Fortunately, it was a good case and I must have argued it effectively before the Executive, which by that stage included Otto Frankel. Over the next 15 years we trebled the size of the Division and, according to the economists, got an extremely good return for the money.

But there were many other things that I was interested in. I was involved not only nationally but internationally in the field of integrated pest management. I became involved also in the establishment of the Australian Biological Resources Study, which was started only just in time, to help to improve the balance and amount of work going on in insect taxonomy. We probably know of - have named - only 50 or 60 thousand of the perhaps two or three or four or five hundred thousand insects that are in Australia, and you can't have sound environmental impact evaluations or establish national parks effectively and so on without knowing more about what is there. There are more beetles – 20,000 or so – than all of the vertebrates in Australia. Insects have a great diversity.

There were lots of other aspects, probably too many to deal with in this interview. It was a very challenging and exciting time, and I wouldn't mind doing it again.

Integrated pest management: dung beetles 1, bushflies 0

You got deeply into studying fly physiology.

Yes. I kept on trying any repellents that became available because, although dimethyl phthalate was effective against biting insects – mosquitoes, fleas, bugs, March flies and so on – it had no effect at all on another worrying but non-biting insect, the Australian bushfly. There is a story of how Australians are always very friendly, because when you see them in the bush they're doing what is called the 'Barcoo salute'. That doesn't mean that they're waving at you, but just waving the flies off their nose. The bushfly has been particularly troublesome but eventually we did manage to get a repellent which is effective against it, and which is still in use. However, one of my later projects, dealing with the dung beetle, has helped to reduce the fly's importance in a number of areas in Australia. This is because the main breeding ground of the bushfly for the past 200 years has been the dung pads produced by cattle.

In fact, integrated pest management has been a great theme of your work in these latter years, more recently with a deep commitment to biological control mechanisms.

Well, they're environmentally sound. Classical biological control is really putting back a missing link, one which was left out when a pest organism was brought in. The story of the dung beetle illustrates what I call biological control. When Captain Phillip came, in 1778, he brought with him five cows and two bulls. But it wasn't realised at that stage that there were no organisms which were adapted to dispersing the big dung pads they produce. Now there are 25 or 30 million cattle, and there are 12 dung pads a day, on average, dropped by these animals. Each bovine produces enough to cover about a tenth of an acre a year, and in Australia they sometimes last for a long time. Overseas, where the cattle originated and evolved, there are many dung beetles which disperse the dung.

If there are 12 dung pads a day per bovine, that means that there is one dung pad every two hours. So, if we've been talking for an hour, and we have one dung pad for every two cattle, and if there are 30 million cattle, then 15 million dung pads have been deposited while we've been talking! And these have to be dispersed where they lie. On the ground they smother the pasture just where the cattle are. Around the periphery of each pad there's tall green grass which has got too high a nitrogen content for the cattle to eat unless they're really very hungry, so it puts out of action a great deal of pasture. One of the projects has been to bring dung beetles in from Africa to disperse the dung pads. We have now brought in 20 or 30 or so and a number have been established. We probably need about 100 of the 2,000 kinds that are native south of the Sahara. It's one of the many instances of missing links which have been left out, but which we will have to re-establish when we move plants or animals from one continent to another.

Doug, it's been great to talk to you about all these things today, and I've been fascinated. Thank you very much.

Thank you, Max.

With wife Dawn at a recent 'Friends of Early Canberra' gathering at Calthorpe's House.
