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As a boy I lived in Ecclesall on the western edge of Sheffield in northern England. My earliest memories are of the gang of boys in Tullibardine Rd. John Stevenson's father was a coal merchant, Frank Proctor's a green grocer, John Hunter's ran a pork-pie shop in town, and Tommy Hogg's father was also a butcher. The gang's business was to make a bonfire in someone's garden, then when turfed out, migrate to another garden. Not a promising beginning.

My grandfather had had a factory in the centre of Sheffield, where they made combs, handles for knives and doors, and all kinds of things, from hardwood, horn, ivory, turtle shell, but had sold out in 1921. My father was mechanically minded and was a small-arms instructor during WW1. After he came out of the army he joined the Hallamshire motor Cycle Club, and did a bit of racing and hill climbing trials on a flat twin cylinder Douglas. He bought a few second hand and crashed bikes, mended them and eventually set up a business with a friend in the club, Reg Wildgoose (whose sister-in-law later married Fred Dainton FRS). They became agents for Ariel motor bikes for Sheffield and did well because most of the houses in Sheffield had no garage, only a gennel to the back of the house, so that a car was out of the question, and a working man could keep a motor bike inside his front door.

We moved to Carterknowle Rd just before the war, into a newly built 2½-bedroom house that cost £600. There I could get through the fence at the bottom of the garden into Nab Farm, where there were large pastures, cows, hens, trees to climb, a stream and several ponds. Soon I had an air gun, but I was ordered to eat anything I shot. Every Sunday we would go out in his red MG car, and picnic in Derbyshire. I would take a fishing net and come back loaded with frogs, lizards, water beetles, caterpillars and crayfish – all kinds of wildlife, that were kept in jars, boxes and home made cages. They were carefully studied on the kitchen floor.

My keenest memories are of the river valleys of the limestone district of Derbyshire, Monsal Dale, Lathkil Dale and the Matlock valley, because there were caves in the hill sides, trout, crayfish and mussels in the rivers. The ponds, too, abounded in water beetles, newts and dragonfly larvae, all of which were my friends. In the evenings my father would study large scale maps (1:50,000), looking for new places to go, and he showed me how to read maps.

I remember almost nothing about Ecclesall church school where, aged 6, I walked twice a day, until moving to the Junior part of King Edward VII School. My father took me to school on the back of his motor bike, on his way to work. I had all kinds of subterfuges and dodges to

avoid playing compulsory games but we had a splendid swimming pool. The move to the senior school meant that I could join the scout troop and go to camp. My first camp, at an Easter week-end, was cold and wet, and I had not packed the right boots, blankets, pullovers, swimmers and secret rations, so I suffered. After that, camping became an obsession.

At week ends, my close friend, Grahame Thompson and I would cycle out to Derbyshire as often as we could to spend Friday and Sat nights in a two-man tent and explore, explore, explore. We went as far as Edale, Castleton, Buxton, Youlegreave, Matlock and Chesterfield. Later, we cycled to the Lake District. There, while whizzing down the Honeston Pass, Grahame's brake blocks burst into flames. From 1940 onwards, at week ends from April to October each year, and all the summer holidays, I organized the Otter Patrol camps in Derbyshire. We would cycle out to Edale, Castleton, Youlegreave, or to nearer places at the edge of the moors, where the heather changed to woods at the geological boundary where the gritstone changed to Carboniferous sandstone, and further away to limestone. If others stayed at home, I would cycle out with Grahame, with a two-man tent.

The roads were mostly deserted on account of the shortage of petrol. In 1941 we cycled to the Yorkshire coast, where the holiday resorts at Bridlington, Flamborough, and Whitby were deserted, the cliffs were tangled with barbed wire, the beaches were studded with concrete blocks and there was no ice cream. No-one took any notice of two boys roaming around the cliff-top block houses and empty concrete gun emplacements. In the summer of 1942, we cycled south for the length of England, and stayed weeks helping with the barley harvest at a farm near Cheddar Gorge in Somerset.

My father and mother believed that I would be safe travelling with Grahame, and his parents thought the same about me. Actually, we had lots of adventures, travelled at negligible expense, and learned to look after ourselves in a way that was invaluable later.

When war broke out and rationing came in, at the age of 13, I decided to keep rabbits. We had 30 or 40 at any one time, which meant that a wheelbarrow load of grass and foliage of the right species had to be gathered every day. As a result, I learned a lot about animal physiology, sex, births and manure. We had rabbit meat regularly; we sent the skins away to be cured, and my mother went to glove-making classes. On account of the bombing of Sheffield, school was closed until 1944, so I spent a great deal of time in the public library, where there was a fine reference collection on all aspects of science and engineering which served the industry of the city. They allowed one 10 books at a time, and I read everything. I became a stinks and fireworks nerd, but it served me well later.

Our school became a reception centre for bombed out families. After an air raid, busses would bring homeless people to the school where they were provided with a place to sleep and live, with meals from the school kitchens. Being a scout, I had to go to school after each air raid and help as a messenger, data collector, washer up, waiter etc. We had a lot of towels, nappies and other useful stuff to hand out. Volunteers looked after the bombed out in the school until they solved their problems. In practice, there were not many serious raids, and those who lost their homes soon went to stay with friends or relatives. The air raids ended in 1944, so School opened just in time for some advanced classes in Chemistry and Physics.

When I was 15, my father sent me down to the town hall to get a driving license. It was Dec 1942; there were no driving tests, and the Town Hall had been damaged by bombs. A man behind a little oval window said "That will be five shillings". I gave him the money and he pushed a form out for me to complete. Without looking except to check that it was signed, he then gave me a driving license for All Groups; that is, for everything from an invalid carriage or motor tricycle, a bus or a truck, to "a vehicle laying its own tracks". I supposed that meant a tank or possibly a tramcar, which I never had a chance to drive. I renewed that driving license for many years, even after coming to Australia.

My first motor cycle was a 250 cc Red Hunter Ariel, lent to me out of the shop. I rode it to school a few times and liberated a plague of infectious jealousy. Within a month my father had sold about 15 of them, his whole stock, mostly to boys at King Edward's School. They were fast and skittish, with excellent acceleration, but not very economical. I had to hand in my new model, which was soon sold, and instead I got a second hand 250 cc Velocette 2-stroke, which was slow and economical, with large pannier bags for camping gear.

The motor bike was too small to carry two and the camping gear, so in 1944 I met Graham and Brian Renwick in Penzance, and we went camping in the Scilly Isles. In the last years before leaving school, I went hitch-hiking alone around the coasts of Ireland, camping and hill walking in the Lake District, and started rock climbing at Cratcliffe edge and along the gritstone cliffs above Hathersage. Mum never seemed to worry about me and dad would give me a £1 note if I said I was short..

The war gave me freedom from continual school. Camping, reading in the huge reference library, doing chemistry experiments, or making rabbit hutches out of old crate wood, was perhaps the key to later interests, confidence and competence. By working alone, it was possible to concentrate for long hours on the job, learn from mistakes, and not be stressed by teacher pressure. When creating, ones failures and successes soon become obvious. Also, because school was shut, there was time to

get new supplies of useful stuff. On visits to the city central library, I would call at Preston's, a supply chemist to the numerous small manufacturers in Sheffield, and buy small quantities of useful chemicals. I had a few library books on almost permanent loan, Bernstein's Organic Chemistry, Fiegl's Spot Tests, and a book on the Analysis of Foods. I needed isothiocyanates, ferricyanide, anhydrous aluminium chloride, fuming sulphuric acid and ammonium molybdate, for all kinds of tests and interesting reactions. With no questions asked, I bought bromine, phosphorus, mercury, metallic sodium, and extremely reactive reagents such as acetyl chloride, acetic anhydride, sulphur trioxide and thionyl chloride. These industrial chemicals were surprisingly cheap. Nowadays, the regulations in what we call advanced countries make this impossible, which implies that real understanding of chemical reactions starts later, when relatively inexperienced PhD students are let loose in a lab. Maybe young scientists still learn to act in a safe way in less regulated countries, if they have the funds.

As the war continued, many schemes were introduced to assist farmers with the harvest. Large harvesting camps were set up, usually sleeping on camp beds in a village or church hall and using a large kitchen. I went to several of these in 1943, 44 and 45, usually as cook and quartermaster, planning, cooking, serving and washing up. These were responsible jobs on which the health and the happiness of the workers depended. In 1943, while my school was closed, I was at a pea-picking camp outside Bedford when the phone rang after breakfast. It was the farmer asking for more men because rain was expected. Would I go down to the prisoners-of-war camp and get 30 men as quickly as possible. The camp was about 2 miles along the road, so I took a bicycle and presented my request to the guard on the gate and then to the duty officer. After a quick phone call to the CO, I soon had 30 Germans lined up in pairs. I had to sign for them and marched them into the pea field to join the Gypsies, school children and land girls. They were paid the same as everyone else for each sack of peas picked, and were glad to get the cash to spend. At 5 or 6 o'clock, I marched them back, signed them off and returned on the bicycle. I was 15.

The same year, I was cycling through Chatsworth Park, in Derbyshire on a Friday afternoon in full scout uniform, to arrange for campers to arrive on the following morning, when a Lancaster bomber, engines idling, came down with no wheels, landing on a flock of sheep on my right, about 50 metres from the road. It broke into two as it hit the ground and a man fell out. Quickly I ran across the grass as the pilot climbed out and lit a cigarette. There was aero fuel all over the place, smashed sheep bleeding, and silence. The pilot was in shock. I took his cigarette and explained that he must walk away from the plane. He

nodded and went off to light another. The man on the ground was bleeding bright red and frothy from his mouth, breathing regularly, but in pain. Broken ribs. He told me they had been hit over Norway and were lost in cloud. There was another man in the plane but he shouted that he was OK. I hoped he had not lit a cigarette.

At that moment, a convoy of army lorries appeared along the road, the kind that trained new recruits to drive heavy trucks. I ran back to the road and stopped them. At the front was a dispatch rider on an army bike. "Go back along the road to the village", I said, "and come back with a doctor" as I pointed to the crashed plane. "Right", he swiveled round and roared off. I climbed on the step of the leading truck. "Do you have a radio transmitter" I asked. "See, over there is a crashed plane". "So there is" exclaimed the driver, seeing it for the first time. "OK", I said. "Radio to your base and tell them to spread the alarm, and pass on the message to the Air Force". The two men in the cabin fiddled with the transmitter. By this time, a few men from the trucks behind had climbed out, so I took them to the navigator lying on the grass. One or two climbed into the broken fuselage and spoke to someone inside. I suddenly felt too tired to get involved. It was time for me to go, so I gently cycled off while their attention was on the crash site.

I bought second hand copies of the Handbook of Physics and Chemistry, the Electrical Engineer's Handbook, and about 1943 I was given a copy of a marvelous book for the self-taught, called simply Calculus Made Easy, by Sylvanus P. Thompson. Inside it said, "What one fool can do, another can." I struggled alone over it, but my mind was never the same again, because as well as thinking about static things, I thought about their rates of change, and the accumulation of change over time or space. The same worn copy in 2001 went to my son Mark, and to my grandson Tor and his sister Finnian, all of whom became mathematicians.

There was not much school until near the end of the war. Very fortunately, we had 4 good science teachers from 1944 on. Trotsky, about 70, who taught lower Physics very thorough, with no humour whatsoever. His favourite sentence was "Has any boy, for any reason, not brought his homework?" He had a cupboard full of lenses, prisms, copper wire, soldering irons, mercury, rubber bladders and tubing, ground glass screens, pinholes (in frames), diffraction gratings and even screens of zinc sulphide so that we could count radio-activity in a dark room. A few alpha particles hurt no-one! Our headmaster, Dr Barton, had been a PhD student of Rutherford at the Cavendish, but had to become a teacher in the Depression. He gave special physics classes for the scholarship stream with the result that we were up to date with the latest discoveries on the measurement of neutron flux, isotope separation, atomic fission

and Relativity, as well as heat and light, on which he had written excellent books.

Chemistry was supposedly taught by Dr Bowman, a research chemist who had been involved in the development of sulphonated fats and other detergents. Actually chemistry lessons were an extension of our home experiments, only with better equipment and the financial backing of the Sheffield City Council. On one occasion we generated bromoacetone in a long tube which we lowered out of the window into the window of the French class in the room below (They had to evacuate). Bowman tried to instill some responsibility into us, especially in things like distilling acetone extracts of poisonous plants and making explosives. It was he who taught the class the safe way to make nitrogen iodide, because he knew that we would make it anyway.

Botany and Zoology were taught as separate subjects by Dr Wheeler, who had written the text book for schools, and who examined for the Higher Certificate, so altogether, we had good opportunities. As a result our school won 11 scholarships to Oxford or Cambridge in my final year. While in Cambridge for the scholarship exam, I was sent to the Chemistry lab in Downing St to be interviewed by Dr Kipping, who was attached to St Johns College. He was not in his room, and so as I waited, I scanned all the bottles on his shelves, and sniffed the contents of a few of them. Many were familiar organic liquids that I had synthesized or modified, terpineols made from lemon grass or pine resin, ketones like acetophenone, or halogenated hydrocarbons. When Kipping arrived, I interviewed him about his research interests. Only later I learned about the contemporary tiff with the Chemistry Dept in Sydney Uni, where the staff refused to have him, an outsider, as professor.

I did four subjects at Cambridge, which meant two or three lectures and two practicals every day, with some on Saturdays also. Instead of the leisurely pace at the top of the school, there was now no time to digest the work during the terms. We were stuffed with facts and expected to be critical, but it was clear that the advantages went to those who knew a lot already, because they had supplies of information and experience to draw upon. There was no substitute for competence and a strong constitution. Life was extremely hectic, but we were young and had a long concentration span, if necessary, the stamina to work all night. Only 10 per cent of the students in Cambridge in my year had come straight from school. The others were ex-servicemen from POW camps or from campaigns in India or France, many with experience of fighting. They had lost years and forgotten their science but were deadly serious and determined to catch up.

The atmosphere in Cambridge just after the war was intensely busy and stimulating. For staff and students returned from the war, everything

had to happen immediately. For us schoolboys, it was instant manhood. My tutor, Colin Bertram, who had spent the war in Palestine and the Persian Gulf, advised me to take advantage of the fact that I knew the chemistry, and concentrate on biology, but in the first year I was interested mostly in biochemistry and physiology.

The scholars, all straight from school, sat together for dinner in Hall. There was Derek Lennon, with whom I shared a room in 2nd court, Kronheimer, (father of Peter, Professor at Harvard), George Gwilt (grandson of Lord Beveridge), John Horlock (later Sir John), John Creed, Brian Ruth, George Pullan, Eddie Stamp, Jim Durbin, Malcomb Jeeves, Crossman, Hunter, and several others. In time, most of them became professors. The conversation was an education.

To make a graduate, select the best and toughest material, keep it in good company, dampen it with Sherry, teach it to pole a punt, tie a bow tie and play bridge, work it intensely and reward it alternately in short bouts. Examine it for rot, nicotine or alcohol. If clear, throw it out upon an unsuspecting world. To continue to the post-graduate stage, let it collect its own herbs and flavours and idly stew for 3 more years. If the flavour is not actually disgusting, award a doctorate and start over again.

A room in College was bliss because it saved precious time. For 3 years I lived in the beautiful 2nd court of St Johns, under the gaze of the statue of the Countess of Shrewsbury (1632 ob.) who, despite being locked in the Tower of London, gave money to build the court in 1598. In the 3rd of these years, I occupied the room at the top of the north-east turret, which was never occupied before or after. My rent was £3 per term. My bedder would come only as far as the bottom of the ladder. "Misterorridge, I'm not cumminup any further; you can throw down your rubbish." So I did.

The tutorials were the highlight if you got a good supervisor. I found some very good ones, notably Roland Winfield supposedly on Physiology but actually on Total Life Matters; Kipping in St Johns for Chemistry, Pratt in Christ's College on Physiology, where I shared the tute with Ian Bush. The best supervisors were not great or famous scientists, but they were willing to listen, explain, and spend time. Education and experience came from the other students because discussion and mentoring was universal and multilateral on all topics.

I joined the Mountaineering Club, met more friends and became secretary of it in 2nd year. We went to the Climbers Club hut at Helig in North Wales, to youth hostels in the Lake District, to Glencoe, Suilven and Loch Torridon in the West Highlands of Scotland. In the winter of 1948 I went with John Veasey to a ski school near Briançon in the French alps, but our favorite spot was the youth hostel at Glenbrittle close to the black Cuilin on the Isle of Skye. In 1949, John and I camped in the centre

of the Cuilin on the shore of Loch Coruisk. In the summer of 1950, I organised an expedition to the island of Gomera in the Canary Islands, where four of us surveyed the birds. I got back to find that John had been killed climbing in the alps and was buried at Grindelwald. I never climbed rocks again.

I had an offer of a PhD studentship. When I turned up at the Zoology lab, not knowing exactly what to expect, I went to the chief technician's office and was given a key to a room on the second floor – and that's all I got. The room was quite empty.

As a research student in Cambridge in those days, you stood up alone and stood on your own feet, then you walked or preferably ran. It was a complete contrast from the process of stuffing undergraduates with facts, but I was well prepared by the wartime school closures. You found yourself your own topic, searched the literature, and somebody who would supervise you. Then you found real helpers, maybe a research student in another department or a Fellow of another College. Then you had to collect your apparatus. You built it yourself or scrounged it from somebody who had just finished or some other member of staff who had got some stuff in his cupboard, and you collected things from various places in the lab such as the chemical cupboards in the corridor, the workshop and the electronics workshop. So, having assembled everything you thought you wanted, you might start some experiments.

Self initiative and self reliance was the key to success, and one had to pay one's own travel and small expenses out of a small student grant. I had no topic, so I went down to the Plymouth laboratory of the Marine Biological Association of Great Britain, which in those days was an independent body that was funded by the government. I had noticed the possibilities of this place while on a two-week class in Marine Biology during 2nd year. This laboratory had two good-sized ships with which it explored the western fringes of Europe, the Atlantic Shelf and the English Channel, kept an eye on fisheries and ocean productivity, and supplied marine animals to the universities. The great advantage was that the lab was filled with enthusiastic and experienced researchers on interesting animals, and they were willing to talk shop all day.

I simply walked in and said I hoped to stay a while. The Director allowed me to work there, supposedly on the mythical Cambridge University table. I discovered that in the 1920s, Berrill, a Canadian zoologist, had studied the regeneration of the head and tail of marine worms, until the whole worm eventually came back to normal. He left behind a bottle full of partially regenerated tube worms. I thought that if I could look at the problem again, using electrophysiological techniques, I could follow the process of regeneration of the nervous system.

In the marine laboratory there was a Polish professor, J. S. Alexandrowicz, who had fought with the Polish army during the war and then been landed in England. I owe him a great debt. Carl Pantin had found him a salary as a gardener in Cambridge, then a place was found for him to continue his pre-war work in Plymouth, where he produced a remarkable series of papers on neurons in various invertebrates, mainly crustaceans. When I arrived, he was staining – with methylene blue and other rather nice methods – the structure of the stretch receptors of the crustaceans. Methylene blue staining is very much an art, with lots of tricks in the technique. He taught me very well how to handle the staining of neurons in invertebrate animals, and showed me the literature in the extensive library. The first essential for picking a research problem was to know the literature so well that the gaps were obvious. Most of the best literature was in German, which I read but never learned to speak properly.

Then I went back to Cambridge zoology department, and collected some of the jellyfish *Aurelia*, by going on my motorbike to Brancaster Staithe, on the Norfolk coast. (Lord) Victor Rothschild had just purchased some microscopy equipment out of his own private money, so back in the lab I was able to use a phase-contrast microscope for the first time to look at transparent jellyfish. The nerves of jellyfish are completely transparent but can be seen under phase contrast. A very lucky break, I thought, and quickly covered the literature, discovering that nothing much had been done on jellyfish nerves since Romanes' great work in 1876, and a few studies by Emil Bozler, working at Naples before he had to flee from the Nazis. It was a matter of grabbing the opportunity.

In those days the experiments had to be designed so that they were simple and cheap. I spent the whole of that year building electronic equipment and recording from snails and odd things that had some nerves in them. I first built a power pack, then a multivibrator stimulator, then a DC amplifier that gave me enormous trouble because it was totally unstable. I got a radar oscilloscope, which had a blue screen and fast time bases, and produced circles on the screen, but I changed the tube, time base and amplifiers, so I had a new oscilloscope with a green screen that gave a long fluorescence. I had help from several people in all this hard work. The Zoology lab had an excellent workshop with large machines and plenty of metal sheet, flats and rod. But more important, there was a workshop assistant, Mr Groombridge, who would show students how to use the tools, and there was a staff member, Raef Brown, who was full of encouragement, design ideas and in the basement had loads of surplus wartime equipment to give away. There was also a good physiology lab across the road – Hodgkin and his assistants – and I got lots of instruction

from Willie Rushton about how to make microelectrodes. One result was that later whenever we had a problem in the lab I was able to solve it. Once you've made all the equipment and discovered the little details of exactly how to do the experiments, you become more confident.

When I had successfully recorded the nerve impulse from jellyfish and identified the synapses, in 1952 I wrote a thesis for a fellowship for St John's College, and then I was obliged to look for work of national importance in lieu of military service. By good fortune, in the Zoology Dept I talked to Mark Pryor, who had worked at the Royal Aircraft Establishment (RAE), Farnborough, in a remarkable group that had built the Mosquito aeroplane out of balsawood. (It turned out to be radar transparent and, because the frames were negligible in weight, had superb acceleration.) He sent me to see his old boss, Jim Gordon, (later the author of a remarkable book '*The strength of materials or why we don't fall through the floor*') who took me on as a scientific officer.

The structures department at Farnborough provided another round of rapid education. I worked on new materials which were being invented at that time for construction of aircraft and rockets. Ground-to-air rockets were being made out of anything from steel to aluminium to glass fibre to asbestos. We were looking very hard at ways of using the covalent bond to maximise the strength of materials based on carbon, boron and silicon because if you use these light elements instead of metals, the specific strengths (the strength divided by the specific gravity), jump by a factor of about 10. One of the things I did there was to invent the material for the venturi, the jet at the back end of the rocket where the high velocity gases come out. I was invited to join a big company making rockets, simply on the strength of that invention, but turned them down because they used asbestos. We knew the dangers in 1950.

We pulled our own glass and silica fibres, we persuaded glass companies to make peculiar weaves of glass fabric. We built helicopter blades out of fibreglass, linen fibre or silica fibres, and spun them until they bust – which makes a lot of noise! – and we filled rockets with all kinds of explosives and then fired them to see what the structural material would withstand. It was a very practical kind of science, and a great learning experience, just my cup of tea.

The research on jellyfish had secured for me an 1851 Senior Award and a research fellowship at St John's College. From there I continued going to Naples at Easter, when it was cold in England. The Stazione di Napoli was supported by universities all over Europe who paid a fee and had table rights in exchange. (That is, they could send people to work there.) The lab was one of the great laboratories of the world until quite recently, At lunch – served in the lab – you could hear six to ten languages being spoken around the table. I got to know quite a number of

people from European labs while there. I spent a lot of time working in the magnificent library dating from the 1880s onwards, holding every possible journal and book and old monograph you could hope to find on marine animals.

I went there to study jellyfish, hydromedusae and Ctenophores, a group of animals that are hardly known. They have the most primitive nervous system of any group of animals. There is no major concentration of nerves anywhere, no 'brain', yet their behaviour is well organized. For example, *Beroë* is carnivorous. It puts a million cilia into each cell on its lips, all packed tight side by side, and uses them like teeth. I used them to show that cilia move by sliding the microtubules. Another ctenophore, called *Mnemiopsis*, has little fingers sticking out. If one of the non-motile cilia on the end of a finger detects a vibration, it extends by contracting circular muscles. It leaps out and sticks on to any copepod or anything similar that approaches it. Another ctenophore revealed giant mitochondria and another neurociliary synapses.

In the spring of 1955, I was in Naples while the Cambridge Professor of Zoology, Carl Pantin, was there. He said to me one day, 'I have a letter from a friend of mine at St Andrews University (Scotland). They are looking for a lecturer who will work with marine animals. Would you like me to write to Callan and suggest that he appoints you?' I said, "Thank you, by all means do that." I wrote a letter myself to Callan, and learned afterwards that he'd thrown it in the wastepaper basket, but when Pantin's letter arrived he changed his mind and appointed me to a lectureship in the Gatty Marine Laboratory (named after Rev. Gatty who presented £2000 for a new building in 1896). My new job was tenured; those were the days !

In 1955 I had written from Cambridge – on College notepaper – asking the Shell Oil Company whether they could help me to go and work on the coral reefs in the Red Sea. I had a very helpful letter back to say yes, if I presented myself at the Shell office in Port Said, they would look after me and take me down the Red Sea coast to the Egyptian marine laboratory at Hurghada. That is about 200 miles south of Suez on the Egyptian coast of the Red Sea – lots of reefs everywhere, and the nearest place to work on corals. I took my equipment in a rucksack.

Before I left Cambridge, Pantin had asked me to read a chapter of a book being written by Ted Bullock, who was a professor at UCLA. Ted had started to write a book which eventually had the title "Structure and Function of the Nervous System of Invertebrates" – a two-volume work, with hundreds of illustrations and thousands of references. The chapter I read was on Coelenterates, the group of animals I had been working on for five or six years. I knew the literature, and I'd seen lots of material

that Bullock was unaware of. So I rewrote that chapter completely, and sent it back.

The result was that Ted Bullock invited me to be a co-author in the great work, and he arranged for us both to have fellowships at the Center for Advanced Studies in Behavioral Sciences, on the Stanford campus in Palo Alto, California. The fellowship meant full 1st class return fares, plus a full salary from the Center for Advanced Studies. In 1958, Audrey, and I went with two children, at first to the house of Steve Wainwright in Berkeley, up Euclid Street, above the campus. Steve lent me his house, complete with housekeeper, while he and family spent the summer in Hawai'i. So for a summer while Ted Bullock was still in Los Angeles, I worked in the marvelous Berkeley library. There I was able to ask a Mexican, Polish or Russian translator to read from journals that were otherwise inaccessible to me. Then for the 12 months of the fellowship he and I lived in Menlo Park. I was still a lecturer at St Andrews and had to give my courses, so somehow I managed to shuttle back and forth.

When I went back to the Gatty in 1959 after California, I found that the Director, Jimmy Dodd, was in the final stage of leaving, and there was about 15,000 square feet of vacant lab space. I was appointed Director, soon attracted a number of bright and enthusiastic young men, and started a golden decade of research on the neurobiology of invertebrates, developing neurophysiological techniques as we went. We had a great deal of money coming in, because in a marine laboratory you can apply to the White Fish Authority, the Nature Conservancy, the National Development Commission, private foundations and the usual research councils. The art of funding a laboratory from all these sources was learned from Ted Bullock, who schooled me, American-style. He made me go to labs all around America and give seminars.

When writing The Book was finished, at the end of 1963, we had all the students in the Gatty sorting the index, with cards spread in rows on the floor. Writing, checking and indexing those volumes was such a task that it was suggested that I never need work again – which was totally untrue! The royalties were sufficient to build a new house in St Andrews.

The book that Ted and I wrote did not initiate the growing interest and subsequent importance of simple invertebrate preparations for the analysis of neuron function. That had already started with Hartline on Limulus eye (Nobel prize 1967), Hodgkin and Huxley on squid giant axons (Nobel prize 1963), Katz, Kuffler, Fatt, Hoyle, Burt and Catton, Florey on arthropods, and Arvanitaki, Tauc and others on molluscs. The book, however, opened the eyes of students to the possibilities made obvious by the beautiful anatomical studies spanning 50 years from Retzius to Alexandrowicz. Ted Bullock, himself together with Hagiwara,

took advantage in 1957 by introducing the giant synapse of the squid as a model of chemical transmission. Many of the numerous electrophysiologists who followed found their life's work by leafing through the pages in a search for big neurons and new ideas, for example, the leech ganglia, the crustacean oesophageal ganglion and the giant neurons of the squid and the marine slug, *Aplysia*. The Nobel prize for medicine given to Eric Kandel in 2000 for his discovery of the effect of cyclic AMP on the memory of synapses (and subsequent efforts on memory retaining drugs) can be traced back to the influence of Steve Kuffler and Ladislav Tauc, and, of course, the accident of having a French wife.

As a result of these contacts with the American scene, and because we were familiar with the new and the old literature, the Gatty just boomed. Everything we touched seemed to turn to gold. Everybody was very happy, and students worked all hours in the laboratory. Some even slept there, despite the lack of Insurance. If you have a marine laboratory, you have an enormous variety of challenges for research biologists.

One of the key factors was the lack of industry in St Andrews, except for hand-making golf clubs for rich players, so it was possible to recruit excellent boys and girls from the local school and train them as technicians. We were also lucky to find a local man, Charlie Roemmele, who had retired as an electronics expert from the Navy and wanted to live in St Andrews. We built an excellent workshop, in the charge of Roland Jack, (later a County Councilor) who was recruited straight from school. The new equipment that we designed and built gave us an edge over other laboratories, for a time.

So began the great procession of students who passed through over the years. They have been an enormously productive and entertaining lot. It was my custom after the early years not to publish with my students, but always to suggest that they publish their own papers in their own name, as I had done. There must be a couple of hundred of their own papers. That is unusual now, because these days a professor has to put his name on the work to keep up the flow of grants, an iniquitous system that destroys the personal ownership, pride and confidence of the very people you are trying to promote.

When I was at Palo Alto in 1959 I had talked with experimental psychologists about learning. I remembered that Pavlov had done an experiment with dogs, sounding a bell and then shocking or feeding them. So I thought, 'Let's see if we can teach locusts to avoid a shock at the sound of a noise.' When I went back to St Andrews I wrote to Wigglesworth for some locusts and instructions how to breed them. Our lab cleaner, Mrs Stevenson, asked me if I could find a job for her husband, John, who had been a postman but had to give up work because

he had a bad heart. I trained John to keep and breed locusts, besides all the usual jobs around the lab, and he became one of the most diligent and dedicated assistants that I have known. He attended so closely to the locusts that he started to look like one. I always had locusts in the marine lab. Some of my students worked on them for years, and still do.

The locust's ear is on its thorax, and I didn't believe that the learning would be in the locust's head. The circuit was arranged so that the plate was divided up into segments, and if a locust had a leg on one and the other leg on another, then it would get a shock. They never responded to the sound. But the locusts would stand on one leg and support themselves on the roof of the cage or in some other posture such that there was no return circuit and they didn't get the shock

Then I found that if a locust was suspended above a water surface and got a shock whenever it touched the water, in a few minutes it would learn to hold its foot just above the water surface. What's more, if you cut the head off after it had learned, the learning persisted. And if you taught a headless locust to hold up a leg up, and then tested it on the other leg, the learning was transferred. So we had a very simple learning preparation in an insect ventral ganglion with a few thousand nerve cells. I published this in '62 as 'Headless learning in insects'. It got into the elementary psychology textbooks to show that learning does not require a brain. A number of other scientists took this up, although I don't think they advanced very far with the mechanism. But for a psychologist, headless learning was quite something!

Although many insects have ears – crickets, cicadas and so on sing to each other – the standard story was that they did not have pitch discrimination: they detected only the amplitude of the wave-form, not its frequency. However, in 1961, when calibrating the locust ear, I found different groups of sensory neurons responding to different tones and single nerve cells in the central nervous system that behaved similarly, in a way that demonstrated pitch discrimination. The discovery really annoyed at least one German professor who had published the old story. I also discovered how easy it is to get into a new topic when you have the basic skills and have read the literature. These experiments illustrated that the field is wide open for those who try. It was not the last time that I trod on toes on someone else's patch, but more of that anon.

In 1992, Burt and Catton at Newcastle published a ridiculous theory that the retina of the locust had super-resolution because there was summation of rays within the retina. We had locusts and three students, John Scholes, John Tunstall and Steve Shaw, who were enthusiastic about sticking microelectrodes into the locust retina. We worked out the fields and sensitivities of the locust retinula cells and showed that the Newcastle theory was rubbish.

At the Gatty, we managed to get an extension to the building, which brought with it an equipment grant that was extremely generous. We were able to buy a new electron microscope. There were no trained technicians in St Andrews, but Ray, a watch repairer, answered my advert in the Citizen. We sent him to London on a two week course, and he turned out to be intelligent, handy, and very good company to work with. He had a Jazz Band, however, that played all over Scotland, so he was sometimes missing, and we found that all the dirty watches in St Andrews were cleaned in our new ultrasonic cleaner that was meant for the components of the electron microscope. No harm done. We turned out a lot of new descriptions of fine structure with the EM, notably the cilia of *Opalina*, the giant cilia of *Beroë* and the retina of a variety of insects and crustaceans.

The events that rule our lives have strange twists. In 1966, a telegram arrived from Clem Market, chairman of the biology faculty at Yale University: "Our member of staff (name given) has unfortunately eloped with the wife of another member of staff, and is not likely to come back." He said. "The course on Comparative Nervous Systems is due to start in two week's time. Would you please come and give the course? What are your terms?" I named a sum equal to a professor's salary plus the air fares in order to commute about every three weeks back to St Andrews – and he immediately agreed. I rented a room in Newhaven and by using the limousine service to Kennedy airport, I commuted back and forth to Scotland. David Frost, appearing in shows in London and New York, was on the same flights. American students demand extensive class sheets and literature. So I wrote it up as a book – '*Interneurons*'.

The cash I earned was banked in the USA. The following year, Steve Shaw and I were offered fellowships at Woods Hole Marine Laboratory for a summer's research. So, I took Audrey, my 4 children and Audrey's mother, granny Lightburne, by ship from Glasgow to the World Exposition at Montreal and then drove down to Cape Cod in a hired car. We spent a good deal of the summer fishing for eels at Sippewissett, visiting Mystic Seaport, Audrey's American friends and relatives, and exploring Nantucket, while reliable old Steve stayed in the lab and did the work. Unknown to me, the end of an era was approaching. A Pony Express Cable arrived with an invitation to visit Australia with a view to accepting a job as a founder professor of a new Institute in Canberra, with a ticket credit attached. Within a few days I was in Australia and they had offered me the job. Life was regenerating itself anew.

Looking back, it was not clear at the time that I was wise to take the chance to go. Indeed, my research had prospered, the Gatty had been built into a substantial graduate student centre. There were underlying

problems, however, that were intrinsic to the position there. First, the academic staff were appointed by the Professors of Botany, Zoology, Physiology in St Andrews Uni, and Pharmacology in Dundee Uni, so I had no staff of my own. Secondly, these professors could never agree, so I ran the place without their assistance, often by the technique of *fait accompli*, which does not make friends. There were too many diversions of valuable time. I was finding the grants to fund all the research and many of the stipends, including some technicians. There were ominous signs that grant money would become scarce. The building was at the East end of the town, next to the sewage works, while the Uni was expanding at the West, posh side of the town. On the research side, I had probably spotted the fruit that hung the lowest during 13 years. There remained plenty of interesting animals and their problems, but I personally saw no new “great” research there for me. It would have been difficult to establish molecular biology, isotope tracing, mass-spectroscopy, or other expensive new subjects, that the most interesting experiments required. Besides, St Andrews was damn cold.

By moving, I took my family and myself away from the valuable friends and connections built up over the years. All I took were my skills and a library of about 50,000 reprints on invertebrate nervous systems. The family loyally supported the move, which turned out well for Audrey, who immediately found a job in the Health Service. Within a year she was chief social worker in Psychiatric Services, with powers to “fetch a policeman” if necessary. My 4 children suffered at first, by loss of friends and uncertainty in a new culture, but none of them have shown any sign of wanting to return to England or Scotland. At the ANU, I was a fresh face full of promise, with honeymoon expectations that a new star was rising in the Southern sky. As indeed it did.