3

Cambridge

Aaron and Liebe's first glimpses of England were the lights of Weymouth as they approached the English coast at night through the Needles channel. They docked at dawn. To the young couple impatient for the new life, mooring the ship at Southampton seemed interminable. Even more time was consumed in getting through customs and immigration. Finally, they were on the train to London. Near London, the train ride to Waterloo Station exposed miles of monotonous grey back-to-back houses. Moreover, it was already the equinox, when the sun struggles up to 38° above the horizon to yield a pale autumn light. It was not Cape Town.

The Klugs arrived at London around midday. They were met by Elana, an old friend from the Hashomer Hatzair, who had booked them into a hotel in Bayswater. With her help they collected the smaller luggage; the large crates and trunks had been sent on to Cambridge. After checking in at their hotel, they set out on a walk of discovery through Hyde Park to Piccadilly, past Buckingham Palace, the Mall, Trafalgar Square, the Strand, and then back to Piccadilly, essentially taking a stroll through the top row of the Monopoly board. London was very grey, with bomb-craters everywhere. The people looked depressed. Food and fuel were rationed. The streets were still lit by gaslight. However, it all seemed somehow familiar: over the years one had read and heard so much about London and seen it all, courtesy of Pathé News. Breakfast at the hotel was interesting: Aaron recalled that it

https://doi.org/10.1017/9781316550304.005 Published online by Cambridge University Press

was the first time he had eaten something called 'bloaters' (smoked herrings) for breakfast, although reading *Comic Cuts* had prepared him for the dish.

They met up with old friends from Cape Town, Bennie Kaminer and his wife Freda. As befits a cinema addict, on their first Saturday night in London Aaron took Liebe and the Kaminers to the cinema in Leicester Square. Here was a taste of cultural differences, queuing for the cinema. Nevertheless, the movie was memorable: Orson Welles in 'The Third Man'. Aaron possessed an up-to-date *Bacon's Guide*, which he proudly used to navigate on buses across north London to visit the sister of their old Cape Town friend Bernard John Krikler. Bernard and his wife Berenice would later move to London.

A couple of days later, on 17th September 1949, the Klugs proceeded by train from Liverpool Street Station to Cambridge, happily not scarred by bombing, arriving at one of the longest railway platforms in England, and duly sought refuge in the Blue Boar Hotel. The Blue Boar was across the street from Trinity College where Aaron held his research scholarship. Many inns, in spite of their dating from the fifteenth century, when Cambridge was still a busy port, nevertheless vanished with little trace as they were absorbed into the expanding colleges. Thus the Blue Boar Hotel, which was at one time a coaching inn – albeit a relative newcomer from the seventeenth century – is now an annex of Trinity College that has spread across Trinity Street to take up all available space as far as Sidney Street. However, in 1949 the Blue Boar was still an upmarket hotel where the better-heeled could stay while visiting their respected offspring.

The Blue Boar Hotel was not affordable for more than a few days. Where should they live? An enquiry with the omnipotent Trinity College porters indicated that the Klugs might enquire of Mrs Heffer of Heffers Bookshop next to the Red Lion Inn (long since demolished) in the small street known as Petty Cury. Mrs Heffer was associated with the Commonwealth League, founded to foster friendship between the peoples and students of the Commonwealth; she duly introduced them to Mrs Fuchs, whose husband Vivian Fuchs was away on his first expedition to the Antarctic. Bad weather on a massive scale marooned him there for three years. In the meantime, in her generous Barton Road house on the western perimeter of Cambridge, Mrs Fuchs indeed had space. She could offer the Klugs a room with its own bathroom

https://doi.org/10.1017/9781316550304.005 Published online by Cambridge University Press

and central heating. *Pro tem*, Aaron could use Vivian Fuchs's study. So the Klugs moved into a Georgian house with an immense garden and woodland – all for two guineas a week – although transport from this remote boundary of Cambridge necessitated owning two bicycles. The rent included the use of the kitchen, but as Liebe's family had always managed to have a cook, Liebe was without any real culinary experience. Nor was the very old-fashioned gas stove of any great help. Mrs Fuchs employed a live-in housekeeper; initially Liebe was rather messy and the housekeeper became most unenthusiastic about having her in the kitchen. However, things settled down, and the housekeeper did manage to teach Liebe how to make lemon meringue pie and a few other dishes.

Joyce Fuchs – formerly Joyce Connell, and Vivian Fuchs's cousin – had married Vivian in 1933. She was a skilful climber and outdoor enthusiast, who accompanied Fuchs on his expedition to East Africa in 1934. The findings from this expedition, in which two of their companions died, gained Fuchs his Cambridge PhD. However, his great achievement was the crossing of the Antarctic. On 2nd March 1958 he conducted his party into Scott Base on Ross Island, having made the 2,158-mile journey in 99 days. He was greeted by congratulatory messages from all over the world and was awarded a knighthood.

Although at this time Joyce Fuchs was living alone (her children were away at boarding school, and Vivian did not return until April 1950) she kept up her standards: she changed for dinner every evening. Moreover, lunch was served at the dining room table, with the serving dishes appearing through the hatch. Even food rationing was not allowed to have an impact on this genteel tradition. On Sundays, a friend came to lunch. To preserve the illusion that she was a guest even in times of rationing, the friend would come round to the kitchen door on Saturday afternoon and pop her chop into the fridge, ready for the housekeeper to prepare for Sunday lunch with Mrs Fuchs's chop.

Now that they had a *pied-à-terre*, Aaron needed to organise his life. He held the prestigious 1851 Exhibition fellowship, which was endowed with £350 per annum. The Exhibition of 1851 had been an enormous success and had made a substantial profit. With the proceeds the Royal Commission purchased 86 acres of land in South Kensington and established three famous museums, the Royal Albert Hall, Imperial College, and the Royal Colleges of Art and Music. When this huge undertaking was largely complete, there still remained sufficient funds

https://doi.org/10.1017/9781316550304.005 Published online by Cambridge University Press

for the Commission to set up an educational trust giving fellowships and grants for research in science and engineering. Aaron was paid from this trust.

Trinity is the largest college in Cambridge. Over the great Tudor gateway presides its founder Henry VIII; following some long-ago prank, he holds a chair leg rather than the more appropriate sceptre. On the right, embedded in the gate, is the Porters' Lodge. Above the Porters' Lodge are rooms at one time occupied by Isaac Newton. Through the gate is the Great Court created at the beginning of the seventeenth century by Richard Neville who razed a number of existing buildings to clear the necessary space. On the north side of the court is the famous clock that chimes the hour twice, once for Trinity, and once, a fifth higher, for Trinity's neighbour, St Johns. At midday this gives rise to 44 seconds of chimes, enough time for an Olympic athlete to run round the Great Court –although Aaron was not a great runner and had no intention of trying this feat.

As Aaron held a Rouse Ball scholarship from Trinity, the activation of his scholarship entailed seeking out the Junior Bursar. The Senior Bursar is responsible for managing the endowment of the College, a position of great financial responsibility, whereas the Junior Bursar tended to be entrusted with more mundane functions such as organising Aaron's scholarship. Aaron went to Trinity Great Court to see Charles Kemball, the Junior Bursar, who was a surface chemist. The Bursary is housed in a Tudor staircase on the east side of the Great Court to the south of the Great Gate. Kemball, a large redheaded Scott, held a half-blue for judo and was member of the Hawks' Club[1]. He announced to Aaron that, in view of the fact that he already held an 1851 Exhibition, his Rouse Ball scholarship would be a token £50 per annum. Although he was scarcely three years older than Aaron, on hearing that Aaron was married, Kemball became alarmed and delivered the riposte, "I suppose we'll be having perambulators on the lawns soon!"

While Aaron was in college, Liebe stood up against a college wall seeking warmth in the weak September sunlight. It was before the start of term and the town was empty. She felt lonely and out of place.

[1] Membership of the Hawks' Club is limited to male sportsmen in Cambridge who have earned a University Blue or Half-Blue, i.e. have taken part in the match against Oxford in a particular sport.

However, the native East Anglians are nice enough folk, if you can understand them, and Liebe was offered friendship by a porter in his bowler hat. Nevertheless, on Sunday evening when the bells of Great St Mary tolled for Evensong she knew that she could never really belong. How could an outsider, particularly a woman, relate to this exclusive male academic enclave? Liebe spent much of her life trying to solve this conundrum.

Aaron next visited his tutor, Walter Hamilton, who had translated Plato's *Symposium* into English for the Penguin Classics edition. Not that Aaron was expected to benefit from Dr Hamilton's academic skills: in the tradition of Cambridge Colleges, a tutor was responsible for general supervision. As a research student Aaron was *in statu pupillari*. Students mostly lived in college. However, since the colleges never seemed to be large enough, some lived in licensed digs (lodgings). In digs the landlady was in the first instance held responsible for the student's behaviour. Landladies were known to take their responsibilities quite seriously, even to measuring the depth of water in the bath so as to avoid squandering national resources (the war-time government had decreed that baths should be no more than 5 inches deep). Students were expected to eat in the college hall, for which purpose they would surrender their food ration books to the college. Moreover, in 1949 *in statu pupillari* certainly did not embrace the concept that a student could be married. Thus Aaron's case was not simple and challenged Hamilton's creativity. In the end, the Klugs' lodging in Barton Road was deemed to be licensed – and Liebe became Aaron's official landlady. She was required to submit and sign a list of 'kept nights' – that is, nights that Aaron had spent in Cambridge.

So on to the Cavendish Laboratory, at that time the fiefdom of James's one-time mentor, Sir Lawrence Bragg. The entrance to the original Cavendish from Free School Lane is through a solid mediaeval gateway. The stone-faced building framing the gateway housed the teaching labs, the notoriously uncomfortable lecture room, and the Cockcroft–Walton accelerator, built in the 1930s and capable of accelerating protons to huge energies by applying up to half a million volts. John Cockcroft and Ernest Walton used this apparatus to split a lithium atom in two and were duly awarded the Nobel Prize for Physics in 1951. Opposite the gateway in a large courtyard stood the Austin Wing, a rather functional four-storey brick building built in 1930, containing

https://doi.org/10.1017/9781316550304.005 Published online by Cambridge University Press

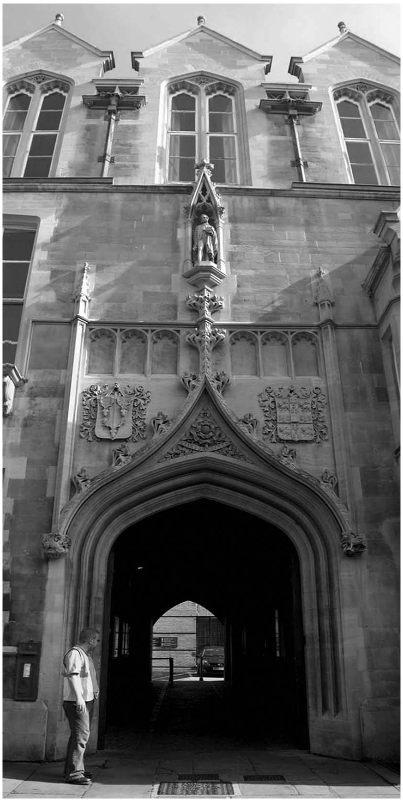

Figure 3.1 The gateway to the old Cavendish Laboratory (from Wikipedia; photo by William M. Connolley. Licence: CC-BY-SA 3.0)

the Cavendish Professor's office, and numerous departments of the Cavendish. Adjoining the Austin Wing was the Royal Society Mond Laboratory for low-temperature research.

On the basis of R. W. James' recommendations, Aaron had already been accepted by Bragg to do his PhD in the Cavendish. On the first floor was the nascent protein crystallography group founded by Max Perutz and now funded by the Medical Research Council (MRC). James was in regular correspondence with Lawrence Bragg. Bragg told him about the work of Max Perutz on the structure of the protein haemoglobin and how Perutz had been joined by the dynamic young John

https://doi.org/10.1017/9781316550304.005 Published online by Cambridge University Press

Kendrew, who was working on myoglobin, haemoglobin's smaller cousin. In Cape Town, James had read some of these letters to Aaron. Aaron had thought of working on something crystallographic but unorthodox: protein structure sounded about right. Therefore, he was somewhat taken aback when Bragg calmly announced that Perutz's MRC group was full. Aaron, who knew he was a clever fellow, contemplated long on what might have gone wrong. His analysis was that the previous year James had sent a student who had given up after one year, which would have put a negative spin on Bragg's appreciation of James's judgement. Be that as it may, Aaron arrived just after Perutz had recruited Francis Crick, who with his continuous loud voice and dominant personality may well have convinced Lawrence Bragg that Perutz's group was full to overflowing.

Substances as diverse as sand, amethyst, mica, cement, glass and asbestos all consist basically of silicon and oxygen. How come there are so many different minerals? One of Bragg's achievements in Manchester was to work out many of the silicate structures. On the basis of these and his own results, Linus Pauling was able to formulate the basic rules for making the silicate structures. They are all built from the same unit: a silicon atom surrounded by four oxygens to form a tetrahedron. These tetrahedra can then combine with each other with various symmetries, some crystalline, some fibrous, and with various metal ions and water to form the host of silicate structures that make up most of the solid earth we live on. Bragg offered Aaron the chance of working on the phenomenon of disorder in silicate structures, a subject he had initiated. The problem is actually rather interesting, but Aaron was unimpressed and decided to look further afield. Since Aaron felt it necessary to consult James on every decision, and since his advice could only be sought by mail, it was a couple of months before Aaron finally settled on a PhD project.

Aaron next consulted John Lennard-Jones, the Plummer Professor of Theoretical Chemistry. Lennard-Jones was famous for working out the force between atoms of a noble gas (such as helium), which is known as the Lennard-Jones potential. Now one great success of quantum mechanics was to allow one to calculate the distribution of electrons around the nucleus of a hydrogen atom. This could be derived exactly from the Schrödinger equation. The background to this equation was the discovery that particles (such as electrons) sometimes behave like waves.

https://doi.org/10.1017/9781316550304.005 Published online by Cambridge University Press

Louis de Broglie had proposed in 1923 that there is a wavelength associated with any particle that depends inversely on its momentum (speed times mass). Schrödinger's equation was an extension of Newtonian mechanics that takes account of the wave nature of particles. Since electrons are very light, their small mass gives rise to wavelengths about the size of an atom. Thus the wave-like properties are very important when trying to calculate how electrons move around, especially in atoms. However, the Schrödinger equation can be applied to any mechanical problem, even a game of cricket, but here the wavelength associated with the cricket ball is so incredibly tiny that it's best to forget about it and just keep your eye on the ball. It turns out that the possible solutions to the equation applied to the hydrogen atom (one proton plus one electron) are grouped in shells with different symmetries and characteristic energies. These are known as atomic orbitals. Electrons, it transpired, could not just be in any old place but had to reside in one of these orbitals. If they jumped from one orbital to another they had to give up energy (or absorb energy) as light of a well-defined colour. For atoms with many electrons (that is, all atoms except hydrogen), the formalism becomes very complicated, and solutions to the Schrödinger equation can only be obtained by numerical methods. Nevertheless, the symmetries of the orbitals from the hydrogen atom can be carried over to atoms with many electrons. Metaphorically, as you add more electrons you fill up orbitals with ever more complicated symmetry. With some wonder, it was noted that the enumeration of the possible orbitals provided the theoretical basis for Dmitri Mendeleev's periodic table of the elements. Furthermore, it became possible to understand what chemical bonds were: they were electrons sharing orbitals between two atoms. Suddenly chemistry became a numerical science like physics.

In the 1920s, Lennard-Jones had been Professor of Theoretical Physics at Bristol where he produced a very important method for computing molecular orbitals (the distribution of electrons in a molecule) out of mixtures of atomic orbitals. One of Lennard-Jones' pupils was Charles Coulson, Professor of Theoretical Physics at King's College London, whose work on the electronic structure of organic molecules had so excited Aaron while he was working on triphenylene in Cape Town. This looked like Aaron's métier. Nevertheless, despite his early enthusiasm, after his discussion with Lennard-Jones, Aaron decided he did not wish to become just another theoretical chemist.

One of the effects of Bragg having come to Cambridge from Manchester was that it encouraged a co-migration of colleagues from Manchester, all of whom were friends of James and therefore available to Aaron. Douglas R. Hartree, Plummer Professor of Mathematical Physics in Cambridge, had been in Manchester until 1946. Hartree was very good at sums, or to put it more formally, was an expert in numerical analysis. In the 1920s, he was thrilled by the Bohr theory of the atom, the precursor of quantum mechanics, and his PhD was on numerical solutions to Bohr's equations. As he finished it, Schrödinger's equation was published. Hartree immediately set to work to obtain numerical solutions.

Schrödinger's equation is a differential equation. Such equations tell you how much one property of some problem alters when you make a small change in another property. This provides a method for getting numerical solutions: you make a small change in a basic property of the system (such as time) and work out from the differential equation what this does to the output (such as distance). Then by adding up (integrating) the outputs from different terms in the differential equation, you end up with, for example, the trajectory of a cricket ball. However, after a few times of going through this procedure with a pencil and paper, boredom sets in and one begins to devise machines to take out the drudgery. The use of mechanical devices to solve equations started in the nineteenth century with Charles Babbage's 'difference engines'. Babbage's machines manipulated numbers and were basically mechanical computers. The results of a calculation were printed out as numbers. Thus Lord Byron's daughter, Ada Lovelace, who worked with Babbage, could claim to be the world's first computer programmer. Another approach was the 'differential analyser', which was invented in 1876 by James Thomson, brother of Lord Kelvin. This was an analogue device. It did not deal in numbers but rather used cams and gears to produce movements responding to some input, such as time. The crux of the system was the integrator: this produced a final movement that was the sum of all the movements arising from the input movement, for example by having cams riding on cams, or summing torques by twisting a rod. Some astronomical clocks are built round integrators (the Strasbourg Astronomical Clock from 1842 in the Cathedral has three cam-type integrators for summing Fourier series: see Figure 3.2). The output is a displacement (for instance a pointer on a dial). About

Figure 3.2 The Strasbourg Astronomical Clock contains three mechanical integrators for summing Fourier series that calculate the positions of the sun and the moon. The series is summed mechanically by using cams riding on cams. The cams have a cosine wave profile that repeats once, twice, three or more times per revolution. The size of the profile determines the strength of contribution to the summation. The left integrator has two terms in the series, the centre six terms and the right integrator just one. (From Wikipedia; photo by David Iliff. Licence: CC-BY-SA 3.0)

1931, a practical version of Thomson's differential analyser was constructed by Henry Nieman and Vannevar Bush at the Massachusetts Institute of Technology (MIT) in Cambridge, Massachusetts.

Douglas Hartree constructed a version of the MIT machine at Manchester and became an enthusiastic user. During the Second World War, Hartree and his differential analyser became an essential part of

https://doi.org/10.1017/9781316550304.005 Published online by Cambridge University Press

the national war effort, doing many of the design calculations for the magnetron that was the mainstay of British radar. One of the problems with which he and his analyser were involved was how to make steel more rapidly. During the war, the usual practice in the steel industry was to take a white-hot iron ingot, quench it in water and wait for nine hours. Could one do better? It turns out that this is a difficult problem to simulate. Nevertheless, using an approximate theory, Hartree did manage to show that you could produce complete transformation to steel in four hours, which was a huge saving.

Through the Manchester connection, Aaron went to see Hartree, who suggested that for his PhD he might sort out the steel problem properly. The iron used for making steel contains carbon dissolved in the liquid iron. When steel solidifies it initially forms a 'solid solution', with the carbon remaining dissolved throughout the iron to create an iron–carbon phase called austenite. As the temperature falls, grains of ferrite, which is pure iron, start to form out of the austenite. As more grains of ferrite form, the remaining austenite becomes richer in carbon. At about 723 °C, the austenite, which now contains 0.8% carbon, changes to pearlite. The structure that results is a mixture consisting of white grains of ferrite intermingled with darker grains of pearlite. Each of these transitions gives rise to a burst of heat. The properties of a steel depend on the details of the final mix. To understand all the different crystal forms, you need a knowledge of crystallography; to work out how the heat gets out requires a good head for calculations. Aaron seemed to have the requisite talents. However, it turned out that the problem needed more: it needed the concept of the speed of nucleation of the different crystal forms of steel and how their growth continually modified the properties of the bulk ingot of steel. Moreover, the rate of formation of the nuclei depends upon the rate of cooling. These ideas came from Aaron: he managed to develop a mathematical model of the austenite to pearlite phase transition, realizing there were two problems, nucleation of a new crystal and subsequent growth. He derived a differential equation that introduced a new time scale for each nucleation. By numerical analysis of his equation, he was able to calculate the rate of growth of new phases and got a very good fit with the available experimental data. From the mass of technical literature, Aaron was able to deduce the dependencies of nucleation and growth on the ambient temperature. He also drew on results from simple

https://doi.org/10.1017/9781316550304.005 Published online by Cambridge University Press

experiments with cylindrical bars that he had set up with Hartree at Baldwin's steel mill in Sheffield.

The problem appealed to Aaron because its solution was useful to society. Nevertheless, Aaron's thesis was never published, which accounts for the fact that in the ensuing 50 years his results have been rediscovered in various forms without any reference to his pioneering work. In later life he was always somewhat dismissive of his steel work, proudly remembering only the ideas of nucleation and growth as the concepts necessary to explain how and why the phase changes happened during cooling.

Aaron needed to solve a partial differential equation for his work. He started by hand using a Brunswick calculator. Very soon, however, better methods became available. A motor-driven Marchant calculator could multiply and divide numbers through the offices of a fearsome collection of gears. Better than gears, electrical circuits and relays can be arranged to store numbers; even better are vacuum tubes (in UK English, valves) used as relays. To do anything useful you also need circuits that can add the numbers together. Then, by repetition of a set of instructions, one can calculate anything. The first important electronic calculator of this type was ENIAC (Electronic Numerical Integrator and Computer) built in the Moore School of Engineering in Philadelphia. ENIAC was designed to calculate artillery firing tables for the US Army, but its first serious use was in calculations for the hydrogen bomb. For a particular problem, the list of instructions that had to be carried out was set up by connecting cables and rows of toggle switches. ENIAC could not store numbers (or not many). It read in and put out answers on IBM punched cards. Hartree became an ENIAC enthusiast. But ENIAC was not quite a computer. John von Neumann and the group at the Moore School were thinking ahead and produced the influential report entitled 'Draft report on the EDVAC' (Electronic Discrete Variable Automatic Computer). EDVAC was a stored program computer with the same store for numbers and instructions, and with instructions executed serially.

But what constitutes a store? Nowadays numbers (and instructions) are mostly stored as magnetic blips on a thin coating of a magnetic oxide of iron that is somehow moved past a coil of wire to sense the magnetism. However, the technology of magnetic drums and tapes was not worked out until the 1950s. In the late 1940s, in a technology taken over from radar, numbers were stored in mercury delay lines: a loudspeaker makes a noise into one end of a long tube filled with mercury, and a few tens of milliseconds later a microphone can hear the sound arrive at the other end. Then you feed it back in again. Hence, circulating pulses of sound can be used to represent numbers.

In 1937, John Lennard-Jones founded the Cambridge University Mathematical Laboratory. Maurice Wilkes had spent the war working on radar and joined the Mathematical Laboratory after the war. In 1946, he visited the Moore School and was so convinced by von Neumann's plans for EDVAC that he went home and built one. EDSAC (the Electronic Delay Storage Automatic Calculator) was built with a small budget and with only two assistants, but even so it took up two floors in the old Anatomy School adjoining the Cavendish. EDSAC executed its first program on 6th May 1949. This was the first full-scale electronic computer to implement the stored-program principle. EDSAC became Aaron's differential analyser.

Programming in those days was a bit more strenuous than using a personal computer today. Instructions to the machine were prepared on punched paper tape that was read into the computer at the beginning of a session. One had to tell the machine in great detail what it should do. Numbers had to be fetched from the mercury delay lines and put into local stores (accumulators, made from vacuum tubes). Then the current instruction said how the numbers in these stores should be manipulated (added, subtracted, multiplied or divided) and where they should be put back into the delay line memory. Then the next instruction had to be found from the delay line and be worked on. This went on and on until the procedure is finished. The last instruction told the computer to put the answers out on punched tape. Just to keep you on your toes, there was a good chance of one of these 10,000 vacuum tubes (all ex-radar stock after the war, much of it German) packing up while you were working, which put you back to square one.

Alongside Aaron were John Kendrew and John Bennett, working out the world's first program to sum up a Fourier series on a computer (a digital version of the Strasbourg clock). During the long nights, John Kendrew's wife Elizabeth used to bring them coffee and sustenance (John's home was nearby in Tennis Court Road). With the energy of youth, Aaron finally got all his programs to work. However, in later life he was always wary of going too close to computers and avoided ever having to send an e-mail himself.

Aaron worked in the theoreticians' room at the Cavendish, a huge room with big windows down to the ground. His fellow research workers included Oliver Penrose, Charles Kuper and Stefan Machlup. Machlup had been a graduate student at Yale and was now a postdoctoral researcher in Cambridge. The impetus for his visit was provided by the sabbatical of his PhD supervisor, the Nobel Laureate Lars Onsager, who came as a Fulbright Scholar to work with David Schoenberg at the Mond Laboratory. Machlup was born in Vienna in 1927 and emigrated as a child to the USA. He shared a Jewish background with Aaron but unlike Aaron was a very bouncy fellow. He was fluent in five languages and an accomplished cellist. Arising out of his time in Cambridge, Machlup published with Onsager two frequently cited papers on the Onsager–Machlup–Laplace approximation. The theory addresses losses in thermodynamic systems not in equilibrium and applies to a wide variety of constituents and forces: nuclei in magnetic fields, atoms in a laser, molecules in chemical reactions, and even ions passing through biological membranes.

Onsager's original theory, for which he was awarded the Nobel Prize in Chemistry in 1968, applied to the coupling of forces and flows in changing systems near equilibrium (for instance a slowly flowing river). Pressure differences will lead matter (water, in our example) to flow from high-pressure to low-pressure regions, and temperature differences will lead to heat flow from the warmer to the colder parts of the system. When both pressure and temperature vary, it can be observed that pressure differences can cause heat flow, and temperature differences can cause matter flow. Even more surprisingly, the heat flow per unit of pressure difference and the matter (water) flow per unit of temperature difference are equal. Onsager showed that this symmetry was a necessary consequence of the statistical behaviour of molecules moving around. Aaron was fascinated by the Onsager relationships and incorporated his own extensions of the theory into his PhD thesis.

Cambridge is a great place for a polymath, and with Liebe often away in London, Aaron had time to spare. He sat in on the Part III Mathematics Tripos lectures, particularly on group theory and Dirac's quantum electrodynamics that had predicted the existence of the positron (a positively charged electron). The ability even to understand Dirac's esoteric formalism is only granted to a few gifted initiates. Naturally, it delighted Aaron.

Vivian Rakoff, Aaron's close friend from the Cape Town days, had whetted Aaron's appetite for the controversial English literature specialist F. R. Leavis, and Aaron attended his lectures. Leavis applied rigorous intellectual standards and attacked dilettante elitism, which for example he thought characterised the Bloomsbury group. In 1948, Leavis made a general statement about the English novel in *The Great Tradition* where he traced a path through Jane Austen, George Eliot, Henry James and Joseph Conrad to D. H. Lawrence. Leavis's main tenet was that great novelists showed an intense moral interest in life, which determined the form of their works. This echoed Aaron's humanist canon, which had been formed while observing the dreadful inequalities of apartheid. In the Leavis lectures Aaron made friends with the future novelist and literary critic Dan Jacobson and his wife Margaret.

Later, Leavis vigorously attacked C. P. Snow's suggestion that practitioners of the scientific and humanistic disciplines should have some significant understanding of each other, and that a lack of knowledge of twentieth-century physics was comparable to an ignorance of Shakespeare. Leavis's angry rejection of Snow and the 'two cultures' would have found little resonance with Aaron; but fortunately for his peace of mind, the confrontation between Leavis and Snow would not happen for another ten years.

In Cambridge, Aaron met his Cape Town colleague Allan Cormack, with whom he had had the alarming climbing experience on Table Mountain two years before. East Anglia is not renowned for its mountains, and apart from the risky nocturnal ascent of King's College Chapel there was not much climbing around Cambridge. Cormack had been trying to do his PhD in Cambridge; he was attached to St John's College, and his PhD Supervisor was Otto Frisch. In Birmingham in the summer of 1939, Otto Frisch and Rudolf Peierls had demonstrated that the splitting of uranium-235 would create a chain reaction that could be used to develop an extremely destructive weapon. After some delay, Otto Frisch was granted British citizenship and allowed to participate in the Manhattan project. In 1947 he was appointed Jacksonian Professor of Natural Philosophy at the Cavendish. Unfortunately, although he was a much-liked lecturer, his skill at running a research department left much to be desired. After two years of frustration and no results, Cormack got the offer of a lectureship from James back in Cape Town. Since Cormack, like Aaron, was a married PhD student the offer of a secure post seemed more important than a PhD. Soon after Aaron arrived in Cambridge, Cormack returned to Cape Town. He would never obtain a PhD; but shortly before Aaron, he was awarded a Nobel Prize.

Liebe and Aaron went to the Arts Cinema often: it was relatively cheap (1/6d – one shilling and six pence) and the programme changed twice a week. Nevertheless, while Aaron was accepted and integrated into the Cambridge scene, Liebe had neither friends or acquaintances in Cambridge, nor did she feel adequately fulfilled just by going to the Arts Cinema. She had hoped and expected that she could study with the Jooss–Leeder School of Modern Dance, which had been sited in Cambridge throughout the War. Unfortunately, in the autumn of 1949 the Jooss–Leeder School was no more.

At the beginning of the twentieth century, Isadora Duncan had developed a new form of dance based on classical Greek models, untrammelled either by the rigid rules of classical ballet or by their tight-fitting shoes. At the time, Isadora Duncan found more resonance in Europe than in her native USA so that, backed by the wealth of her lover's Singer Sewing Machine Empire, she opened an influential dance school in Berlin. During the Weimar Republic there was an explosion of dance activity – 'Ausdruckstanz' or expressionistic dance – in which Rudolf von Laban played a leading role. In 1925, Kurt Jooss and Sigurd Leeder, both students of von Laban, opened a new dance school, the 'Westfälische Akademie für Bewegung, Sprache und Musik', in Munster. In 1927, Jooss moved the Westfälische Akademie to Essen, and it became the 'Folkwangschule'[2]. Jooss's most important choreographic work, 'The Green Table', won first prize at an international competition for new choreography in Paris in 1932. It was a strong anti-war statement. On account of their ballet having Jewish members, in 1933 Jooss and his company had to flee Germany. They eventually found support from Dorothy and Leonard Elmhirst, the philanthropic owners of Dartington Hall in Devon. Dorothy's interest in dance arose from observing the development of Martha Graham's Modern Dance in

[2] Information about Leeder–Jooss has been obtained from *Dancing in Utopia: Dartington Hall and its Dancers* by Larraine Nicholas (Dance Books, 2007).

New York; Leonard had grown up in the British Raj and was friendly with Rabindranath Tagore (revered by Liebe's father) who enthusiastically furthered Indian dance. Thus the Elmhirsts welcomed the opportunity of establishing a world class school of modern dance. The Jooss–Leeder School of Dance was founded at Dartington Hall in 1934. There was also a companion touring company, the Ballets Jooss.

But after six successful years, this important experiment in establishing modern dance in England was terminated in 1940 because both Jooss and Leeder were interned as enemy aliens on the Isle of Man. They were released in 1941 and reformed the Ballets Jooss and the School of Dance, but the Dartington Hall connection was no longer available. Instead they finally found a home in Cambridge. They were put up in a large house on the western perimeter of Cambridge belonging to the Roughtons, 9 Adams Road. F. J. W. (Jack) Roughton was professor of colloid science. Alice Roughton, who was a family doctor, helped look after the dancers, and even installed a dance floor in the large living room. The Jooss School was supported by CEMA (the precursor of the British Arts Council), which was chaired by John Maynard Keynes. He, much to the dismay of his associates in the Bloomsbury group, had married a famous ballet dancer, Lydia Lopokova. Jooss added new works to his repertoire, including 'Pandora' (1944), containing disturbing images of human disaster and tragedy, which was later interpreted as foretelling the dropping of the atom bombs on Japan. Disappointingly, it was not a success[3]. Moreover, in spite of CEMA support, 9 Adams Road lacked the magic of Dartington Hall. Soon after the war, Kurt Jooss closed his ballet to take up an appointment in South America. In 1949 he returned to Essen where he re-established the Folkwangschule. In 1947, Sigurd Leeder opened his own school at Morley College, London, behind Waterloo Station, where he worked out his own teaching method, later known as the European Contemporary Dance Technique.

It became clear that Liebe's future lay in London, which could offer her both dance and friends. Thus on 5th December 1949, Liebe moved to digs in London on a weekend commuting basis. At the weekend, Liebe sometimes returned to Cambridge, sometimes Aaron went to London. Soon they were joined by Vivian Rakoff.

[3] In 'Dr. Alice Roughton', obituary by John Gregory. *The Independent* (8 July 1995).

https://doi.org/10.1017/9781316550304.005 Published online by Cambridge University Press

Rakoff had travelled on the mail ship to England with Ralph Hirschowitz and his first wife Tiby (Thelma), intending to leave them in England to go to Cambridge while they went on to join an immigrant ship in the south of France. But somehow this never happened. Instead of leaving them, in fact Rakoff travelled with the young couple to Israel. Here he joined a kibbutz on Mount Tabor, where a group of break-away Hashomer Hatzairs had already settled. He stayed there for about a year, and was there when Aaron and Liebe married. Then Rakoff returned to Cape Town by the same circuitous route. He decided he no longer wanted to be an actor but would rather pursue a solid middle-class career, so he took a Master's degree in psychology. In December 1949, after completing his Masters, Rakoff came to London to study medicine at University College Hospital. In due course he completed his medical degree and married his first wife Judy, who also came from Cape Town. However, the marriage was not a success: they returned to Cape Town and divorced. Rakoff returned to London and took up psychiatry. For some years he himself was analysed by Willi Hoffer, a student of Freud. Later, he returned to Cape Town, married his present wife Gina and then emigrated to Montreal, where he did an internship in psychiatry at McGill University. Then the family, now including three children, moved on to Toronto where Rakoff became Chair of the Department of Psychiatry and had an Institute named after him. He was much sought after for radio and television interviews, where no doubt his acting experience came to the fore. He also wrote a number of plays for radio and television.

Liebe (and Aaron at weekends) decided to share a London flat with Rakoff (who had come to terms with Liebe's marriage to Aaron) and another couple, the Fanaroffs. They found a flat in Clanricarde Gardens off Bayswater Road, where nowadays a one-room flat fetches £500,000. In those days, Notting Hill was not so salubrious. Indeed, prostitutes used to line both sides of Bayswater Road. The flat was filthy and no chair stood upright. Liebe's companions called it Clan-rickety Gardens. Nevertheless, although they had no money and food was rationed, they had plenty of fun. Refugees from apartheid South Africa were always turning up. Liebe started attending Dance School with Sigurd Leeder in a drafty church hall in Loudon Road, Swiss Cottage. In the second year it moved to somewhere behind King's Cross Station. At the same time, Liebe was trying to teach dance at a school in Clerkenwell. After the

https://doi.org/10.1017/9781316550304.005 Published online by Cambridge University Press

War, this part of London suffered an economic decline. The school turned out to be a hellhole: no other teacher lasted for more than one term, nevertheless Liebe survived for two.

Liebe attended the Leeder School from January 1950 until the middle of 1951. However, the Leeder method was very structured and technical. In Cape Town, Liebe had had a teacher called Lou van Eyck, who had danced with the Ballets Jooss. He came to London and watched a day of classes. He confirmed what Liebe already had been feeling: while the Leeder method was successful for some students, for her the classes were arid (as well as expensive). Leeder's rigid dance notation left no room for improvisation. Van Eyck felt that Liebe would be better off going to a selection of classical ballet, or indeed any other sort of dance.

In the summer of 1951, quite by chance, Liebe attended performances of a West Indian group – the Boscoe Holder Dance Company – in a little theatre off the Strand. Arthur Aldwyn Holder (known as Boscoe) was a dancer, choreographer and artist. Born in Trinidad in 1921, he showed early talent as painter and pianist. As he grew up he became fascinated by his island's culture. He researched and learned the local dances and songs, and by the late 1930s had a dance company depicting the music, songs and dances of Trinidad. In 1948, Holder married a member of his dance company, Sheila Clarke, and two years later with their son Christian they settled in London. Holder was befriended by the designer Oliver Messel, who introduced him to his Mayfair friends, including Noël Coward. In 1950, Boscoe Holder and his Caribbean Dancers, with Sheila Clarke in the lead, had their own show on BBC television, Bal Creole. His dance company performed at the Queen's coronation. Liebe joined the company and danced with them from the middle of 1951 until the Klugs departed for South Africa in the autumn of 1952. No doubt influenced by her South African childhood, Liebe showed great talent for dancing these ethnic forms. She performed a number of times with the troupe in a theatre off Leicester Square. Vivian Rakoff came to one of the performances and remarked acidly that Liebe stood out: firstly, she was technically much better than most of the troupe; secondly, in no way could she be construed as being West Indian. Aaron came when he was in London and encouraged Liebe to continue dancing with the Boscoe Holder Troupe.

https://doi.org/10.1017/9781316550304.005 Published online by Cambridge University Press

In the summer of 1950, Liebe and Aaron had at last visited Israel (of which more in the next chapter). The Cambridge University Jewish Society organised a tour including eight weeks as members of a kibbutz. Since they would be away for three months, Liebe gave up her place in Clanricarde Gardens. When they came back, Liebe lived for some months in a bed-sit in Belsize Park Gardens, just north of Primrose Hill, next to the house where her son David and his family live now. When the money ran out she became an *au pair* with the Golbergs, a South African couple who lived in a flat in Ennismore Gardens in South Kensington. He was a chest physician with an expertise in tuberculosis. They had a severely disabled child, and Liebe's main job was to wash the nappies (diapers). However, Liebe blotted her copy-book by not turning up after one weekend in Cambridge, and was replaced. In spite of this hiccup the Klugs and Golbergs stayed on friendly terms. Later, when the Klugs were living in London, they traditionally went to the Golbergs in Richmond for lunch on Boxing Day.

So for a few months Liebe bunked down and lent a hand with her old dance teacher Jennifer Craig from the 'School of Charm' in Cape Town, where Liebe had first started to dance seriously. Then for a short time she stayed in a flat that Vivian was sharing in St John's Wood. Subsequently, while she was rehearsing and dancing with the Boscoe Holder Troupe, she came to rest in a flat-share on the Bayswater road, near where she had started out.

In the meantime, in Cambridge, Aaron's lodgings were no less transitory. By April 1950, Vivian Fuchs's ship had been released from the ice and he was coming home. The Klugs were asked to leave. Aaron moved to share a flat in Chesterton Road with Doris Krook, an acknowledged expert on the later writings of Henry James, a fellow of Newnham and ex-University of Cape Town. There was drama associated with Doris: back in Cape Town, it was her spurning of his advances that had moved the future brother Elias to attempt suicide. Aaron had a tiny room in Doris's flat and shared her kitchen and bathroom. In the garden of the house next door, Aaron used to see a pretty young woman hanging out the washing. Years later Aaron learned that this was Stella Porter, wife of George Porter. He, like Aaron, was a future President of the Royal Society, and perhaps just as important, the future PhD supervisor of their second son David. While head of the Royal Institution, Porter mentored David to become a successful scientist.

In July 1950, Aaron moved again, to share a flat in Green Street. This apartment had views over the housetops of the town and, more important, a back door direct into Rose Crescent, which is but a stone's throw from the Arts Cinema. Aaron (and Liebe at weekends) shared with Richard, who was a librarian at the University Library, and Cecily, a teacher. This was very much an "open house" – anyone who cared to could pop in. The kitchen utensils were washed in the bathroom as the kitchen had no running water. The lavatory was two floors below. Later, their final share from June to September 1952 was with Asher and Shirley Korner in Luard Road.

Since Liebe was away in London during the week, Aaron had plenty of opportunity to eat in College, but somehow it never seemed to fit with EDSAC schedules; so he often ate with friends or made do with fish and chips in King's Street. He did not enjoy living without Liebe. Aaron dreaded the weekly partings and sought consolation in poetry. In one of his midweek letters[4] to Liebe, he quotes from W.B. Yeats collection 'The Wild Swans at Coole':

> Said Solomon to Sheba,
> And kissed her Arab eyes,
> 'There's not a man or woman
> Born under the skies
> Dare match in learning with us two,
> And all day long we have found
> There's not a thing but love can make
> The world a narrow pound.'

While Cambridge winters are cold, grey and miserable, the months of May and June are a delight. 'The Backs', the college gardens along the river, become a kaleidoscope of colour. The fragrant flowerbeds along the 'Wedding Cake' of St John's merit international recognition. Moreover, the dusk is so long and the dawn is so early that the hours of darkness are just an intermezzo. The College May Balls (held in the first week of June) are conducted in this magical ambience. Like Aaron, Asher Korner was at Trinity, but the Trinity May Ball was too expensive for impecunious pre-docs. However, at 2.00 a.m. the back gates of the

[4] Churchill Archives Centre: Klug Papers.

colleges onto Queen's Road were opened to facilitate a mingling of the summer night revellers. Thus, at 2.00 a.m., Asher, his wife-to-be Shirley, Liebe and a few other friends gate-crashed the Trinity May Ball. Naturally, one had to look the part. Liebe had it easy since her mother, apprehensive of clothes rationing, had provided her with a complete wardrobe for three years. They simply strolled in from Queen's Road and mingled. It was a warm summer's night, and there was music and a general air of gaiety – but the event was not as exciting as they might have hoped. That was the summer of 1950, and life was still a bit on the drab side in Blighty.

The Backs have more to offer. In May Week, the Cambridge Madrigal Society sings a concert from a raft of punts moored next to Trinity bridge. As dusk approaches, lanterns are lit and the raft is allowed to drift languidly past St John's under the Bridge of Sighs. Traditionally, the last item is John Wilbye's melancholy six-part madrigal 'Draw on sweet night – to shades of darkness find some ease from paining'. This is an enchanting experience. The Klugs had made friends with another South African couple, Margaret and Murray Carlin, who had two children and lived in the Grape House, Grantchester; Murray was studying for the English Tripos. During May 1951, Aaron and Liebe were walking to see the Carlins. The mile walk to Grantchester through the water meadows of the Cam is a delight, and they stopped on the way to picnic near the river. Suddenly they were regaled by ethereal music such as bewitched Ferdinand in *The Tempest*. It turned out, more prosaically, that the Cambridge Madrigal Society was rehearsing its May Week Concert on the river near Grantchester.

A couple of weeks later, Aaron went to talk over some aspects of his thesis work with Neville Mott, the Professor of Physics at Bristol. Murray Carlin was staying in town to swot up for his finals. In a break one evening, he invited Liebe to have coffee with him in Petty Cury, where she was introduced to Norman Podhoretz, who was also studying for his finals. Podhoretz was a clever Jewish student from Columbia University in New York, the star student of the great literary critic Lionel Trilling. At this time Norman was engaged to Jacqueline Clarke, who had been Harold Laski's secretary at the London School of Economics (LSE); she later married Huw Wheldon of TV Monitor fame and became a successful author. Laski recognised her potential and organised a bursary for her to be a mature student at LSE. The May

Balls were looming after finals. Podhoretz had a ticket for the Clare College May Ball but also had an infected big toe, so that he could barely walk. Moreover, it transpired that Jackie Clarke did not want to interrupt her studies to come up for the May Ball, so to use his ticket he invited Liebe to join him. Out of sympathy for his plight she agreed (moreover, an invitation to a May Ball is not to be turned down lightly). Liebe's store of clothes was at last depleted so she borrowed a ball gown from an American friend. Unfortunately, the friend was nearly six feet tall, a height difference too great to be accommodated with heels, so Liebe spent a day taking up the hem. She went to the ball, and spent most of the evening at Clare College in a strictly non-romantic mode commiserating with Norman Podhoretz. However, Liebe felt that she had created a situation in need of resolution, so she invited Podhoretz to meet her husband in Luard Road. Aaron and Podhoretz disliked each other at first sight. Yet there was a spark of recognition between them. Over the years, Podhoretz and subsequently his wife, Midge Decter, became close friends of the Klugs. Through Podhoretz, they became acquainted with Steven Marcus, who had also studied at Columbia with Lionel Trilling. Aaron, Steven Marcus and Norman Podhoretz became firm buddies, so much so that Liebe subsequently referred to them as 'The Three Musketeers'.

In the autumn of 1952, at the end of the three years allocated for the PhD, Aaron and Liebe were keen to get back to Cape Town. Aaron's 1851 Exhibition Scholarship included a return first-class ticket. Liebe went to the Headquarters of Union Castle Line in the City to try to persuade them to change this into two cheaper tourist-class tickets, but they refused. Liebe had to buy another cabin-class ticket and Aaron had to downgrade. They had been away for three years, but now the return date was fixed, even though Aaron was now assimilated into the Cambridge world and some large part of him wanted to stay. Rather belatedly, he decided to try for a Junior Research Fellowship at Trinity College. These Fellowships are awarded on the basis of publications, often a PhD thesis. Aaron suddenly realised that his thesis had to be in College before they sailed, which left them scarcely two weeks to get the whole thing together – and six copies were required. The Klugs were now residing with Asher and Shirley Korner. Shirley and friends helped with the organisation of Aaron's thesis. There ensued a frantic typing with five carbon copies, writing in of mathematical formulae

https://doi.org/10.1017/9781316550304.005 Published online by Cambridge University Press

and sticking in of figures and getting it all to the binders. Finally, on the evening before the sailing, a copy of the thesis *The Kinetics of Phase Changes in Solids* was deposited at Trinity Porters' Lodge. Then at the crack of dawn, driven by Asher, they were off to Southampton with a picnic breakfast in Windsor Great Park to get the mail boat to Cape Town. The first Cambridge adventure was over.