The Collected Papers of Albert Einstein: Volume 1 – The Early Years, 1879–1902; Volume 2 – The Swiss Years: Writings 1900–1909; Volume 3 – The Swiss Years: Writings, 1909–1911. English Translation. Princeton University Press, Princeton, New Jersey – a combined review.

When Albert Einstein died in April 1955 at the age of seventy-six, his estate passed into the joint custody of his long-time secretary Helen Dukas, and his close friend Otto Nathan who was named sole executor. Making Einstein's writings and papers – especially his collected scientific works – widely available to the community of scholars has taken an inordinately long time, not merely because of the volume of material involved. Under the joint sponsorship of the Hebrew University of Jerusalem, where the Einstein Archive of 43,000 documents is housed, and Princeton University Press, and with John Stachel of Boston University as overall Editor, a monumental series of about forty volumes – the Documentary Edition – started appearing in the late eighties. Simultaneously, under a separate project supported by the National Science Foundation of the USA, Princeton University Press is making available a companion series of volumes containing English translations of the original volumes, specially prepared by Anna Beck with the assistance of Peter Havas and Don Howard. Some volumes in the series contain general correspondence during the various phases of Einstein's life, while the others contain his scientific papers in the same periods. The present review looks at volumes 1, 2 and 3 of this latter project, while a review of the later volume 5 has appeared earlier in *Current Science* (1995, **69**, 882).

The prefaces to these volumes clearly state that they do not stand on their own, but must be taken as supplementing the more comprehensive Documentary Edition which contains material in the original languages, with numerous footnotes and explanations, which are here omitted. This robs these volumes of their value only slightly, though one misses some of the presumably illuminating cross-references and editorial comments.

Volume 1 is devoted to correspondence during the years 1879 to 1902 – from Einstein's birth to age twenty-three. More than half the letters included here were apparently discovered by the editors while preparing this volume, and this includes over fifty letters between Einstein and his fellow student and first wife Mileva Maric. The volume begins with an extract from a biographical sketch of Einstein by his younger sister (and only sibling) Maja, written with sisterly affection. It covers the history of the family over a couple of generations, and the ill-starred business adventures of the father Hermann Einstein who ultimately died early really unaware of his son's extraordinary powers. Maja sees her mother Pauline nee Koch with understandable fondness, and talks of the qualities of perseverance, concentration and love of music evident in Albert already at a young age. 'Only persistence that does not rest until all that is unclear is eliminated and all difficulties are overcome allows an idea to take shape and be recognized as truly one of genius.' He was given to violent tantrums as a young child but these soon disappeared. Maja credits Pauline for Albert's affinity for music, and Hermann for his love of logical thinking and mathematics. After the parents' move to Italy in 1894, in search of better fortunes, Albert became acutely unhappy with the rigid curriculum at the Luitpold Gymnasium in Munich – we remember that a generation later a similar school produced Werner Heisenberg! Young Albert ran away from school to Italy, then spent a year at a more congenial cantonal school in Aarau in Switzerland, and vowed to make it on his own to study at the prestigious Federal Institute of Technology – ETH – in Zurich. In this he was supported by his parents. This excerpt ends in 1896, about the time Albert was ready to enter the ETH as a student of mathematics.

From the rest of volume 1, we get already a clear picture of what was to come: his great admiration for the writings of Kirchoff, Helmholtz and specially Boltzmann; and his early thoughts and preoccupation with problems of electrodynamics of moving bodies, the problem of the ether, with the Planck radiation law and the photo effect of Lenard, the foundations of thermodynamics, and molecular motions and sizes. There are also grade sheets from various exams, and the lengthy encounter with the Swiss bureaucracy in connection with his application in 1899 for Swiss citizenship granted in 1901. Good to see that these wheels grind slowly always and everywhere! There is a touching letter from Einstein's father to his teacher and guardian Jost Winteler at whose home he stayed while in Aarau: 'It is a great relief to know that my son is under such loving care which is not only concerned with his physical well-being but also promotes his intellectual and inner life in such a noble fashion. At this young age the heart is most receptive to a good model and I am convinced that your good influence will leave a lasting effect.' A brief – almost inevitable – adolescent affair with the Winteler daughter Marie ended by 1897. Then begins the exchange of letters with Mileva Maric, his fellow student at the ETH during 1896–1900. Gradually one sees the intensity of feelings grow and find expression. What does strike one is his generally optimistic and sunny disposition even in the most adverse circumstances, while she tends to be introverted and given to moods of depression and apprehension on various counts. Also there are remarkably few letters from Mileva to Albert – perhaps irretrievably lost?

At the ETH the mathematician Hermann Minkowski taught Einstein no less than nine courses over the four-year period. He also attended a course on Kantian philosophy. Detailed class notes on a 1897–98 physics course by Weber are included. While figures are unfortunately missing, it is interesting to see what such a course encompassed a century ago – heat flow and thermal conductivity, the nature of heat, Carnot's theorem and the Second Law; and some material on static and current electricity, with a good deal of experimental detail to accompany the theory.

An early 1898 letter from Albert to Maja recalls their parents' sad state and his inability to help them materially. Then already in 1899 in a key letter to Mileva he says the ether is problematic and that electromagnetic waves propagate in empty space with no carrier: 'I am more and more convinced that the electrodynamics of moving bodies, as presented today, is not correct, and that it should be possible to present it in a simpler way. I think that the electric forces can be directly defined only for empty space, (which is) also emphasized by Hertz.' The initial friendly but formal letters to Mileva turn more warm and intimate; but at the same

time there are references to family tensions and his parents' profound unhappiness at this friendship. Now and then we see expressed Albert's feelings of frustration and happiness denied, but a faith that the future will make amends: 'But destiny seems to bear some grudge against the two of us. But this will make things all the more beautiful later on, when all obstacles and worries have been overcome.' The earliest reference to his interest in the photo effect and Lenard's experiments is in a May 1901 letter, about the same time he expresses his being not fully convinced by Planck's work on radiation. On the employment front, there were many enquiries but few opportunities, and for a while Albert and Mileva lived a hand-to-mouth existence with temporary 'leave vacancy' teaching positions. Despite all these difficulties his intense commitment to scientific problems and independence of thought are always evident. The offer of the post of 'Technical Expert Class 3' at the Patent Office in Bern in June 1902 – with the timely help of a good friend – finally brings freedom from financial worry, and the chance to devote himself 'in his spare time' to his true interests.

Turning next to volumes 2 and 3, these contain Einstein's scientific writings during the periods 1900–1909 and 1909–1911 respectively. From 1902 to 1909 he worked at the Patent Office, then from 1909 to 1911 as an Associate Professor at the University of Zurich. There was then a brief move to Prague, followed by a return to Zurich as a professor at the ETH. This did not last long, as in early 1914 he made the move to the Prussian Academy of Sciences at Berlin. Thus ended his Swiss period. Towards the end of volume 3 there are some papers written from Prague. In spite of the declared shortcomings of these volumes they are an unbelievable treasure for every serious student of physics.

The earliest papers in volume 2 deal with problems of capillarity, intermolecular forces and ways of parametrizing them. Then appear three fundamental papers on statistical mechanics, which are however not very well known. The first of these was submitted in June 1902, evidently exactly one week after receipt of the letter of appointment at the Patent Office. In this paper Einstein declares that his aim is to close the gap, in the foundations of thermodynamics, between mechanics and probability, and arrive at the laws of entropy, thermal equilibrium and the Second Law. These were his own independent approaches to these very basic problems; while he was deeply influenced by Boltzmann's work (in many letters to Mileva he asks for 'my copy of Boltzmann'), it turned out that Gibbs' work was not available to him. Indeed in a short note of 1910 reproduced in volume 3, Einstein remarks: 'Had I been familiar with Gibbs' book at that time, I would not have published those papers at all, but would have limited myself to the discussion of just a few points.' These papers are written in a not too transparent style – compared of course to his later masterpieces. But without doubt careful study of each of them, even almost a century later, would be most rewarding.

Now we come to the magic year 1905. So often have we been told, and so often have we told others, that this was a year of miracles for physics. In volume 2 we see why, and using the colloquial expression any decent physicist would gladly give an arm and a leg to have translations of the trio of 1905 papers next to her pillow – the 'photon paper' submitted on March 17th, the Brownian Motion paper submitted on May 11th, and the Special Relativity paper sent in at the end of June. The thrill of reading the originals, even in translation, is indescribable. In each of these papers we find a vastly improved writing style (compared to 1902), and complete mastery of ideas and understanding. Already in the first paper deriving the existence of quanta of radiation from the Wien limit of Planck's radiation law, Einstein speaks of localization and indivisibility of quanta – '... when a light ray is spreading from a point, the energy is not distributed continuously over ever-increasing spaces, but consists of a finite number of energy quanta that are localized in points in space, move without dividing, and can be absorbed or generated only as a whole'. The application to explain the Lenard photo effect comes towards the end. The Brownian motion paper is designed to present convincing evidence for the reality of molecules and estimating their sizes. A few years later, in 1908, he presented a simpler account specially for chemists (Document 50 of volume 2). In between, his Ph D thesis submitted to the University of Zurich – again in 1905, dedicated to his close friend Marcel Grossmann, titled 'A new determination of molecular dimensions', and just eighteen pages long – is reproduced in its entirety.

The special relativity paper is the last of the three great works of 1905, and also the longest. The two postulates are stated boldly at the very outset, and it is stunning to see the majesty of the arguments unveiling the inevitable consequences. The analysis of time and the problem of simultaneity, the insistence on clearly given operational procedures for measurements, are as fresh to read today as ninety years ago. The first part deals extensively with space–time kinematics, the Lorentz transformation laws and their consequences, and even the twin paradox. He then proceeds to the application to the electrodynamic equations of Maxwell and Hertz, the Doppler effect, aberration, etc. The level and comprehensiveness of the exposition – in this very first paper – is unbelievable. Yet many years later Einstein would say that this work on special relativity was no comparison at all to the struggles he faced both with quantum theory and general relativity.

Many later papers come back to one or another point raised by these landmark works. The mass energy equivalence is given in a September 1905 paper. Volume 2 contains also a multitude of reviews of papers by others. Among his own master works we find here the 1906 paper applying the Planck idea to the problem of specific heats; and the December 1907 Jahrbuch review of special relativity towards the end of which he hints at the problem of gravitation. This fine sentence on the dispensability of the ether is well worth recall: '... electromagnetic forces appear here not as states of some substance, but rather as independently existing things that are similar to ponderable matter and share with it the feature of inertia'. We also remember that the Principle of Equivalence – 'the happiest thought of my life' – which formed the cornerstone of general relativity, came to Einstein while he was composing this review.

The final jewel in this volume is the text of the 1909 Salzburg Lecture wherein he analysed the energy fluctuation formula based on Planck's Law, and from this was led to the wave–particle duality for radiation – 'All I wanted is briefly to indicate ... that the two structural properties (the undulatory structure and the

quantum structure) simultaneously displayed by radiation according to the Planck formula should not be considered as mutually incompatible.'

Volume 3 is somewhat different in character and content from volume 2. It covers the period 1909 to 1911 throughout which Einstein was at the University of Zurich. The major part of this volume is devoted to the lecture notes he prepared for three of his courses – mechanics taught during winter 1909–1910; kinetic theory of heat taught during summer 1910; and electromagnetism taught during winter 1910–1911. Elsewhere (in volume 5) Einstein writes that he enjoyed teaching a great deal. These lecture notes tend to be telegraphic and fragmentary, not in the style of his beautiful papers; yet they are valuable to see the organization of his thoughts and the way he conveyed them to students. Of the three sets of notes, the one on mechanics is relatively complete and coherent; while that on the kinetic theory of heat tends to be sketchy. Einstein goes to some effort to stress the nontrivial content of the principle of virtual work and d'Alembert's principle in dynamics, and many down-to-earth problems of mechanics are presented including rigid body kinematics and rotational motion. While the standard conservation laws are covered, the link to symmetry is not yet seen! The kinetic theory course emphasizes that molecular theoretic foundations can lead to all the basic statistical results for macroscopic systems. In the notes on electricity and magnetism, we see a sophistication in style and level of ideas, including this statement of the conception of a theoretical scheme as a totality and how it should be judged: 'We set up a conceptual system the individual parts of which do not correspond directly to empirical facts. Only a certain totality of theoretical material corresponds again to a certain totality of experimental facts.' These notes are also fairly well-organized, and have a practical feel about them. They go up to the Maxwell equations, but stop short of discussing the vector potential, the Lienard–Wiechert solutions, the gauge transformation idea, or a covariant formulation.

Aside from these three major items in this volume, there is a superlative 1910 review of special relativity, giving the historical origin of the ether concept, its problems, its demise, and then going on to his own work. A later 1911 Zurich lecture is equally superb, but this time highlighting the role of Galilean invariance in mechanics and the need to retain it in electrodynamics. In the discussion that follows the lecture, Einstein handles all the searching questions with complete confidence, and at the end points out that special relativity is a restrictive concept and not a specific model for any phenomenon: 'The principle of relativity is a principle that narrows the possibilities; it is not a model, just as the second law of thermodynamics is not a model.' Some papers go back to the ideas of the 1905 'photon' paper and pose questions which at that time were of the greatest import: are quanta intrinsic to radiation or are they only linked to matter? Inter alia he refers to his 1905 calculations, and says in effect, 'I have shown that the Maxwell field on its own "must be quantized"'. What bold declarations and deep insights into phenomena, and of the directions in which future progress would have to go! In so many of his papers we see his grasp and mastery of statistical concepts – the manifold and often startling uses of the Boltzmann connection $S = k \ln W$, the exploitation of fluctuations – to tease out the implications of experimental observations, the limitations of theory. We see the power of his arguments from first principles, an uncanny gift for seeing far in advance of others the need for fundamental conceptual advances in so many directions. He had the ability not only to lead but to point to others the most promising directions.

Towards the end of volume 3 are two papers written – one suspects in a leisurely style – from Prague, one on molecular motions in solids and another on his first insights into the influence of gravity on light. Another major document is the extended 1911 Solvay Congress lecture on the specific heat problem. Here again Einstein expresses his conviction that the foundations of both mechanics and electrodynamics would have to be profoundly altered to take account of the quantum; it is staggering to read these lines from one who had done so much for the understanding of space and time. And the 'paradox' of wave particle duality for radiation is expressed again.

The declared limitations notwithstanding, every professional physicist will find these volumes (and surely the succeeding ones) of abiding value and interest. To see how fundamental theories took shape and came into being, to perceive what led to them, to be face to face with documents which heralded the birth of many conceptions taken today for granted, to see that there was a time when they did not exist, and to view them condensing out of a mist and take on permanence after creation in Einstein's mind – these are experiences beyond value.

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Wild Edible Plants of India: Diversity, Conservation and Use. R. K. Arora and Anjula Pandey. National Bureau of Plant Genetic Resources, New Delhi. Price not stated.

From an initial phase of hunting and gathering to agricultural societies and finally to industrial economic societies, there has been progressive decline in the number of species on which human race has depended for food and other needs. In this process, while the biodiversity base became progressively smaller, bioproductivity per unit area and time increased dramatically. The chief reason was application of principles of genetics and plant/animal breeding. This resulted in the release of time for vocations other than growing food, and also led to increase in population in some parts of the world. However, there is now a realization that to make agriculture sustainable, wide genetic diversity base has to be combined with high bioproductivity. This is a major challenge before agricultural scientists and technologists.

Judging against this background, the book is both very timely and most welcome. This book is the sum total of life-long work of R. K. Arora on India's agri-biodiversity, its ancestors and the related species. Arora's special strength has been that he combines knowledge and experience of a professional botanist, ecologist and geneticist, all rolled into one. The authors, and NBPGR and ICAR deserve hearty congratulations for this