Julius Jeffreys - Pioneer of Humidification

by Dr. D. Zuck

That John Snow based his ether vaporiser on the humidifier designed by Julius Jeffreys is a footnote in the history of anaesthesia. (1) But that Jeffreys himself is now totally forgotten is surprising, because for several decades during the mid-nineteenth century his name must have been a household word. He was a pioneer in the treatment of respiratory ailments, and in the physiology of lung volumes, anticipating the work of John Hutchinson. He was thought to be sufficiently eminent to merit an entry in the Dictionary of National Biography, and there is where this investigation started.

According to the DNB, Julius was the son of the Reverend Richard Jeffreys, Rector of Throcking, Hertfordshire, and he was born at Hall Place, Kent, in 1801. Throcking is a tiny hamlet about one mile west of Buntingford, which is on the A10, the road from London to Cambridge. Going there on the off chance, I was rewarded by the sight of the largely C13 church of the Holy Trinity, built of flint, with a brick tower dating from 1660. Inside, the list of Rectors confirmed that Richard Jeffreys had been the incumbent from 1786 to 1830, and also revealed that he had succeeded his father, Edward, who had been Rector from 1745 to 1786; Richard Jeffreys' 46 years in office is commemorated by a white marble tablet.

The question then arose, if Richard Jeffreys was a Rector in north Hertfordshire, why was his son born at Hall Place, somewhere in Kent? Several possibilities came to mind: a family connection, or the unexpected onset of labour. Hall Place is now the local history museum, and headquarters of the Libraries Department of the London Borough of Bexley. Part of the house dates back to 1540. Enquiries of the Curator revealed that on 30th December 1795 the Reverend Richard Jeffreys, while Rector of Throcking, had taken a 21 year lease on Hall Place from the owner, the notorious Sir Francis Dashwood. The parish register revealed that Julius Jeffreys was born there not in 1801 but on 14th September 1800. So much for the accuracy of the DNB which did, however, supply sufficient information to keep me going in the right direction.

Subsequent research in the India Office Library revealed that the Reverend Jeffreys, while still Rector of Throcking, served as Chaplain to the East India Company in India from 1803 to 1810. The whole family, including Julius, accompanied him. Several other children were born there, and his eldest daughter, who plays an important role in this story, later married there. I
would propose the Reverend Jeffreys as a pretty good example of clerical pluralism and absenteeism, although by the standards of the times he doesn't seem to have been doing anything very much out of the ordinary. (2)

Of Julius's early life, apart from his stay in India, we know very little. Like his brothers he was educated mainly by his father, whom his eldest son described as a profound mathematician and classicist. Julius studied medicine at Edinburgh and London, and became a Member of the Royal College of Surgeons of London on 1st March 1822. He then applied for a post as assistant surgeon in the Bengal Presidency of the East India Company. His application, along with dozens of others, is preserved in the India Office Library. (3) His Membership was accepted as adequate training in surgery, but for medicine the Company's regulations required a six month attachment to a recognised physician, followed by an examination. Candidates were also required to attend a course of lectures on Hindoostanee, and to produce a certificate of attendance. (4) Jeffreys' file contains certificates confirming that he had passed the exam and attended the course, together with a certified copy of the record of his birth in the parish register.

**India - a pioneer in public health**

Jeffreys sailed to India, and on landing at Calcutta was first attached to the General Hospital, where there was a cholera epidemic raging. He was thrown into this head first, and at one time had more than two hundred patients under his care.

He had already published two papers which revealed an interest in the application of physics to medicine, and his intention was to continue with research along those lines, but the carelessness of the shipping agents caused the destruction of all his scientific instruments, so he turned his interests into a different direction. He set himself to study the effects of the Indian climate on health. The British had made no concessions to climatic differences. Regiments drilled during the hottest time of the day; anything less was considered effeminate, with the result that one third to one half of the troops were in hospital with heat stroke at any one time, and there were many deaths. There was also the belief that it was dangerous to live at an altitude above 4000 feet, because of the rarefaction of the atmosphere. Jeffreys set himself to study the physics of heat and solar radiation. After a year he went on a tour of the Himalayas. He found that in the hill country the climate was superior even to that of England. He stayed at Simla, about 8000 feet above sea level, where there was at that time only one house, and that only occupied
during part of the year. On his return he wrote a report strongly advocating
the establishment of convalescent stations at places such as Simla, where
those exhausted by the heat of the plains could be sent to recuperate. This led
to a commission of enquiry, then action, so that one could say that the
subsequent modus operandi of the British in India, the establishment of hill
stations, and the annual move from the plains to the hills and back again,
stemmed at least indirectly from Jeffreys’ report. (5)

Jeffreys served most of his time in what is now Uttar Pradesh, mainly in
Cawnpore (Kanpur) and Fatehguhr. He married in 1826, and during the next
six years three sons and twin daughters were born. Arising from his climatic
studies, he designed apparatus and installations for the cooling of dwelling
places and barracks. One of these consisted of a series of water-filled pits,
over which air was drawn and cooled by evaporation, and then pumped into
the dwelling by a pendulum-action quadrantic pump of his own design, which
he called the Refrigerator, an early use of the word. He studied air flow
through the solar topee, insisting that it should not be hermetically sealed to
the head. He allowed his faith in the application of scientific principles to
overtake commonsense on more than one occasion, as in his design of a
flounced heat-resistant military costume for the tropics, of distinctly unmilitary
appearance.

In about 1830 he transferred from the military to the civilian establishment,
and started interesting himself in developing the natural resources of India. He
established factories for the manufacture of pottery, brickware, saltpetre, soda
water and the stoneware jars to contain it, designed furnaces and kilns, and
provided employment for a thousand Indians. He was commended for his
enterprise by the reforming Governor General, Lord William Bentinck.

Jeffreys' health began to fail, and he resolved to give up medical practice. He
was offered the superintendentship of the East India Company's main opium
factory, but turned it down on moral and religious grounds, and he and his
family returned to England in 1835. En route he invented a method of
converting the rolling and pitching motion of becalmed ships into a useful if
slow forward movement. In October of that year he published in the `Asiatic
Journal' a long article on the Resources and Industrial State of India, strongly
advocating that much of the wealth that was being drained out of the country
by the East India Company should instead be reinvested there for the
development of agriculture and industry.

Return to England - a sister's cough
At home he found that his eldest sister, now a widow, was suffering from advanced pulmonary disease, manifested especially by a troublesome cough. He was struck, as he went about, by the prevalence of lung disease. As he later wrote: `in every quarter of a congregation, in church or other assembly, the stifled cough was to be heard during the colder months'. (Theatre, cinema, and concertgoers might add that things are no better today!) He was particularly struck by the irritating effect of cold air, and especially by change of temperature, as when going out of doors, or from a warm room to a cold passage or bedroom. This observation turned his mind to the devising of a means of warming the inspired air. At first he thought of using a portable source of heat, such as a lamp, but he discarded that idea as impractical. He considered the humidifiers already available, but ruled them out also; their output was inconstant, they cooled rapidly, and they could not be used during sleep, which was when they would be of greatest value.

He designed his volute humidifier as an improvement on Mudge's, and he seems to have been among the first to make practical use of this method of lengthening the path over a fluid surface so as to increase the vapour uptake, an idea which appears to have originated from James Watt in 1795. As we know, John Snow based his ether vaporiser on this design, but as far as Jeffreys was concerned, this humidifier was virtually a throwaway. It was not the answer to the problem that he had set himself, which was to devise a means of constantly warming and humidifying the inspired air, which could also be used during sleep.

**The 'Respirator'**

He described how the idea suddenly came to him, that exhaled air itself could be used as the source of both heat and moisture. What was needed was a means of trapping both, and transferring them to the next inspiration. Quickly he worked out the scientific principles involved. The medium must be a good conductor, which meant a metal. It must not obstruct the breath, nor affect the transmission of the voice. Since heat passes down a temperature gradient, some sort of cascade mechanism was required. All these considerations led him to the idea of a series of metal grids, or lattices, insulated from one another, through which the breath would pass. During exhalation, warmth would pass from the breath to the lattices, and moisture would condense on them. During inspiration the cold air would be warmed and humidified.

He made a crude model, and was so encouraged by its effect that he
continued with his experiments on heat transfer, gradually refining the design. He then looked for a craftsman to make it, but the requirements were such that he was forced to design his own machinery. To the device he gave the name `Respirator'. He claims to have invented the word, and the *Oxford English Dictionary* credits him with it. When I started this investigation, Jeffreys, to me, was just a name attached to an apparatus of interest only tangential to the history of anaesthesia, so you may imagine my excitement when I realised that I had stumbled on the inventor of what we now call the condenser humidifier, or heat-moisture exchanger.

The Respirator, as finally designed, consisted of two parts: a packet of metal lattices, called a plate, and a frame in which the plate was mounted. The lattices were of different gradations of silver wire. Those nearest the mouth were $\frac{1}{300}$ inch thick and $\frac{1}{300}$ inch apart. The intermediate layers were $\frac{1}{600}$ inch thick and $\frac{1}{600}$ inch apart, and the outer even finer and closer together. Each lattice was insulated from the next by a similar lattice of a waterproof material. The silver lattices were overlaid by a gold lattice both inside and out. A complete plate consisted of from eight to twelve lattices and their insulating layers, and was curved to suite the curvature of the mouth. Attached to the frame was a silk cover and tapes.

This design required the construction techniques of the age of microelectronics, and Jeffreys' machine must have been a marvel. It was able to solder 40,000 to 50,000 minute points accurately in each respirator, and after 20 years it was still in use, having made over one million lattices during this time. Unfortunately, we have no information about its design.

Because of the intricacy of the manufacture, and to protect the accuracy of its construction, Jeffreys took a step that was to put him at loggerheads with some members of the medical profession for the next twenty years. He decided to patent the design. He sought advice from Messrs Poole and Carpmael of the Government Patent Office on the likelihood that his invention might be acceptable to the public, and they advised him to consult Dr Neil Arnott, one of London's most fashionable physicians, and the inventor of the water-bed. This he did, but the meetings later gave rise to a lengthy dispute about originality and priority. It is evident that at the time Arnott had no idea about the Respirator; he did not understand the principle on which it worked, nor did he appreciate its purpose, until Jeffreys was able to persuade him to try it.

The patent was taken out in January 1836.(6) On 11th March 1836, Arnott,
during a lecture on heating and ventilation at the Royal Institution, during which he attempted to promote a stove of his own invention, damned the Respirator with faint praise. It was a useful device, he said, but not original in conception. Any coachman who wound a scarf round his mouth during the cold weather and breathed through it would achieve the same result. He also commented adversely on the patent, and on the cost of the device. This attack incensed Jeffreys greatly. He had confided in Arnott, and he was very proud both of the original idea, and of the mental processes whereby he had applied scientific principles to achieve the final design. (7)

Later in 1836 Jeffreys published a brochure addressed to the medical profession, explaining the construction and purpose of the Respirator. (8) He claimed that no exhaled air was retained, since the whole of the internal space was only ¾ of a cubic inch, about 12 ml. He mentioned an unexpected side effect; since little body heat was lost in the exhaled air, it was retained in the circulation, and it was found that the whole of the body, and especially the extremities, became much warmer after using the Respirator for a little while.

When I made enquiries at the Science Museum, at first it was thought, because of cataloguing uncertainties, that there were no Respirators in the collection, but with more information the search was very helpfully resumed, and one was found, and later two more. The figure to the right is a photograph, courtesy of the Science Museum (London, UK).

Purchasers were supplied with a leaflet giving instructions about how to clean it.

**Compliments and brickbats**

On Saturday 7th January 1837, the Respirator was demonstrated before a medical audience at a meeting of the Westminster Medical Society. (9) Jeffreys’ signature appears in the attendance book. John Snow would not have been present. Although he registered for lectures at the Hunterian School of Medicine in Great Windmill Street (where the Society met in the school’s museum) beginning in October 1836, his first appearance at a meeting of the Society was in April 1837 as a guest. Snow was proposed and approved for membership at the beginning of the fall session, and his first signature in the
Attendance Book of the Westminster Medical School was on 28th October 1837.

A complimentary annotation about the respirator appeared in the Lancet the following week, and the quality of the workmanship was endorsed in a letter to Jeffreys from Charles Babbage. Jane Carlyle (wife of Thomas, the historian and philosopher, who suffered from a weak chest) bought one, and described it as a most wonderful acquisition: 'It is a thing made of black silk with a quarter of a mile of brass wire in it, which I clasp on the under part of my face when I go out, and which is precisely like the muzzle on a mad dog; but has the property of making all the air that goes down one's throat as warm as summer air. They call it a respirator.' (10) Other literary references are by Ruskin, and Gissing in his novel New Grub Street.

The Respirator was again under attack, and Jeffreys said that it was now being sold for 28/- and, far from making a large profit, he claimed to have lost £200 on the first batch of 700. During the current season, sales had been very large and consequently, at last remunerating, the total profit on each instrument, which had to be shared with the retailers, was not more than 4/-. One of the Respirators in the Science Museum bears a price tag of 30/-.

Discussing Arnott's proposal to modify the Respirator by substituting a counter-current system of thin-walled valved metal tubes, Jeffreys supposed, sarcastically, that it might work: 'If we had two windpipes - one, for instance, from the right lung, going to the nose, and the other from the left lung to the mouth, and had the power of expanding the right side of the chest while we contracted the left, and vice versa...'

Jeffreys' articles were followed by the publication in the 'Lancet' of a most unpleasant anonymous personal attack, by someone who signed himself 'Medicus'. (12) I wondered what could have caused all the animosity that was being directed against Jeffreys, and after some thought it struck me that probably the worst thing that he could have done in the eyes of the profession was to advertise it to the public. Acting on this suspicion, I searched The Times and the Morning Post, and eventually found an advert which seems first to have appeared in both papers on Friday 12th October 1838. It reads as follows: "THE BREATHWARMING INSTRUMENT. -- Mr. JEFFREYS' RESPIRATOR, for the use of all persons to whom the breathing of cold air is distressing and injurious, and for affording rest at night where it is interrupted by cough. It renders warm and genial the most cold and foggy air. From the numerous communications the Inventor has been favoured with, he need not hesitate to
refer inquiries to any of the invalids in the different parts of the kingdom, wearing the instrument, whose number amounts to many thousands, and these will confer an obligation upon many a person meeting its use if they will make known to the neighbouring agents the result of their own experience of the effects of the Respirator during whatever period they may have used it. London depots are 82, Cheapside, and 148, Regent Street; wholesale office, Cheapside. In London and the larger towns certain respectable houses are also agents for the Respirator.”

This advertisement, which could learn little from modern advertising practices, since it manages, for example, to repeat the name of the instrument four times, reappeared in a shortened form the following week, but with the addition of a list of suppliers, among whom are several familiar names, notably Mr P. Squire, chymist to the Queen, Messrs Savory and Moore, Mr John Read, inventor of the syringe-pump, Messrs Weiss, and Mr S. Maw, who later seems to have become the main distributor. The advert reappeared sporadically during that winter.

In 1840 Jefferys was campaigning against the increasing importation and use of opium in this country. In 1841 he was elected Fellow of the Royal Society. In his application he gave Bath as his usual place of residence. Among his sponsors were the celebrated historian and philosopher of science, William Whewell, and the Presidents of both Royal Colleges.

**Humidifiers and the respiratory tract**

In 1842 he published a very long series of articles in the *London Medical Gazette*, entitled: 'On artificial Climates and the Restoration and Preservation of Health'. There is an indication that these may have been prepared at the invitation of the Editor, and that they were originally intended to be the first part of the book that Jefferys published the following year. In these papers he set out his ideas about the pathology of diseases of the respiratory tract, and their treatment.

We cannot see the lining of the trachea, he said, but we can see an analogous membrane, the surface of the eye. From the appearance of the eye when irritated or inflamed, we can infer the appearance of the trachea - the swelling, the redness, and especially the dryness. He went on to conceptualise the idea that both the skin and the respiratory membrane are external surfaces of the body; so both are open to the actions of the atmosphere, but they meet only at the nose and the mouth. Hence it is possible to put the lungs and the skin
under the influence of different climates, an idea that had previously commanded little attention. So one can supply warm, moist air to the lungs, while keeping the skin cool and dry.

He went on to consider the workings and effects of humidifiers, Mudge's and others, and gave a long account of the physical principles on which the function of the Respirator was based, and of its construction. He discussed the importance of clean air, and the need to filter the atmosphere in large cities, because it was heavily charged not only with dust, but with acrimonious particles of all kinds, mainly composed, as his investigations with the microscope had shown, of dried horse droppings. He found it surprising that healthy lungs could endure unstrained city air, and a marvel that affected lungs could sometimes recover while breathing it. To employ drugs to suppress cough before removing the chief atmospheric cause of it, ‘...may be compared to the act of a native surgeon in India, whom I found applying a plaister of opium and herbs to the foot of a person in great pain, in which there proved to be a very large thorn, which he had overlooked.’

As regards warming, a person in a cold room lost heat in two ways - by conduction and by radiation; many people entirely overlooked the second. So, Jeffreys continued, not only should the air be heated, but there should also be a source of radiant heat, so that too much atmospheric warming would be unnecessary. He himself had designed a stove exactly for that purpose. He went on to stress his conviction, arrived at after lengthy study, that ventilation should be adequate in volume and, contrary to current practice, should be from above downwards. This would avoid draughts, avoid raising and dispersing dust, and would bring the freshest air first to the mouth and nostrils. He had advocated such a system for the ventilation of the new House of Commons, but his views had been disregarded. Air had been brought in at floor level, and extracted near the ceiling, but within a short time the volume of complaints from members was such that the whole system had had to be reversed. In his view, the application of scientific principles to the many domestic wants concerned with comfort, health, and even life, was of the greatest importance, and not only one science was concerned, but several.

In the next year, 1843, Jeffreys published a book of some 230 pages, entitled: *On the Statics of the Human Chest*. (14) The first two-thirds of this book, which deals with the physiology of lung volumes, and theories of metabolism, is most interesting and important; the last third is totally cranky. Jeffreys made at least two important contributions concerning lung volumes and their measurement, that were then absorbed, without any acknowledgement, into
the work of Hutchinson. He was also one of the first to make some cogent
criticisms of some of the metabolic hypotheses of Liebig published in his
‘Animal Chemistry’ of 1842, for which others were later given the credit.

In 1844 Jeffreys modified the Respirator patent to include a nasal model, and
also to allow for the addition of detachable packets of plates, so as to increase
the power of the device when necessary. In 1850 he modified it again,
providing a louvred front. Also, there was a model which attached to the
handle of an umbrella.

There can be little doubt that the Respirator was an effective device. Many
tens of thousands were sold, and the design was widely copied. Purchasers
were invited to write to the suppliers, who collected bookfuls of testimonials.
People who had been housebound during the winter reported that they were
able to continue at work. Those who had been forced to winter abroad found
that they were able to remain in this country. People slept better, with no
cough, and warm feet. It was in use on the Continent, and was being produced
also in Germany. (15) But an unforeseen complication was the effect on the
general practitioner. Patients could buy a Respirator from the chemist, and no
longer needed to visit the doctor regularly and pay for his bottle of linctus; and
the adverse effect on their incomes seems to have accounted for much of
Jeffreys' unpopularity with some members of the profession. But Jeffreys, for
his part, stoutly defended his patent. Apart from all other considerations, he
declared that he would rather live on the returns from his intellectual property,
which was bringing great benefit to the public, than on the income gained by
prescribing ineffective rubbish. Because it was, in a sense, a form of
'alternative' medicine, not being prescribed by the doctors, the Respirator
received no mention in the textbooks; but with so many having been sold, it is
surprising that it has faded so completely from memory, not appearing even in
books or collections of Victoriana.

More inventions - more troubles

In 1851 Jeffreys invented a much improved method of launching ships'
lifeboats, greatly reducing the tendency to capsize. After successful trials it
was fitted to a number of vessels, and it substantially increased the rate of
survival from shipwreck.

Then in 1854 the Respirator came under fire again, on this occasion in a letter
to The Times from a lecturer in chemistry at St Bartholomew's Hospital, John
Stenhouse. (16) Stenhouse was pioneering the use of charcoal as an
adsorbent of unpleasant odours. He wrote drawing attention to this innovation, and he followed up his letter with a lecture at the Royal Institution in March 1855. (17) Among his proposals was that charcoal be incorporated into a breathing device, sandwiched between two layers of metal gauze, and this led him to attack Jeffreys' instrument, and to repeat the allegations made by Arnott almost twenty years earlier, but with additions, implying that Jeffreys had stolen the idea from Arnott.

In the Red House Museum at Christchurch, near Bournemouth, I came across what seems to answer to the description of Stenhouse's device; it was made by Bourne & Taylor, and the retail price was 4/-. Stenhouse's attack had the beneficial effect of stimulating Jeffreys' older brother, Colonel Edward Jeffreys, to write a booklet, a confutative biography, in which he set the record straight, and provided some useful information about both Jeffreys and the family. (18)

During the Crimean war, Jeffreys invented a projectile intended to demolish the Russian fortifications that sounds very much like the modern armour-piercing shell, but he was unable to interest the War Office in it. He also, with much foresight, strongly advocated the fireproofing of battleships, which would have saved many lives, even as recently as during the Falklands campaign.

Then in 1858 Jeffreys published his last work, *The British Army in India*, into which he distilled all his experience and his thoughts. It deals with the topics we have mentioned, life in a hot climate, and the preservation of health.(19) It received a very long and most laudatory review in the *British Medical Journal*. At last Jeffreys' quarrel with the profession was over. (20) The Respirator was exhibited at the 1862 International Exhibition and was featured in a full page description in the catalogue. (21) (I am grateful to Richard Ellis for drawing my attention to this.)

Jeffreys died at Richmond on 13th May 1877, and is buried in the cemetery there. With the help of the old-boy network of cemetery superintendents I was able to discover both the cemetery and the location of his grave. In his will he refers to a different wife from the one he married in India, and to only two of his five children, one of whom had emigrated to New Zealand. He had retained an interest in the Respirator, but his whole estate was valued at less than £2,000.

The Respirator remained a stock item available from pharmacists, being strongly promoted during the winter months, as can be seen from advertisements in the *Chemist and Druggist*. It was, for example, the subject
of whole-page advertisements during 1879, and pharmacists were being offered mahogany display cabinets free. It appeared in Arnold’s catalogues for 1885 and 1895, and it continued to appear in Maw's catalogue for the next fifteen years or so, but then it gradually dropped out of use; but the principle was reintroduced, unknowingly, by Walley in 1956, as an auto-humidifier for use with mechanical ventilators, (22) and it soon appeared in a more elegant form. The physical principles on which it was based were explored by Mapleson and his colleagues in 1963, and in a most interesting piece of research they, again unwittingly, provided justification both for Jeffreys’ design, and for everything that he had claimed. (23)

Summing up

Julius Jeffreys could claim credit for some remarkable innovations in India. Also, he invented the Respirator, made important contributions to respiratory physiology, and to the science and practice of heating and ventilation; and he was one of the earliest environmentalists. He embodied all the qualities that characterise our idea of the typical Victorian, he was inventive, enterprising, entrepreneurial, and philanthropic. He had a simple religious faith that was strongly combined with a belief in progress and in the ability of science to solve all problems - to the extent that the single-minded application of scientific principles, unaccompanied by commonsense, took him into the ridiculous on more than one occasion.

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References


7. Arnott N. - for further information see DNB.


23. Mapleson WW, Morgan JG, Hillard EK. “Assessment of condenser-humidifiers with special reference to a multiple gauge model.” *British Medical Journal* 1963; 1:300-305. See also Zuck D. “HMEs and body temperature.” *Anaesthesia* 45(11):991-992; 1990. (This brief letter notes that the principle of the heat and moisture exchanger was developed in 1836 by Julius Jeffreys. 4 refs.)