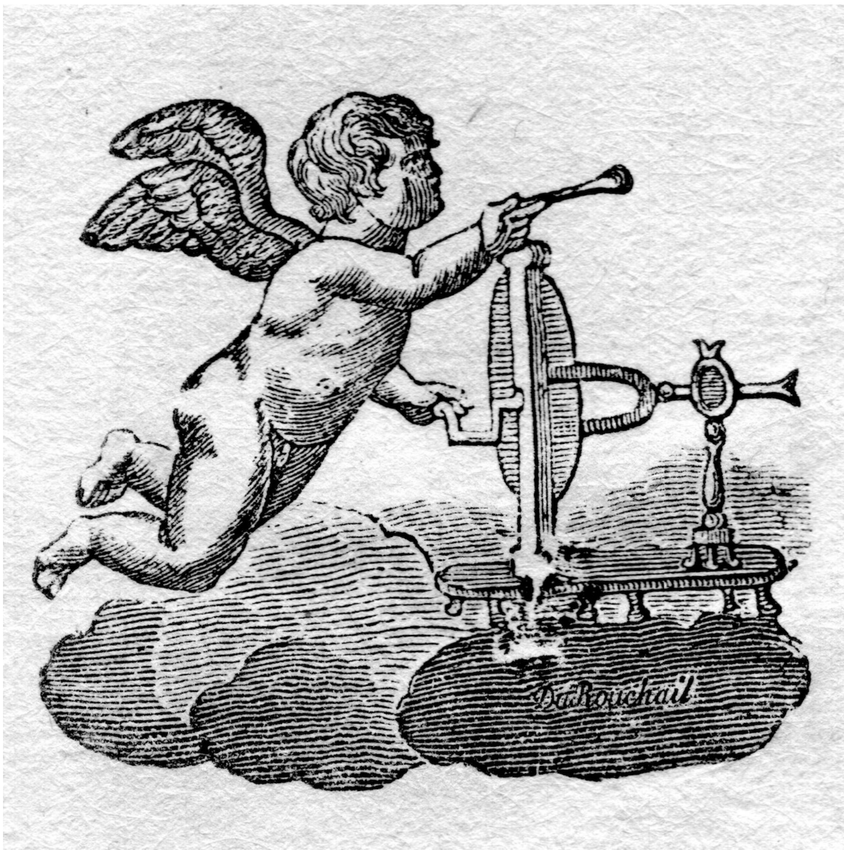
The Invisible Light
The Journal of The British Society for the History of Radiology



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Contents.

Editorial.

Historical Medical Equipment Society (HMES).
I hope you enjoy the cover illustration which is from my copy of an 1839 book by the Italian Geminiano Grimelli (1802-1878). It is a charming figure of an angel in the clouds using a static machine and shown in the act of making lightning There is a strong tradition of medical electricity in Italy. [1]. The illustration shows the angel's knowledge of both electricity and of the work of Benjamin Franklin. [2] Benjamin Franklin (1706-1790) believed that electricity on the earth and in the air were the same essential phenomenon and this view had been ridiculed. Franklin overcame the opposition in his famous experiment with a kite. This experiment by bringing lightning down to the earth demonstrated its electrical nature, and at the same time proved his theory. Franklin noted that "thereby the Sameness of the Electric Matter with that of lightning is completely demonstrated." It is surprising that Franklin was not killed by the experiment. I used this illustration in a talk on electrotherapy that I gave to the HMES earlier this year.

The HMES welcomes presentations and will next meet in the Autumn of 2024. If you want to present a paper on medical equipment then please contact me. It's an interesting and friendly society and new members are welcome.

UKIO 2023 & 2024.
In 2023 we had a stand at UKIO which was again held in Liverpool. The history session was well attended although there were only two papers presented. Please consider offering a paper at UKIO in 2024. It's important that historical papers are presented, not the least reason being that we retain the session.

The International Society for the History of Radiology (ISHRAD) 2023 & 2024.
http://ishrad.org
ISHRAD had an excellent recent meeting at the German Röntgen Museum which is in Lennep, the birthplace of Wilhelm Röntgen. ISHRAD is a society especially dedicated to the History of Radiology and Radiological Technology. The aims of the society are the advancement of scientific research and exchange of information in the field of the history of radiology and radiological technology and practice.

[1] https://link.springer.com/article/10.1007/s00016-023-00296-0 (accessed 12 November 2023).
[2] Geminiano Grimelli, *Osservazioni ed esperienze elettro-fisiologiche dirette ad istituire la elettricita` medica* (Modena: Coi tipi Vincenzi e Rossi, 1839).

The next meeting of ISHRAD is from October 7-10, 2024, and will be held in Paris at the same time as the meeting of the French Society of Radiology (SFR). Do consider presenting a paper, and also joining ISHRAD. Again, please contact me.

Adrian Thomas
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The BSHR Annual lecture 2024.

Our popular annual lecture will be given on 5th February 2024 by BSHR member Stephen Keevil. His title is: "Signs and Symbols: Heraldry and Radiology from Röntgen to the Present Day."

The lecture will be held at Governors' Hall at St Thomas' Hospital, Westminster Bridge Road, London SE1 7EH. The lecture will be both in-person and on-line, and tickets can be obtained from Arpan Banerjee: arpankb007@gmail.com .

Heraldry has been described as 'the shorthand of history' because of the wealth of information that heraldic signs and symbols can reveal about families, organisations and wider societies. But it is not just an historical curiosity: heraldry remains a living art and science with coats of arms in widespread use and new ones granted every year. Radiologists of course are also familiar with signs: the characteristic appearances of different pathologies on medical images. How might these two very different semiotic worlds come together? How might the concepts of radiology be represented in coats of arms and other heraldic devices? These questions arose recently when the British Institute of Radiology (BIR) decided to apply for a grant of arms to mark its 125th anniversary. As part of the process of designing the arms, research was carried out into logos and insignia used historically by the BIR, and also into existing coats of arms connected to radiology. In this lecture some basic principles of European heraldry will be described, illustrated by examples of arms used by prominent figures in the history of radiology which uncover some interesting genealogical and personal insights. The arms of medical imaging societies in the UK and around the world will be discussed as examples of the symbolism that has previously been used to represent radiology heraldically. Finally, the way in which this research was brought together to produce a design for the BIR's arms, and the process leading to the formal grant by the Kings of Arms in April 2023, will be described.

Stephen Keevil is Head of Medical Physics at Guy's and St Thomas' NHS Foundation Trust and Professor of Medical Physics at King's College London. He is the current President of the BIR and a Trustee of the British Society for the History of Radiology. Steve has had an interest in heraldry and related matters since childhood, having first joined the Heraldry Society at the age of 11. He designed the BIR's achievement of arms in collaboration with Chester Herald at the College of Arms. Steve is a 'progressive traditionalist', keen to see traditions such as heraldry preserved, but also evolve so as to remain alive and relevant in modern society.

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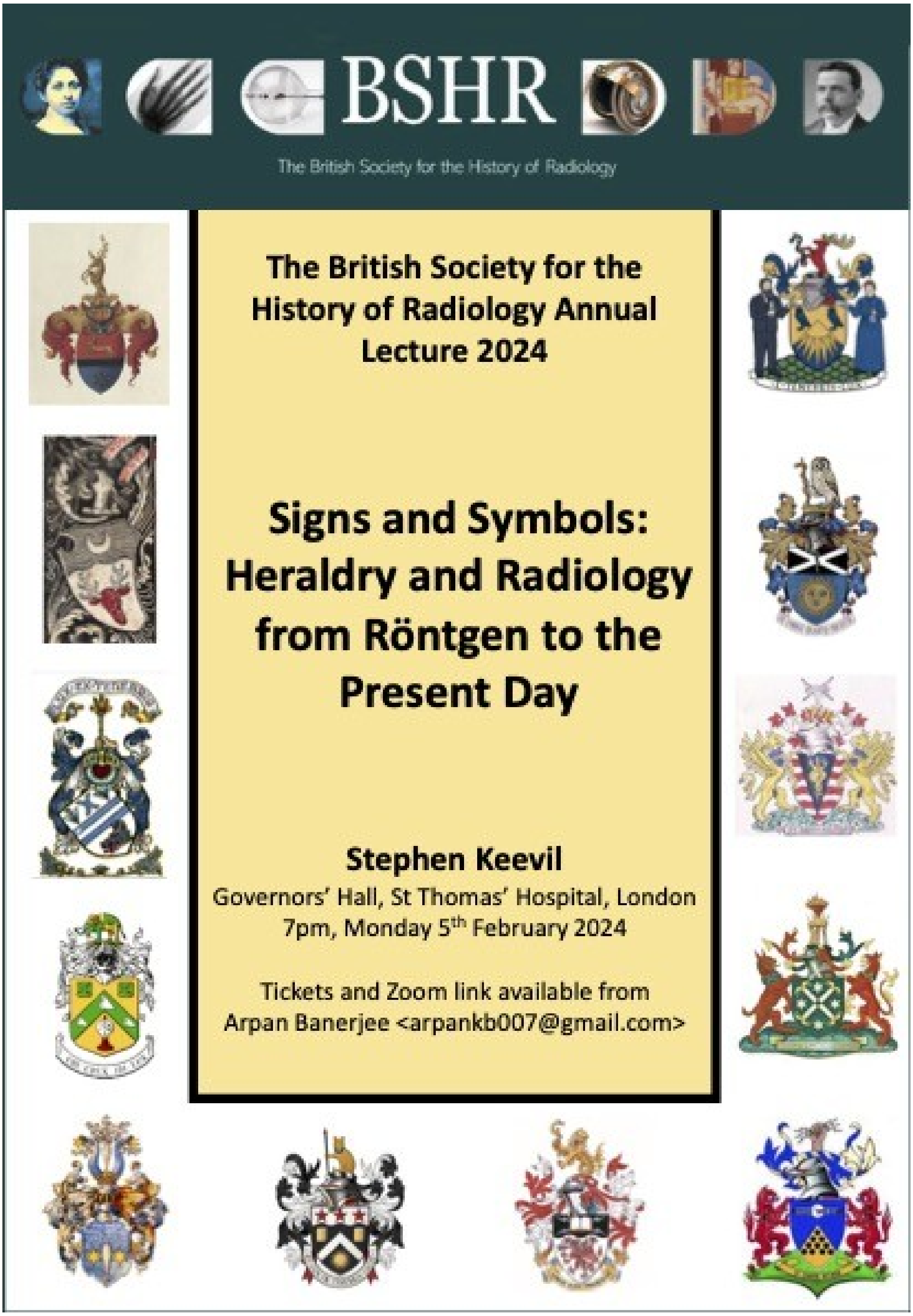
BSHR
The British Society for the History of Radiology
The British Society for the History of Radiology Annual Lecture 2024
Signs and Symbols: Heraldry and Radiology from Röntgen to the Present Day
Stephen Keevil
Governors' Hall, St Thomas' Hospital, London
7pm, Monday 5th February 2024
Tickets and Zoom link available from
Arpan Banerjee <arpankb007@gmail.com>

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Two Recent Stereoscopy Books.

Stereoscopy and 3-D imaging is most interesting. 3-D imaging is central to modern radiology and has a surprisingly long history. Röntgen had a stereoscopic camera which he used on his holidays, and his camera, viewer and photographs can be seen in the German Röntgen Museum in Lennep. Brian May has written several interesting books on stereoscopy which are of great fun.

Stereoscopy is Good For You: Life in 3-D.

by Brian May.
The London Stereoscopic Company (2022).
ISBN-10 : 1838164553
ISBN-13 : 978-1838164553

Brian May, the creator of the 21st-century incarnation of the London Stereoscopic Company, became an Internet evangelist for 3-D photography during the recent Covid lockdown period, and created a whole new community of stereoscopists, all sharing their 3-D pictures on Instagram. This is a book of stereoscopic memories of life during the Covid Years. The range of subjects in these entirely new stereo pictures is immense, with more than 100 contributing photographers finding inspiration in Nature, people, pets, architecture, the sky above, and much more. This book is a lasting testament to the evocative power of 3-D photography. The book includes a Lite Owl STEAM PUNK 3-D Viewer. It is a great coffee-table book.

Stereoscopy: the Dawn of 3-D.

by D. PELLERIN (Author), Brian May (Author, Editor)
Publisher : London Stereoscopic Company; Illustrated edition (10 Nov. 2021)
ISBN-10 : 1838164502
ISBN-13 : 978-1838164508

This book tells the astonishing and sometimes controversial story of the birth of STEREOSCOPY, the phenomenon we now call 3-D, which entranced Victorian society and is the great-grandparent of today's VIRTUAL REALITY. Peering into a small, dark, magical box (a STEREOSCOPE!) an eager new audience in the FULL account of the first 30 years of this extraordinary scientific, artistic and social revolution. You will also experience the pictures it created in full 3-D, just as they were originally intended to be viewed. Brian May's high-quality London Stereoscopic Company OWL viewer, included free in this deluxe package, is all you need to embark upon this visual journey of discovery. It all began in the mind of the Victorian genius CHARLES WHEATSTONE, several years before photography was even invented. The dispute between Wheatstone and Brewster over the invention and design of the stereoscope is of course included, but followed with more precision than other sources through the author's access to original letters and clippings. Throughout the book are scattered high quality reproductions of rare stereo views from the periods or subjects being covered. This is especially the case in Chapter 4, "Enter the London Stereoscopic Company" and Chapter 5, tempted to grab your OWL viewer and browse the 150 amazing stereos.

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Fifty Years of CT at the Mayo Clinic.

The 50th Anniversary of CT at Mayo Clinic Scientific Symposium was held on Monday June 19th, 2023, and was most interesting. The first CT scan in North America occurred in 1973 at the Mayo Clinic in Rochester, Minnesota. There are now valuable on-line resources following that meeting.

On June 19, 1973, Mayo Clinic in Rochester completed the very first CT scan in North America. Dr. Cynthia McCollough, the director of Mayo Clinic's CT clinical innovation centre, described how things have changed in the United States since that day 50 years ago.

https://kstp.com/special-coverage/minnesota-live/50th-anniversary-of-north-americas-first-ct-scan-at-mayo-clinic/

Their videos from the 50th Anniversary Symposium are available to view, and can be accessed.
The Blog:
https://ctcicblog.mayo.edu/50th-anniversary-of-ct-at-mayo-clinic-scientific-symposium/

The YouTube Playlist:
https://www.youtube.com/playlist?list=PLSWR1ylG_6JaZ4I1hBfA9-_2VIZS3bqR0

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50th anniversary of CT scanning at Mayo Clinic: film review and historical notes

By: Richard M. Waltham, MIEE

A CT scan of a patient on 19th June 1973 at Mayo Clinic in Rochester (MN, USA) was the first outside Atkinson Morley's Hospital (Wimbledon, UK). It was a very significant milestone, because it showed that CT was now available for regular clinical use in any hospital. The CT image was reconstructed using a mini-computer in the radiology department. The installation of a mini-computer in Atkinson Morley's Hospital in November 1972 marked the end of transporting data by car on magnetic tape between EMI's mainframe computer and the clinical prototype in Wimbledon. It gave the hospital CT images within minutes of the patient being scanned and it gave EMI a CT scanner which was ready for use in hospitals anywhere in the world.

An excellent new Mayo Clinic Heritage Film marks this 50th Anniversary. In 23 minutes it shows how the key people at Mayo Clinic and at EMI worked together to make this happen. EMI were the pioneers of CT scanning and needed to decide how to make it available to hospitals, which was a market which they had no experience in. Both organisations saw the benefits and took significant risks in fast-tracking their usual processes. Mayo Clinic decided to place an order within 9 weeks of first becoming aware of computerised 3D X-ray imaging, knowing that EMI lacked experience in hospitals beyond Atkinson Morley's and had not yet completed the mini-computer software.

To watch Mayo Clinic Heritage Films visit HISTORY.MAYOCLINIC.ORG and click BOOKS/FILMS. The film gives the highlights of the story. The remainder of this article adds detail, based on email discussion between the writer / director of the film and the author of this review. I worked for EMI on CT scanners, starting a few months after the events in this film. Mayo Clinic want the films to be historically accurate and relevant to current patients and staff, so their archivists and radiology experts contributed strongly to this film, as did documents archived by EMI in the 1970s and the recollections of the people who were involved 50 years ago.

The links between Mayo Clinic and the UK go back to the birth of William Worrall Mayo in May 1819 in Salford about 2 miles west of the centre of Manchester, UK. William studied chemistry in Manchester under John Dalton FRS who pioneered atomic theory, and who (according to W.W. Mayo's son) "simply enthused him with chemistry." In 1845 he emigrated to the USA at the age of 26. The years from then onwards are covered in Helen Clapesattle's very readable account, first published in 1941 shortly after W.W. Mayo's sons Will and Charlie died in 1939. The three Drs Mayo welcomed opportunities to exchange knowledge and skills with medical practitioners across North America and in Europe. In 1889 Dr Charlie Mayo visited his uncle and aunt in Salford during one of his trips to hospitals in Europe. In 2009, marking the 190th anniversary of Dr William Worrall Mayo's birth, the Salford Royal NHS Foundation Trust opened a facility named in his honour. The Mayo Building provides advanced services for medical education and research — a fitting tribute for the first Dr Mayo, whose international outlook and commitment to excellence helped shape Mayo Clinic. More recently, Mayo Clinic Healthcare opened in Portland Place, London, UK in 2020.

Six days in New York

The story of the first CT scan in Rochester began when Dr Colin Holman arrived in New York on Sunday 14th May 1972 and booked into the Waldorf Astoria hotel in the city centre. He was a leading neuroradiologist at Mayo Clinic and was due to speak at a 5-day neuroradiology postgraduate course at the Albert Einstein College of Medicine, about 10 miles away in The Bronx. Other speakers included Drs Juan Taveras and Ernest Wood who in 1964 co-authored the first American textbook on neuroradiology 'Diagnostic Neuroradiology'. Also speaking was Dr James Bull, the leading neuroradiologist at 'Queen Square' hospital in London UK, which is now the National Hospital for Neurology and Neurosurgery. Those four neuroradiologists were among the most renowned in the world, and they came to learn from each other as well as to teach the next generation. James Bull brought Godfrey Hounsfield of EMI with him, to present CT scanning for the first time in the USA. In his obituary of Colin Holman, Frank Earnest quotes Colin's recollection:

Godfrey Hounsfield and I had breakfast together one morning, and he explained his idea of developing a computerized tomography machine and he was writing it all down over the damask tablecloth at the Waldorf Astoria. I didn't understand the mathematics about it, but I did understand the general idea and it certainly sounded like it might work. At the end of that session, he said that if we would be interested in taking one of the machines he would be very grateful because he knew we had far more cases than most any place else and could evaluate it in a hurry. I thanked him for that offer and told him that if he would like to give us a call sometime when he had something that really worked we would come over and have a look at it if we could.

Perhaps this breakfast meeting implies that Colin Holman missed the talk on CT by Bull and Hounsfield during lunch-hour on 15th May. Godfrey often wrote on the first thing which came to hand. While developing fast image reconstruction with Chris LeMay he wrote on the wall in the corridor in EMI's research labs, while working on the body scanner with Brian Lill he wrote on a block of wood, and he often wrote on menus when eating lunch with Tony Strong. Colin Holman probably intends two different meanings of 'work' in this quotation: 'Work' seems to mean that CT will revolutionise neuro-radiology due to the ability to resolve 0.5% differences in tissue density. 'Really worked' seems to mean being available for clinical use at Mayo Clinic.

Later in the week Godfrey moved to a $5 per night hostel to stay in New York for the full working week because many radiologists asked him to visit their hospitals and show his slides to colleagues who did not see them on Monday 15th May. He hadn't arrived with enough currency to stay that long, perhaps because the trip was arranged at short notice with no time for the government exchange control process which was needed to take more than £50 in US dollars out of the UK. So his breakfast at the Waldorf Astoria may have gone onto Colin Holman's hotel bill and have been on any day 16-20 May. On one of the days in that week Godfrey visited the Massachusetts General Hospital in Boston, perhaps by car with Juan Taveras and with another meal provided. He also visited Columbia Neurological Institute of New York where Ernest Wood worked. Godfrey's visit report describes the friendship and mutual respect between James Bull and Drs Holman, Taveras and Wood. So James Bull was the ideal person to describe CT to those top neuroradiologists in the USA. That opened the door for Godfrey to have follow-up meetings with them and many others in his improvised 4-day marketing campaign.

Mayo Clinic decides rapidly.

Colin Holman returned from New York to Mayo Clinic and showed some slides borrowed from James Bull to others in the radiology department. Events moved very rapidly, as described by his somewhat younger colleague Dr Hillier Baker, always known as Bud. In a 1993 paper he wrote:

Colin was deeply impressed by what he had seen and, therefore, asked James Bull, who was a good friend to both of us, if he could borrow several slides to bring back to Rochester so all members of the department could view them. Despite the crudity of the images, it was immediately apparent to all that structures inside the skull and brain could be seen with some clarity and that this new technique was a major advance in imaging. After some discussion within the department and the institution, I was asked by our departmental chairman, John R. Hodgson, to go to England and evaluate the machine, as well as Dr Ambrose's patient studies, on site at the Atkinson Morley's Hospital. Before leaving I consulted with James Bull who was very cordial and offered to arrange introductions to Ambrose, as well as to the principals at the Central Research Laboratories and corporate headquarters of EMI. I also asked Jack Hodgson to obtain permission from the Mayo Board of Governors which would allow me to place an order for a scanner "on the spot" if, indeed, the instrument looked to be as valuable to our practice as it appeared in our early but superficial introduction. In due course, this permission was granted, although such a setup was somewhat unusual in that these instruments cost about $350,000 at that time — enough money to furnish several regular radiographic rooms with standard equipment or one or two angiographic rooms with more sophisticated equipment. On July 18, 1972, I arrived in London accompanied by several members of my family. While they enjoyed sightseeing for the next several days, my time was occupied by the important evaluation I was sent to accomplish.

The fact that Bud Baker was authorised to place an order on the spot for such a large amount of money is simply extraordinary. It shows that Mayo Clinic wanted to be first in the world outside Wimbledon, and that the revolutionary improvement in imaging from CT scanning strongly outweighed the unknowns about EMI as a supplier.
Bud Baker wrote this partly from memory in 1993, so there are understandable inconsistencies with known facts such as the date when Colin Holman met Godfrey in New York. But Bud kept a diary while in London which he used when writing his 1993 paper and that part tallies closely with documents placed in archives by the hospital and EMI. Bud had three very busy days.

Three days in London

On the 19th of July, I spent the day with the people of EMI. In the morning at the Central Research Laboratories, I met with William E. Ingham, director of the laboratories; Alan G. Blay, the assistant director; Godfrey Hounsfield; Edward Gowler, a production engineer; and a very personable administrator, Robert Froggatt, who gave me a guided tour of the entire installation in which multiple electronic projects, in addition to the CT effort, were in progress. Hounsfield's so-called laboratory was a large shop-like room with various machine tool and electronic installations used in assembling the prototype EMI scanner. The room appeared to contain everything needed except large casting and stamping equipment for fashioning major metal parts. Laboratory personnel explained how the instrument worked and they scanned a phantom that was on hand, to demonstrate how rapidly and well the image could be reconstructed and displayed. After luncheon we went to EMI corporate headquarters on Manchester Square in central London where I met Sir John Read, CEO of EMI, Ltd. Sir John briefly outlined the history of CAT scanner development and invited me back for further talks after I had visited James Ambrose and his installation at the hospital.
Bud isn't quite right about the roles of Bob Froggatt and Eddie Gowler. Both could perform many roles, but Bob was an outstanding scientist who usually left admin to others, and Eddie was the man who was appointed to set up and run EMI's CT scanner business including sales, field service, marketing, finance, and production. Bud's description continues:
On the 20th day of July, I was taken to the Atkinson Morley's Hospital where I met James Ambrose, the neuroradiologist who was conducting evaluations of the EMI scanner on neurologic and neurosurgical patients. After we discussed machine operation, maintenance problems, downtime, and other pertinent points, I looked at the records of patient examinations. Dr Ambrose was quite meticulous in his record keeping and he had collected and mounted in loose-leaf binders the histories and images of all patients examined in the past year. Each case was consecutively numbered and, when available, histologic, surgical, or neurologic diagnoses were included.
There were several hundred such cases which I studied for about 3 hours; consequently, I reviewed virtually all of the material then available from this remarkable machine. As I saw the images it was obvious that, despite some streaking on certain sections caused by patient motion, the system was capable of displaying with remarkable clarity many pathologic processes involving the brain, including tumors, infarcts, hemorrhages, and infectious processes. I came away with a very positive attitude but deferred final judgment until I had a chance to talk to James Bull that afternoon.
At the National Hospital later that day, over a cup of tea, James and I talked for more than an hour about the meaning of the CT scanner and its possible impact upon neuroimaging in general and at our two institutions in particular. He told me that a machine had been ordered for use in his department but, because of the age of the building and the weight of the equipment, as well as the inadequacy of the elevators, installation within his present

department was impossible. A search was going on for adequate space in the basement of the hospital buildings, which might be used for scanner installation. He estimated that the identification, clearing, and preparation of such space for equipment installation and use in patient care might take up to 2 years, so the instrument then being built for his use might be available for use outside of the United Kingdom. Bull's very positive response to CT, as well as the information he was able to impart to me, reinforced my tentative conclusion that the time was ripe for Mayo to acquire this technology. I, therefore, asked James to inform the people of EMI Central Research that I would like to visit Atkinson Morley's Hospital once more to further review the patient studies of Dr Ambrose.
On July 21, 1972, Bob Froggatt drove me to Dr Ambrose's department where I spent another hour re-reviewing scanner case material. As we walked back to the car, I informed Bob that I would like to place an order for an EMI scanner to be installed as soon as possible at Mayo Clinic in Rochester, Minnesota. He was somewhat taken aback by this announcement and excused himself to call his office. When he returned to the car he informed me that we had a luncheon date with Sir John Read at corporate headquarters in London. After lunch, Sir John questioned me rather sharply concerning my impression of the CT system, its possible impact upon neuroradiology, and what I thought the market for these machines might be in the United States. My estimate was between 2000 and 2500 units, if all institutions with residency training programs in radiology, neurosurgery, and neurology found that they could not function without this technology (which I thought would be the case).
Why was Bob taken aback? EMI knew that Mayo Clinic were very interested, but they were on the back foot because Bud had arrived in London before booking appointments to visit EMI and see the CT scanner at Wimbledon.
Tom Williams, the film's writer/director, told me his interpretation of various documents and memories at Mayo: *James Bull is an important figure in this story. It seems like he knew everybody. He and Baker were long-time friends. Bull came to Mayo to give a talk in 1963, and in 1967 Bud Baker and his wife visited him at his home in London. When Bud was charged with going to England to see the scanner, the first thing he did was call Bull to ask him to arrange meetings with EMI and Ambrose.*
Unfortunately, Bull was very busy. He wrote back to him after some delay, suggesting Bud simply write to Ambrose himself to ask to see the scanner. He did… and Ambrose didn't reply! Nor did he hear from EMI. After a month of waiting, Bud wrote Bull again and announced he was coming to London soon with his wife and two of his kids. Bull had told him Ambrose was trying to get a speaking slot at the RNSA meeting in Chicago, as well as exhibition space. Bud casually mentioned that he had managed to arrange a booth for the scanner and that Ambrose would have a prime place on the agenda. (Baker was secretary of the RSNA, so he could pull some strings.)
Baker says that when he arrived in London, the first thing he did was call Bull to announce he was in town. Bull made a call, and the next day EMI sent a car to pick Baker up and give him the VIP treatment. The day after that, Bob Froggatt himself drove Baker to Atkinson Morley's. He then consulted with Bull before making his decision. Before going home, Bud and his family visited Bull's country home in Nettlebed.
Bud arrived in London on a Tuesday, so EMI and the UK Dept. of Health and Social Security (who funded EMI's work) only had a few hours to prepare for his visit. Bud used all three of the remaining work-days of that week to get the clearest possible view about whether to place an order.
Only 58 days had elapsed since Colin Holman brought the news of CT scanning to Rochester, and in that time Bud had exchanged letters with James Bull, written to EMI and James Ambrose on 15th June and decided to go to London and set up the meetings after he arrived.

Bud was a self-confident and determined person. Perhaps the fact that Bud and his wife were long-time friends of James Bull gave Bud confidence that when he landed in London James would make the introductions to EMI and Ambrose, but arriving without an appointment was risky.

Did Bud realise that he must prod EMI into action? He wouldn't have known at the time, but EMI was in the process of changing the main board director who Bill Ingham reported to and how the CT activity was managed. This may explain EMI's delay in replying to Bud's letter. It might also explain the puzzle of why Bud met EMI chief executive John Read twice during his visit to London but didn't meet either John Kuipers or John Powell.

Up to May 1972 all CT activity was in Godfrey Hounsfield's group which reported to Bill Ingham via Bob Froggatt. The main board director who Bill Ingham reported to was John Kuipers who ran EMI's Electronic and Industrial Organisation. Kuipers was replaced by John Powell in the summer of 1972.

Before taking on the challenge of setting up EMI's nascent medical imaging business on 4th May 1972, Eddie Gowler had spent a year as right hand man to Kuipers, so they knew each other well. The transition between these roles was somewhat strange: first John Powell (who had recently joined EMI from Texas Instruments) told Eddie that when he took over from Kuipers he would not require Eddie to continue in his previous role, so it would be a good idea if Eddie found something else to do. Eddie already suspected that Powell would replace Kuipers, but nothing had yet been announced, and no announcement emerged for many weeks: Powell was being indiscrete. Eddie waited for Kuipers to tell him this formally, and quite soon Kuipers burst into his office and asked if he would like to run the CT activity. Eddie had been in meetings with Kuipers which discussed offering that role to various people in EMI. Eddie thought that he could do it better than the others, but didn't feel able to say that. So when Kuipers asked, Eddie said yes immediately. Initially his reporting line to CEO John Read was via Bill Ingham and John Kuipers because no announcement of Powell's role in CT scanning had yet been made. Kuipers was replaced by Powell in the reporting line some time between 15th June and 26th July. Which man was the EMI main board director in charge during Bud's visit is unclear. That might explain why Bud met John Read twice but met neither of Kuipers or Powell. Kuipers moved to EMI Australia and a few years later wrote an unreliable account of his role in CT. John Read subsequently left most CT decisions to John Powell.

EMI weren't able to quote a price for the CT scanner during Bud's visit, possibly because of imminent changes in main board roles. Eddie supplied a quote on 26th July'72 of $302,000, of which $2,000 was for installation. Mayo Clinic's Board of Governors approved the purchase on 16th August'72. It then fell to Mayo's Karl Ladner to agree the conditions. On 1st September he posted a letter to Eddie which is a purchase order but which lists 15 points which are still under negotiation. EMI's Geoff Byers advised Eddie during the negotiations. Both parties were trying to give each other the confidence that the sale would happen, while also sticking as closely as possible to their incompatible ways of doing business. How they resolved that doesn't matter much today.

Rolf Schild of EMI visited the USA and Canada in September 1972, and his visit report said that *There is no doubt that the name EMI-Scanner is becoming as familiar to the neurologists as the name Hoover is to the housewife, and with this, the name of EMI. Nearly all the Doctors visited have recently purchased EMI stock, as they expect EMI results to change. Hospitals like Mayo Clinic expect to examine up to 30 patients daily. This means that Mayo Clinic will examine as many patients in one week as so far have been examined by the Atkinson Morley Hospital in Wimbledon during the whole year.*

Installation and operation of the first CT scanner outside Wimbledon

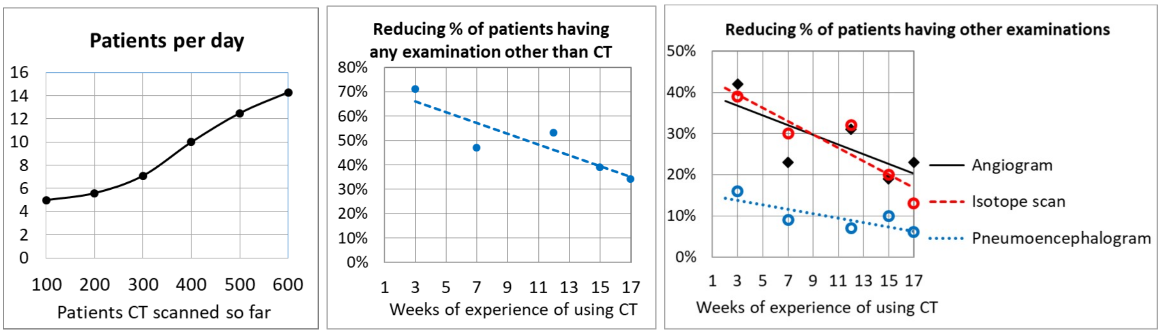
Dave King and Peter Clarke of EMI started installing the scanner in Rochester in May'73. Until recently, I assumed this came after installing CT scanners in the UK at Manchester Royal Infirmary and at Queen Square in London. That would have been invaluable experience before an installation more than 4,000 miles away. But the EMI documents show that the Manchester and Queen Square machines were shipped just in time to be counted as sales at EMI's 30th June'73 year-end and were installed in July. Clearly all parties (the hospital, EMI, and UK DHSS) wanted a CT scanner in the USA to scan as many patients as possible before the annual radiological congress and exhibition in Chicago, RSNA, in November 1973. So Peter and Dave learnt what they should have brought with them, without having the ability to drive a car back to London to fetch it. Luckily they were able to borrow an oscilloscope and other items from the very helpful hospital maintenance department.

Darrel Holtz was chosen to become the hospital's first CT scanner technologist. Darrel became friends with Dave and Peter while they were installing the scanner and helping him to learn how to operate it. He recalls the rapport and informality during his first meeting with Dave: *I said, "I'm going to have to learn how to speak English all over again just to do business with you guys". Dave's response: "you bloody colonists don't speak English in the first place!"*

Left: Peter Clarke and David G. King installing the scanner at Mayo Clinic in May 1973. **Right:** David King as the 'subject' during calibration and checking in early June 1973. Darrel Holtz, first American CT scanning technologist, adjusts the machine while Dr Hillier Baker looks on.

The January 1974 paper by Dr Baker and others shows how quickly the throughput of patients increased. They had calculated a maximum throughput of 16 patients per 8 hour day from the scanning and image reconstruction times. They wrote that: *As our experience broadened, clinicians with a special interest in the neurologic sciences became increasingly enthusiastic about this noninvasive and relatively innocuous but very informative procedure. Their enthusiasm was reflected in the rate of patient referral : the first 100 patients were evaluated in a 24-day period, whereas each succeeding group of 100 evaluations was accomplished more rapidly; the times required were 20, 18, 14, 10, 8, and 7 days,* *respectively. We are rapidly approaching saturation of our appointment schedule and have investigated means of extending operating hours to accommodate more patients.*

They soon reached 14 patients per day. A few months later, EMI upgraded the scanner to give 160 pixel images using faster filtered back projection reconstruction, enabling about 22 patients per day.



Graphs plotted from numbers in Table 2 in Baker et al 1974 and from his text.

The graphs show that CT quickly reduced the use of the previous mainstays of diagnosis of brain disease. CT helped patients in three ways: by allowing more accurate diagnosis, by faster diagnosis, and by reducing the mortality and morbidity side effects of previous invasive diagnosis.

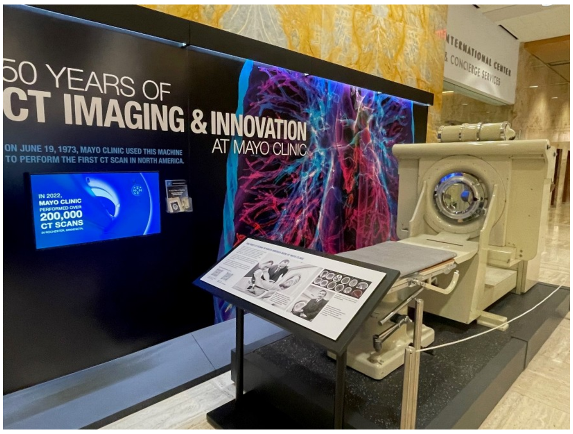
The side effects of the pneumoencephalogram (also known as ‘air study’) were particularly bad. It involved removing cerebrospinal fluid and replacing it with gas which bubbled up into the head and made the ventricles visible in conventional X-rays. Patients refused potentially life-saving re-examinations rather than endure that examination for a second time. A radiologist in New York told me that the screams from the radiology department made it sound like a torture chamber.

Mayo Clinic found faster diagnosis invaluable in deciding how to treat emergencies such as head injury and blood clots. The accident and emergency team wanted 24-hour access to a CT scanner. Soon a second machine was purchased.

Atkinson Morley’s Hospital, Wimbledon	October 1971	London, UK
Mayo Clinic	June 1973	Rochester, USA
National Hospital, Queen Square	July 1973	London, UK
Manchester Royal Infirmary	July 1973	Manchester, UK
Massachusetts General Hospital	August 1973	Boston, USA
Montreal Neurological Institute	Approx. Sept 1973	Montreal, CA
Presbyterian St. Luke’s Hospital	Approx. Sept 1973	Chicago, USA
Southern General Hospital	Approx. Sept 1973	Glasgow, UK
Karolinska University Hospital	Approx. Sept 1973	Stockholm, SWE
George Washington University Hospital	Approx. Sept 1973	Washington DC, USA

By September 1973 CT scanners were in 10 hospitals
and CT was an unstoppable revolution

In summary, the risks and hard work which Mayo Clinic and EMI accepted in fast-tracking this first CT scan outside Wimbledon had an enormously worthwhile outcome. The number of patients benefitting from CT across the world has increased in each of the 50 years since then. The photos below show the scanner on display at Mayo Clinic's symposium celebrating this 50th Anniversary on 19th June 2023. The slides and videos of the excellent talks from that symposium are on the web at:
https://ctcicblog.mayo.edu/50th-anniversary-of-ct-at-mayo-clinic-scientific-symposium/



Left: In 2022 Mayo Clinic performed over 200,000 CT scans in Rochester Minnesota
Right: Transparent cover reveals the warm water reservoir above the motor control circuits

References

Baker H, "Historical Vignette: Introduction of Computed Tomography in North America." American Journal of Neuroradiology; Mar 1993, 14 (2) 283-287

Baker H et al, "Computer Assisted Tomography of the Head - An Early Evaluation." Mayo Clinic Proceedings; Jan 1974; 49: 17-27

Clapesattle H, "The Doctors Mayo" University of Minnesota Press, 1941. 7th printing published by Mayo Foundation for Medical Education & Research, 1990, Rochester, MN.

Earnest F, "Memorial - Colin B. Holman" American Journal of Roentgenology; Nov 2009; 193: 1461–1462

The table of approximate dates of the first 10 CT scanners is based on two unpublished sources. A memo in EMI's archives dated 13th June 1973 from Bob Froggatt to Eddie Gowler says that although the scanners for Manchester and Queen Square have a noise issue to be resolved, they must be shipped forthwith. That proves that Mayo Clinic's 19th June 1973 CT scan was the first outside Atkinson Morley. Eddie Gowler's monthly report dated 24th Sept 1973 lists the first 17 orders accepted. It does not include Manchester and Queen Square because those orders had been accepted by CRL but with delivery and support performed by Gowler's team after they became an independent business.

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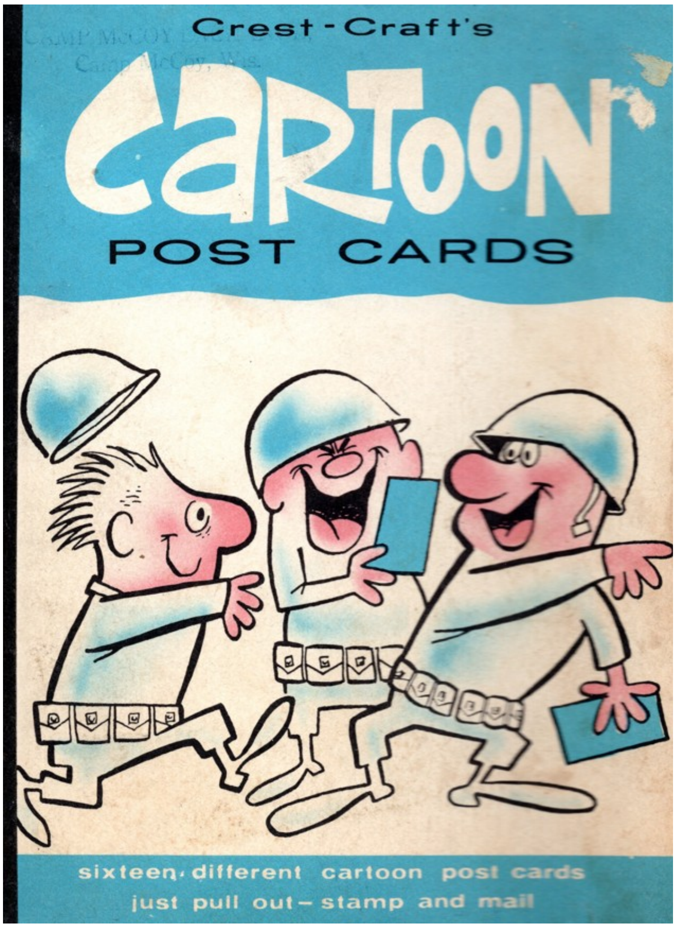
Glowing in the Dark.

By: Adrian Thomas.



It's funny what one comes across. I found this booklet of 'Crest-Crafts Post Cards' (Cincinnati, Ohio) with an ownership stamp from Camp McCoy in Wisconsin, USA. It is a fun book and the individual postcards have been annotated with names of soldiers presumably known to the original owner. It looks to be of an early 1940s vintage. Fort McCoy is named after Maj. Gen. Robert Bruce McCoy [3].

The camp was fully used during the Second World War and indeed needed to grow. Over 45,000 acres were apparently added between 1938 and 1942. This addition included the construction in 1942 of a large triangular cantonment area which was referred to as the 'New Camp', which still serves as the installation's cantonment area today. The US Congress allotted funding for the construction of facilities that were large enough to house, train and support 35,000 US troops. This was inaugurated on Aug. 30, 1942, and some 8,000 local workers took part in this building project. The triangular shape of the cantonment area, or 'triad,' was designed to allow troop units to live and train efficiently under one headquarters. More than 1,500 buildings were constructed at an estimated total cost of US$30 million.
On the reverse of the booklet is an amusing verse.

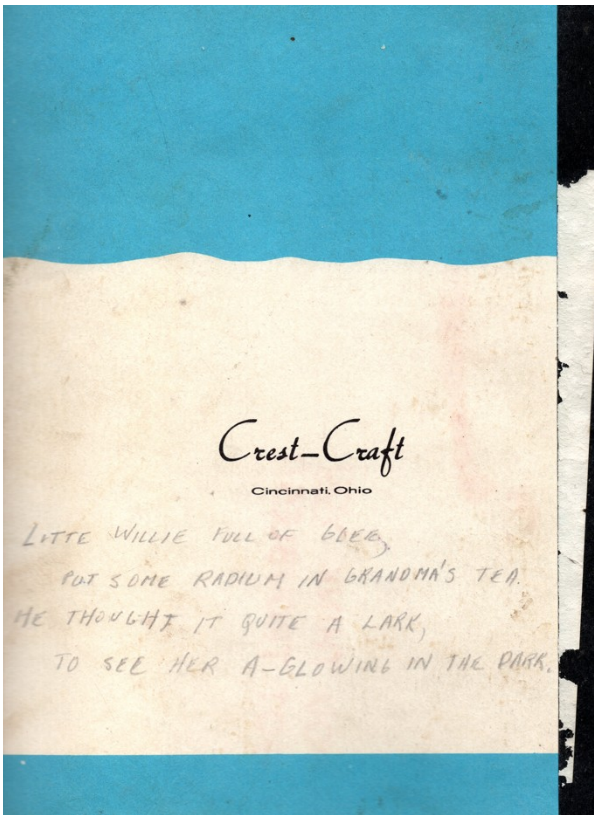
The verse reads:

Little Willie full of glee,
Put some Radium in grandma's tea,
He thought it quite a lark,
To see her a-glowing in the dark'

[3] https://home.army.mil/mccoy/about/history

This poem is based on the 'Little Willy' series, and is inspired by the 'Ruthless Rhymes' of 'Harry' Graham (Col. D. Streamer) [4].

The poems have a callous and light-hearted spirit and involve the dreadful actions of the horrid and eponymous Little Willy, but remarkably no one becoming particularly upset or more than a little irritated resulting in the humour [5].



That radioactive material glows is an interesting property. The radiation emitted is a mixture of the viable and invisible, with the invisible rays being highly dangerous. This as shown in the incident in the 1980s at the Goiânia Institute of Radiotherapy in Brazil[6]. On 13 September 1987, a shielded and strongly radioactive caesium-137 medical radiotherapy source was removed from its housing in a teletherapy radiotherapy machine. The machine had been left in a clinic abandoned by the *Instituto Goiâno de Radioterapia* in Goiânia, the capital of the State of Goias in Central Brazil. The incident was fully reviewed by the International Atomic Energy Agency in Vienna in 1988 [7].

In 1985 the Goiânia Institute of Radiotherapy moved location, leaving behind a Cesium-137 radiotherapy unit. Two years later, on September 13th, 1987, two criminals broke into the building to steal the machine, when the guard did not showed up for work.
The men wheeled it home and began to dismantle it, with both men falling sick that night. Despite this they continued to dismantle the machine and by the 16th of September, they were able to puncture a hole in a capsule inside the machine.

Inside the capsule was a bright blue powder that they scooped up. They shared it with friends and relatives, even painting blue crosses on their shirts and some even used it as make-up, completely unaware of what they had.

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[4] https://web.archive.org/web/20160306021133/http://ruthlessrhymes.com/category/little_willies/1911-little-willies-book (accessed 26 August 2023).
[5] https://litfl.com/little-willie-the-poisoner/ (accessed 26 August 2023).
[6] https://www.iaea.org/sites/default/files/publications/magazines/bulletin/bull30-4/30402781017.pdf (accessed 26 August 2023).
[7] https://www-pub.iaea.org/MTCD/Publications/PDF/Pub815_web.pdf (accessed 26 August 2023).

The handling of the blue power was enough for the two thieves to require fingers and an arm to be amputated. But before it had gotten to that point the men decided to sell it to a local scrapyard. The machine was further dismantled by the owner, Devair Ferreira. When he was finally able to release the blue powder himself, he was fascinated by the it. Believing it to be highly valuable, even possibly supernatural, he invited family members over to see it, even passing it around.

From there it was then sold to another scrapyard. Devair's brother, Odesson, even took a chunk of the material home with him. He was a local bus driver and unknowingly contaminated dozens of passengers. He's also one of the most contaminated surviving victims of the disaster and he says he can still feel the burning in his hands.

His six-year-old daughter even played with the blue powder on the floor before having dinner, where some of the radioactive material had fallen on her sandwich and she consumed it. Tragically, within just one month she passed away and was buried in a lead coffin, encased in concrete.
Nobody knew that the material was highly radioactive. As time passed, everyone who had come in contact with the machine or the powder began falling seriously ill. It wasn't until a concerned relative had a feeling the machine had something to do with it and took some of the blue powder to the hospital to be tested. Doctors were quick to determine that they were suffering from acute radiation poisoning.

They resulted in over 100,000 people being isolated in the Olympic stadium for screening. 250 people were found to be contaminated. 28 skin related injuries from radiation and two men, one woman and one child died.

Over 40 homes and buildings had to be demolished. The remaining chunk of Caesium, as well as over 6000 tons of contaminated clothing, furniture, pieces of buildings and even dirt were packed into steel drums and containers and dumped in an abandon quarry.

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The John Clifton Essay Prize 2023

The British Society for the History of Radiology has launched the John Clifton Essay Prize, an initiative to promote research and insight into the history of medical imaging and nuclear medicine.

The BSHR keen to receive essays that explore all aspects of radiology history including scientific discovery and technological development; biographical accounts; societal impact and cultural dimensions. Essays which explore less well-known events/figures, or which demonstrate the relevance of historical events to current and future practice are encouraged. Topics can include diagnostic imaging, interventional techniques, radiotherapy and may seek to highlight the work of radiologists, radiographers, physicists and engineers, or may explore imaging and therapeutic techniques from the patient's perspective. Whilst entries are open to all, the BSHR particularly welcomes participation from healthcare professionals in training and from undergraduates. Essays are primarily based on accurate historical research, but personal insights, reflections and perspectives can be included.

The prize is named in honour of the late Prof. John Clifton, a medical physicist and member of BSHR. John had a deep interest in history, and many of us attended a memorable visit that he organised to University College Hospital where we were shown some of their historical treasures. We congratulate John Chen for winning the 2023 John Clifton Essay Prize, and are pleased to publish it below.

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The Origins And Specialisation Of Radiology In The United States Of America, 1895-1940.

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ABSTRACT

The history of radiology is often traced back to the fortuitous discovery of x-rays by Röntgen in 1895. The discovery was met with huge scientific excitement and x-rays were rapidly applied for medical use. Professional societies and specialist journals formed around the remarkable new technology, gathering a keen following of scientists and physicians. Further advances in x-ray technology would revolutionise the diagnosis and treatment of many diseases.

The discovery of x-rays therefore signified a new era of medical science. It did not, however, usher in the era of radiology that we know today. Radiology at the time was a disorganised mass of investigators and practitioners, made up of physicians and non-physicians, legitimate practitioners and quacks. Electricians, electrical engineers, and photographers were among those providing medical x-ray services to the public. There were no recognised training programmes or standards. Radiology at the end of the nineteenth century bore no resemblance to the organised specialty that it is now.

Yet over the next few decades, radiology would be completely transformed from its technical beginnings into an exclusively medical discipline, where physicians emerged as the only licensed practitioners following specialist training and certification. A generation after its birth as a technology, radiology would finally come of age as an established medical specialty. How did this transformation take place? What were the forces that shaped the specialty during its formative years? Part of the change was due to technological developments that enabled radiology to gain an increasingly prominent role in medicine. But more profound were the changes in professional organisation, where physicians took control of the growing discipline, generating numerous conflicts with others.

In this essay, I chart the origins of radiology as a medical specialty in the United States of America, from the extraordinary scientific discovery of x-rays and the technological developments that followed, to their remarkable societal and cultural reception, to the complex struggles between various groups that eventually led to the professional structure of radiology that we know today. I pay particular attention to the early radiological societies and journals, which were key professional institutions of the time, exploring the tensions that arose between the physician radiologists and their technical colleagues, manufacturers, quacks, electrologists, and other medical specialists.

Primary sources include articles from the early radiological journals, and speeches and editorials from notable figures in radiology, both a century ago and now. Secondary sources include prominent texts on the history of radiology in America by Emanuel Grigg, Edward and Ruth Brecher, Ronald Eisenberg, and Bettyann Kevles; the history of medical technology by Joel Howell; and the history of medical specialisation by Rosemary Stevens and George Weisz.

I argue that, contrary to popular belief, the emergence of radiology as a specialty in medicine was not simply a passive result of the new technology. Instead, it was driven in large part by the professional aspirations of the early radiologists, who worked to transform their discipline from a technical novelty into an established medical specialty whose role and prestige rivalled that of any other. Furthermore, I argue that the historical elements that moulded the specialty in its early years, many uniquely related to radiology, continue to shape its practice today as it faces ever new opportunities and crises.

I. THE REMARKABLE DISCOVERY

X-rays were discovered by Wilhelm Röntgen in Würzburg, Germany, in 1895.[i] Despite the fact that x-rays had certainly been produced by others unknowingly,[ii] Röntgen was the first to recognise and investigate the mysterious phenomenon, which he described as "a new kind of light."[iii] Spread of the news through the world was rapid and reactions were sensational.[iv] In their account of the history of x-rays, Ruth and Edward Brecher propose that "no prior scientific discovery in history…aroused such interest and enthusiasm among American newspapers and their readers."[v]

The potential of x-rays was immediately perceived and their medical application began rapidly.[vi] Within weeks, x-rays were being used to image bones, fractures, and foreign bodies.[vii] Within months, they were used on other organs, for detecting lung cavities and kidney stones, imaging the womb, and for therapy.[viii] Hundreds of books and articles were written about the new technology.[ix] X-rays were admitted in court as evidence,[x] and their use intensified dramatically in the wars at the end of the century.[xi] Outside medicine, x-rays were used in art to detect forgery,[xii] and in customs inspections.[xiii] Röntgen received the first Nobel Prize in Physics in 1901.[xiv]

There was huge public fascination with x-ray technology, which became a familiar feature at exhibitions.[xv] As Bettyann Kevles describes in her chronicle of medical imaging, "X-rays triggered a craze unlike any that had come before."[xvi] Unaware of the dangers of radiation, people gathered to have x-ray images taken. The Tsar and Tsarina of Russia had their hands x-rayed, and the Queen of Portugal sent her ladies-in-waiting to have their rib cages x-rayed.[xvii] Within a few years of its discovery, x-ray technology was seen as the most significant development in medicine for decades. According to Kevles, it was possibly "the only major scientific discovery that was entirely unanticipated, but which was nonetheless accepted immediately, universally, and without question."[xviii,xix]

II. SCIENTIFIC & TECHNOLOGICAL DEVELOPMENT

Many technical developments took place in the succeeding years.[xx] These included fluoroscopy, aiding investigation of moving organs such as the heart or intestines; intensifying screens, allowing shorter x-ray exposures; improvements in power sources; improvements in photographic glass plates, fluoroscopic screens, and eventually photographic film; and stereoscopy, for depth perception.[xxi] Particularly important were the introductions of the Coolidge tube[xxii] and the Bucky-Potter grid.[xxiii] The pace of advance was such that George Johnston, president of the American Roentgen Ray Society, complained in 1909 that "the apparatus of today is obsolete tomorrow. There is a constant race between our pocketbooks and the inventive genius of the up-to-date manufacturer."[xxiv]

It was an unfortunate fact that many advances were triggered by war. This was due to a massive increase in demand resulting in large-scale training of radiologists and production of portable x-ray units.[xxv] As Ronald Eisenberg describes in his account of the history of radiology, World War I "placed radiology in the limelight as an urgently needed specialty."[xxvi]

Later, there were developments in tomography, phototimers and automation,[xxvii] and in the application of contrast, whether air, oil, bismuth, or iodine, allowing further investigations of the gastrointestinal tract by Walter Cannon, the nervous system by Walter Dandy, and cardiac catheterisation by Werner Forssmann, the latter earning the Nobel Prize in Medicine in 1956.[xxviii] Many more impressive developments were made in the technology of radiology, leading to huge improvements in clinical potential. But advancing technology was not the only factor that marked the emergence of a new discipline. There was also the formation of specialist organisations and publications, representing the beginnings of professional structure.

III. RADIOLOGICAL SOCIETIES & JOURNALS

The birth of any new field requires organisations to bring investigators and practitioners together and publications to facilitate the sharing of expertise.[xxix] Specialist societies had already been established for other medical disciplines, including the American Ophthalmological Society (1864) and American Otological Society (1867). These acted as nuclei for emerging specialist identities.[xxx]

Following the huge scientific and medical interest generated by x-rays, there was a rapid formation of professional societies and journals devoted to radiology in America.[xxxi] The first radiological organisation was the Roentgen Society of the United States (1900), renamed the Roentgen Society of America in 1901 and then the American Roentgen Ray Society in 1902. Later organisations included the Western Roentgen Society (1915) which became the Radiological Society of North America in 1920, the American Radium Society (1916), the American College of Radiology (1923), the Section on Radiology in the American Medical Association (1925), and the American Board of Radiology (1934). The first radiological journal was the *American X-Ray Journal* (1897),[xxxii] followed by the *American Electro-Therapeutic and X-Ray Era* (1901), and the *Transactions of the American Roentgen Ray Society* (1902).[xxxiii]

The organisations and publications associated with radiology are a historical lens through which we can observe the evolution of the specialty. They began as egalitarian organisations open to all who were interested in radiology, but this quickly changed, to the advantage of some and disadvantage of others. The organisations became focal points of professional tensions, and there would be a significant period of struggle before radiology emerged in its final form. In her analysis of specialisation within medicine, Rosemary Stevens argues that any discussion of specialisation cannot reasonably ignore its scientific, social, and professional context,[xxxiv] suggesting that science and technology are "embedded in a social process…driven by multiple personal, economic, and organizational agendas."[xxxv] This was certainly the case for radiology.

IV. PHYSICIANS, SCIENTISTS & TECHNICIANS

The composition of the radiological organisations was important because it signified who represented the discipline and therefore the nature of the discipline itself. When the American Roentgen Ray Society was founded in 1900, it was an open society. The initial constitution specified that members shall be "physicians and surgeons, dentists, investigators, authors on X-ray topics, inventors, radiographers, or their assistants in hospitals, military or State institutions, technical electricians, chemists, teachers of chemistry and physics, specialists and experts in electro-techniques."[xxxvi] Essentially, anyone with an interest in x-rays was permitted to join.[xxxvii] The membership at the beginning of the twentieth century therefore represented the broad technical nature of radiology.

Over the next decade, however, the American Roentgen Ray Society went through a dramatic restructuring that was beneficial to the physicians and detrimental to everyone else. Admission requirements were modified in 1911 such that only the medically qualified could become full members of the society.[xxxviii,xxxix] What were the reasons for such a transformation? Why were the technicians, who had earlier been such valued members and welcome contributors, now excluded?

In the early years, physician radiologists *had* to work closely with their technical colleagues. The experimental nature of early x-ray work meant that they depended upon the technicians for their expertise. Many of the first applications of x-rays were performed alongside physicists.[xl] When the pioneering radiologist Francis Williams first began investigating x-rays, his work took place at the Physics Department at MIT, where patients were brought from hospital in the evenings.[xli] Thus at the beginning, the collaboration of the technical professionals was considered crucial. Kevles writes, "in 1900 no serious practitioner of radiology could imagine excluding the experts they had learned to depend upon."[xlii] Heber Robarts, the founder and president of the society, simply explained, "we need the assistance of physicists in our meetings."[xliii] As technology improved and became more dependable, however, physicians were presumably able to operate radiological equipment more independently.[xliv] Paradoxically, technical advances abrogated the need for as much technical assistance, and gradually the physicians did not need to be as closely associated with the technicians.

More importantly, however, it seems that the physicians did not *want* to be so closely associated. There are many indications that they became increasingly keen to distance themselves from the technical nature of their discipline, deliberately engineering the transformation of their society for the sake of their professional interests. Kevles writes, "medical experts…were determined to ensure that organised medicine controlled the new technology" with a "campaign to push out photographers and engineers from their radiological organisations and publications…As doctors consolidated control, they campaigned to keep X-ray technicians subordinate everywhere: in hospitals and on the staffs on the newly founded X-ray journals and organizations. The very nonphysicians who had, in many instances, founded the journals, were no longer welcome as contributors."[xlv]

The early radiologists sensed that their work suffered from a degree of diminished status, brought by its close associations with electricity and photography. They perceived public sentiments that radiology was a type of photography that could be practiced by anyone with basic equipment. Such views unsurprisingly generated a lack of prestige for the role of radiology in medicine. The radiologist physicians thus became intent on separating themselves from these other groups, and on portraying their work as medical rather than technical.[xlvi] They emphasised that what they were providing were diagnostic medical opinions and interpretations, rather than images or plates. One way of doing this was to refuse to show the images to patients,[xlvii] demonstrating that the service provided was not photography but clinical consultation.[xlviii] Another was to transform their specialist societies into medical organisations. Stevens explains that radiologists, along with pathologists and anaesthesiologists, were in a special situation. "They were hospital based, providing necessary services to other physicians as a back-up or second-line function…these specialties did not fit into the prevailing concept of the physician as a frontline private practitioner. They were vulnerable to criticism as "technicians.""[xlix]

This was, therefore, a key battle for the professional identity of the radiologists. Throughout history, the traditional portrayal of medicine had always emphasised the notion of the caring, bedside doctor. This was perhaps most famously depicted by Sir Luke Fildes in his renowned 1891 portrait, *The Doctor*, with its enduring image of the noble, sympathetic physician.[l,li] As a modern technological discipline using machines, radiology was perceived differently from this depiction. The early radiologists took assertive steps in response. They purged the American Roentgen Ray Society and announced as their goal the establishment of radiology as a distinct specialty with the same standing and respect accorded to surgery, obstetrics, or medicine.[lii] As a result, the technicians were among the earliest casualties in the professional trajectory of radiology.

V. MANUFACTURERS & COMMERCIAL INTERESTS

In addition to medical investigators, the commercial scene was also important. Numerous manufacturers eyed the economic potential of x-ray technology, including Thomas Edison,[liii] who built himself an x-ray machine within just four days of learning about the discovery of Röntgen.[liv] The manufacturers competed to develop better equipment, spurring many advances. Edison's industrial laboratory dramatically improved the fluorescent screen, replacing the original barium platinocyanide with calcium tungstate.[lv] There were small companies and giants such as General Electric and Siemens.[lvi] As with the technicians, the relationship between these companies and the radiologists involved both benefit and struggle.

Some connections between manufacturers and radiological organisations were mutually advantageous. Companies provided funding for journals to survive, and in return received space for advertising. When Joseph Flannery launched the production of radium in the United States in 1913, he wished to publicise his product. He funded *Radium* (1913), journal of the American Radium Society, through the Radium Publishing Company, which was affiliated with his Radium Chemical Company and the Standard Chemical Company. Each issue carried advertisements of these two affiliates and no others.[lvii] Companies also exhibited their products at society meetings, making the newest technological developments available to radiologists and receiving business in return. It was said of the commercial exhibits at a 1900 meeting that "without any doubt there was exhibited…the finest collection of X-ray appliances yet brought together anywhere in the world…Two hours in this room were worth more to the incipient X-ray operator in search of information than two years of price list study."[lviii]

Other relationships resulted in tension and conflict. Society members protested against the commercialisation of the journals, including advertisements about oil and gold mining stocks.[lix] These concerns were exacerbated when companies tried to gain power within the professional societies themselves. When the Radiological Society of North America established the *Journal of Radiology* in 1920, it set up the Radiological Publishing

Company to deal with the finances and management of the journal. Over time the society lost control of its own journal to the publishing company, resulting in litigation that reached the state Supreme Court before being resolved in favour of the society.[lx] Several years later, the society was again beset by commercial conflicts when it allowed the Chemical Foundation to subsidise its new journal, *Radiology*. When the Chemical Foundation tried to interfere with the management of the society in 1931, threatening to cut off the subsidy to *Radiology* unless it changed its constitution and by-laws, the relationship was terminated.[lxi] These repeated occurrences demonstrate a widespread commercial desire to gain control in this new and lucrative field. Radiology thus both benefited and struggled to retain control over its organisations and journals in the commercial environment of the time.

VI. LEGITIMATE & FRAUDULENT PRACTICES

Initially, the provision of x-ray services was unregulated and certainly not limited to physicians.[lxii] Physicists, engineers, electricians, and photographers set up x-ray laboratories and provided services for the public.[lxiii,lxiv] The lucrative potential attracted numerous practitioners who tried to take advantage of the new field. Without regulations or standards, there arose numerous quacks and frauds. This was particularly the case for x-ray therapy and radium therapy,[lxv] and virtually every condition imaginable was treated with irradiation.[lxvi]

In 1908, Percy Brown spoke at an American Roentgen Ray Society meeting that, of the “impediments” hindering the field, "possibly the greatest…was the adoption of the Roentgen rays by the charlatan for his irregular purposes. This type of individual was quick to see the impression which might be produced in the lay mind by a demonstration, chiefly of fireworks, which could be masqueraded beneath the protecting cloak of the Roentgen rays.”[lxvii]

Was radiology particularly susceptible to quackery? To the public, there was an unmistakable mystique and attraction about x-rays. The earlier scientific reaction to their discovery had been extraordinary. William Morton, the New York experimenter, exclaimed, “the mind walks in among the tissues themselves.”[lxviii] But the impact of x-rays went beyond the scientific realm; they also had a profound cultural impact. Kevles writes that the “earlier, opaque world so full of mysteries on every level—anatomical, sexual, and mental—began to dissolve when X-ray mania swept the West.”[lxix] This sensational new way of seeing captivated the imagination of the public, and it is no surprise that they attached exaggerated hope on the miraculous technology.

The prevalence of quackery had important implications for the discipline. If radiology were to become an established medical specialty, the radiologists had to remove fraudulent practices. As we will see, they did this by establishing formal training programmes and limiting the practice of radiology to certified physicians. Yet practices of dubious legitimacy did not only exist outside the medical profession, but within it too. This was especially the case in the now obsolete field of electrology.

VII. RADIOLOGY & ELECTROLOGY

It will not escape notice that many of the early radiological journals were associated with what was known at the time as electrology, electrotherapy, or electrotherapeutics.[lxx] For example, the *American X-Ray Journal* (1897), the first radiological journal in America, later merged with the *Archives of Electrology and Radiology* (1904), itself the successor of the *American Electro-Therapeutic and X-Ray Era* (1901). Similarly, the *Archives of Clinical Skiagraphy* (1896), the first radiological journal in Britain and in the world, later became the *Archives of Radiology and Electrotherapy* (1915). Other examples of journals associated with electrology include *Medical Electrology and Radiology* (1903), and the *American Journal of Electrotherapeutics and Radiology* (1916). These examples may seem strange today, as radiology is now a prominent specialty while electrology no longer exists. Yet at the start of the previous century, the two were categorised together.

Electrology encompassed the use of electricity in medical practice, and was a popular form of therapy in the late nineteenth century. It consisted of running an electric current through a particular part of the body, and was applied for a variety of conditions.[lxxi] When x-rays emerged in medicine,[lxxii] they were automatically classed with electrology and other physical therapies, presumably because they were produced using electricity and considered a similar technology. These newer therapies were listed on the cover of the *American Journal of Progressive Therapeutics* in 1905 as “Electrical Science, X Ray Photography, Electro Therapy, Radio Therapy, Photo Therapy, Thermo Therapy, Hydro Therapy, Mechano Therapy, Psycho Therapy”, and, somewhat perplexingly, “Animal Therapy.”[lxxiii]

The alliance between x-rays and the other technologies was fraught with struggle. Tensions emerged between those working with x-rays and those promoting electrology. In the American Roentgen Ray Society, there were conflicts, with the electrologists trying to take control over the new x-ray society.[lxxiv] They failed, but managed to take editorial control of the *American X-Ray Journal*, which became a voice for electrology.[lxxv] Over time, it gradually became apparent that x-rays were effective but electrology was not, suffering from many suspect and unproven treatments.[lxxvi,lxxvii] In the limited therapeutic space available, the rise of x-ray therapy may have directly caused the decline of electrology. Within radiology itself, it would not be until much later that x-ray diagnosis would become separated from x-ray therapy and radiation oncology. The general struggle in characterising radiology and defining its boundaries was a major feature of the early years and continues to this day, as we shall discuss later.

In addition to their struggles with electrologists, radiologists also had to contend with competition from other medical specialties. Namely, what was to stop other physicians from reading their own films and practicing radiology themselves? How could radiology establish control over x-ray imaging? In the early days the intensely technical nature of radiology prevented the intrusion of others, as radiologists had the technical proficiency in operating complex x-ray equipment whereas others did not. But with improved technology, there was a risk that others could take their place. Radiologists had to be better at interpreting x-ray films than other physicians, and have ways of proving that this was the case.

VIII. EXPERTISE, TRAINING & REGULATION

The key question, therefore, was that of expertise. Radiologists naturally claimed that they were better at interpreting images. Did other physicians believe this? Some did, and some did not. At the meeting of the American Roentgen Ray Society in 1908, Reginald Sayre, a prominent New York surgeon, explained that many physicians who had formerly used x-rays themselves had now abandoned them and were referring their patients to specialists. He advised, "if you want a proper examination of the body by X ray, call in the assistance of a competent radiologist who will give you satisfactory interpretations on the points on which you are in doubt…This is the day for specialism."[lxxviii] In contrast, in his chairman's address to the Section on Radiology of the American Medical Association in 1930, Fred Hodges decried that while "it requires as long a time to become proficient in this work as it does in any other branch of medicine…a great part of the medical profession…does not realize this and some physicians feel that a six weeks' course will make them fairly familiar with x-ray work."[lxxix]

There was clearly an ongoing need to build expertise and to demonstrate this in a formal manner. How did the early radiologists gain their expertise? The first generation of radiologists achieved this largely through their own experimentation. A survey in 1910 found that a large proportion of radiologists at the time had previously been physicists, engineers, electricians, photographers, or in other technical capacities when x-rays were discovered, and had thereafter earned their medical degrees specifically to qualify as radiologists.[lxxx] These included leaders of the profession such as Walter Dodd, Eugene Caldwell, and Mihran Kassabian.[lxxxi] In the interpretation of pathology, radiologists employed a process known as retrospectoscopy,[lxxxii] where they would examine x-ray images and then follow the clinical developments of their patients, attending surgical operations or post mortem examinations. Having discovered the real pathology, they would return to the x-ray images and correlate the findings, discovering the characteristic radiological appearances of diseases.[lxxxiii]

If radiology were to become an established medical specialty with recognised expertise, however, it had to have a more formal method of scholarship. There needed to be standardised educational and training programmes to ensure the expertise of future generations of radiologists. As Stevens explains, radiologists defined routes of training for reasons "both of safeguarding their own interests and of safeguarding the general public.”[lxxxiv] The first residency programme in radiology began in 1915 at a Harvard-staffed hospital,[lxxxv] and in Britain, the first diploma course in radiology began in 1919 at Cambridge.

Closely related to this was the question of certification and licensing. If radiologists were competent there had to be a system of formally proving this to other physicians and to the public.[lxxxvi] Certification boards had already been set up for other specialties. The first specialty board was the American Board of Ophthalmology, founded in 1916.[lxxxvii] By forming the analogous American Board of Radiology in 1934, proposing to “test qualifications through examinations, to issue certificates, and to maintain a list of diplomates”, radiologists hoped to establish radiology as an equally reputable specialty. In their efforts to become the equals of other medical specialists, radiologists faced one remaining struggle: a remunerative structure identical to that of other medical practitioners.

IX. REMUNERATIVE & ECONOMIC STRUCTURES

In America, medical professionals were remunerated in a very specific manner. Physicians were paid by a fee-for-service system, receiving direct compensation for individual services rendered to individual patients, rather than by fixed salary or contract. Medical practitioners highly valued this structure.[lxxxviii] Financially, it allowed them to designate their own fees, an important consideration given that pecuniary potential was a major reason for becoming a specialist.[lxxxix] Symbolically, the fee-for-service model was a mark of private medical practice.

Radiology struggled in this domain. Because radiologists dealt with machines, were usually based in hospitals, and mainly dealt with patients referred from other physicians, they were liable to be perceived as part of a technical hospital service rather than a private medical practice.[xc] The radiologists were therefore engaged in a battle to be paid by fee-for-service rather than by a salary from the hospital.[xci] As Stevens explains, "the radiologist or pathologist…was in a different professional category from other, more prestigious physicians…By the late 1930s, the demands of the hospital-based specialists to be reimbursed by hospitals on a fee basis instead of a salary…had become crucial activities of the professional associations." The radiologists eventually emerged victorious, with hospitals agreeing to their demands in 1937.[xcii]

Further economic challenges would take place over the succeeding years with changes to American health care funding. But by the late 1930s, having secured the economic mark of fee-for-service payment, radiologists had at last succeeded in becoming a specialty in medicine that was identical in status to the others. Building on their triumphs, the various radiological societies would over the following years join closer to form an increasingly powerful lobby on the national stage. Notwithstanding the major technical developments that would take place in the next decades, the professional structure of radiology in America had finally established itself in completed form and would largely remain the same until today.

X. EPILOGUE

Thus it was that over the first few decades of its existence, radiology was transformed from an unregulated technical discipline into an organised medical specialty. It is easy to assume that the specialisation of radiology emerged as a passive result of new science and technology. While radiology could not have existed without the discovery of x-rays, the emergence of the remarkable technology was not sufficient to result in the formation of a distinct medical specialty. This would only take place many years later, following significant developments in professional organisation. These involved a multitude of social factors, not least the professional aspirations of the radiologists themselves. Driven by concerns over their status and exasperated by associations with the technical nature of their work, the radiologists mounted a campaign to transform their discipline into one of greater prestige. These efforts included the exclusion of technical elements from their organisations, resistance against commercial pressures, removal of dubious practices both external and internal to radiology, establishment of formal methods for training and certification, and negotiation of agreeable payment structures. Inevitably, these generated a multitude of tensions between groups within the discipline, with radiologists eventually emerging at the top.

The specialisation of radiology and subjugation of its technical elements exhibits similarities to the origins of other medical specialties. In the historical relationships between obstetricians and midwives, anaesthesiologists and nurse anaesthetists, and ophthalmologists and optometrists,[xciii] parallels can be drawn where the consolidation of medical specialties took place at the expense of their supporting fields. In one sense, radiology was another example of this general pattern. Yet in other ways, radiology was particularly susceptible to many of the struggles it experienced. Radiology was liable to concerns about its medical status due to the technical nature of its work and perception as a hospital service. It was a target for commercialisation due to its inescapable involvement of technology. It was prone to quackery due to the mystique of x-rays. It was vulnerable to territorial conflicts with other specialties due to its classification by technique rather than organ system. These susceptibilities are all related to the inherent nature of radiology itself and continue to have important consequences now.

More than a century after the discovery of x-rays, how relevant are these historical factors today? Radiology now has a formidable organisational structure and there is no doubt about its status as a medical specialty nor its vital role in modern medicine. Yet radiology continues to face challenges and there remains appreciable anxiety about its future.[xciv,xcv] The factors and susceptibilities that influenced the early development of radiology are relevant not just to the past, but very much continue to shape the specialty at present. The technical perception of radiology persists, with concern over the professional image and role of radiologists. This no longer carries with it any questions about whether radiology is a medical discipline, but there have always been questions about the visibility of the work of radiologists and their interactions with patients.[xcvi] In 1956, Arthur Christie wrote that the American Roentgen Ray Society "has jealously guarded the idea that the practice of radiology is the practice of medicine; that its practitioners…must maintain a close relationship with their patients."[xcvii] Half a century later, in his presidential address to the American College of Radiology in 2007, James Borgstede emphasised the need for radiologists to interact with patients and clinical colleagues, with the risk of becoming faceless providers of a commodity.[xcviii]

Technological advances continue to occur in radiology. As Sande Bishop writes, "No field of medicine is so closely allied with and dependent upon technological advancement as is radiology."[xcix] The previous decades have seen the advent of ultrasound, computed tomography, magnetic resonance imaging, and positron emission tomography.[c] There is uncertainty about the potential impact of teleradiology, the remote provision of radiological services, on the specialty, including on issues of workforce and employment. James Thrall, former president of the American Roentgen Ray Society and the American College of Radiology, expresses concern that, "if the interpretation of radiological studies can be outsourced via teleradiology and can then be bought and sold as a commodity, what does that say about the specialty of radiology and the professional standing of radiologists?"[ci] The rise of artificial intelligence technologies for examining images[cii] threatens to disrupt the status quo even further.[ciii] As Jha and Topol write, "big data and artificial intelligence, referred to some as the fourth industrial revolution, will change radiology", and that the specialty "must plan strategically for a future in which artificial intelligence is part of the health care workforce."[civ] What will be the impact on the practice of radiology? Will the companies that design these technologies exert increasing control over radiology, or will radiologists, as they have done in the past, retain their authority over the field? The potential implications for replaceability, remuneration, and status, are enormous.

Increasing expertise in different domains of radiology has resulted in the emergence of subspecialties,[cv,cvi] whether organ-based, such as neuroradiology, or technique-based, such as radionuclide imaging.[cvii] New organisations and journals have formed in response to these new subspecialties and technologies, with the risk of increasing fragmentation of the specialty.[cviii,cix] Indeed, as previously discussed, the characterisation of radiology and the delineation of its boundaries has always been difficult. What should be considered within the domain of radiology and what should not? The difficulty in answering this, due to the perception of radiology by many as a technique, inevitably leads to territorial conflicts with other specialties. Previously this was the case with electrology and physical therapies; it has since been the case with turf wars between radiology and cardiology or vascular surgery.[cx] Muroff and Williams write, "Too many radiologists don't care if they lose their cardiac imaging because they have 'more than enough brains, knees, and spines to read.' They fail to realize that those studies just as easily can be lost. It is only a matter of other specialties realizing they can be as successful as cardiologists in wrestling turf from apathetic radiologists."[cxi]

Economic issues in healthcare continue to impact politics and society, and are particularly relevant for radiology. The cost-intensive nature of medical imaging procedures means that radiology is often blamed for excessive costs in American medicine.[cxii] With constant economic and political battles about healthcare funding, payment models for radiologists will likely continue to evolve.[cxiii] No doubt, the joined forces of the professional radiological organisations will act as a strong lobby to protect their economic interests.

More than a century after x-rays were first revealed, radiology now occupies a central role in medicine both as an effective technology and as a prestigious medical specialty. Yet radiology continues to face no shortage of challenges, and there is both enthusiasm and apprehension about its future. Amidst an inevitable advance towards greater technology and an ever changing healthcare environment, one thing remains certain: the specialty will continue to evolve and be shaped by the same factors that were so formative in its development more than a century ago.

BIBLIOGRAPHY

Brecher, R. and Brecher, E.M., 1969. The Rays: A History of Radiology in the United States and Canada. Williams and Wilkins.

Eisenberg, R.L., 1992. Radiology: An Illustrated History. Mosby-Year Book.

Grigg, E.R.N., 1965. The Trail of the Invisible Light: From X-Strahlen to Radio(bio)logy. Charles C Thomas.

Howell, J.D., 1995. Technology in the Hospital: Transforming Patient Care in the Early Twentieth Century. Johns Hopkins University Press.

Kevles, B., 1997. Naked to the Bone: Medical Imaging in the Twentieth Century. Rutgers University Press.

Mould, R.F., 1993. A Century of X-rays and Radioactivity in Medicine. Institute of Physics Publishing.

Stevens, R., 1998. American Medicine and the Public Interest: Updated Edition with a New Introduction. University of California Press.

Thomas, A.M. and Banerjee, A.K., 2013. The History of Radiology. Oxford University Press.

Weisz, G., 2006. Divide and Conquer: A Comparative History of Medical Specialization. Oxford University Press.

REFERENCES

i Brecher, R. and Brecher, E.M., 1969. The Rays: A History of Radiology in the United States and Canada. Williams and Wilkins, pp.3-9.
ii Eisenberg, R.L., 1992. Radiology: An Illustrated History. Mosby-Year Book, p.41.
iii Kevles, B., 1997. Naked to the Bone: Medical Imaging in the Twentieth Century. Rutgers University Press, p.2.
iv Ibid., p.22.
v Brecher, R. and Brecher, E.M., 1969. The Rays: A History of Radiology in the United States and Canada. Williams and Wilkins, p.23.
vi Eisenberg, R.L., 1992. Radiology: An Illustrated History. Mosby-Year Book, pp.63-77.
vii Kevles, B., 1997. Naked to the Bone: Medical Imaging in the Twentieth Century. Rutgers University Press, pp.35-36.
viii Brecher, R. and Brecher, E.M., 1969. The Rays: A History of Radiology in the United States and Canada. Williams and Wilkins, pp.59-67.
ix Kevles, B., 1997. Naked to the Bone: Medical Imaging in the Twentieth Century. Rutgers University Press, p.23.
x Golan, T., 1998. The Authority of Shadows: The Legal Embrace of the X-ray. Historical Reflections, pp.437-458.
xi Kevles, B., 1997. Naked to the Bone: Medical Imaging in the Twentieth Century. Rutgers University Press, pp.39-40.
xii Eisenberg, R.L., 1992. Radiology: An Illustrated History. Mosby-Year Book, pp.551-555.
xiii Kevles, B., 1997. Naked to the Bone: Medical Imaging in the Twentieth Century. Rutgers University Press, p.44.
xiv Eisenberg, R.L., 1992. Radiology: An Illustrated History. Mosby-Year Book, pp.36-37.
xv Howell, J.D., 1995. Technology in the Hospital: Transforming Patient Care in the Early Twentieth Century. Johns Hopkins University Press, 136.
xvi Kevles, B., 1997. Naked to the Bone: Medical Imaging in the Twentieth Century. Rutgers University Press, p.24.
xvii Ibid., p.58.
xviii Ibid.
xix In Technology in the Hospital: Transforming Patient Care in the Early Twentieth Century, Howell argues that although x-ray technology was available in hospitals, it was not widely *used* until the 1920s, due to the need for accompanying social and organisational changes. The medical and scientific *potential* of x-rays, however, seems to have been widely recognised relatively soon after their discovery.
xx Eisenberg, R.L., 1992. Radiology: An Illustrated History. Mosby-Year Book, pp.85-155.
xxi Brecher, R. and Brecher, E.M., 1969. The Rays: A History of Radiology in the United States and Canada. Williams and Wilkins, pp.44-58.
xxii Kevles, B., 1997. Naked to the Bone: Medical Imaging in the Twentieth Century. Rutgers University Press, pp.61-63.
xxiii Ibid., pp.64-66.
xxiv Johnston, G.C., 1909. Address by the President. American Quarterly of Roentgenology 2, pp.53-55.
xxv Eisenberg, R.L., 1992. Radiology: An Illustrated History. Mosby-Year Book, pp.389-399.
xxvi Ibid., p.576.
xxvii Brecher, R. and Brecher, E.M., 1969. The Rays: A History of Radiology in the United States and Canada. Williams and Wilkins, pp.266-269.
xxviii Kevles, B., 1997. Naked to the Bone: Medical Imaging in the Twentieth Century. Rutgers University Press, pp.100-107.
xxix Brecher, R. and Brecher, E.M., 1969. The Rays: A History of Radiology in the United States and Canada. Williams and Wilkins, p.301.
xxx Stevens, R., 1998. American Medicine and the Public Interest: Updated Edition with a New Introduction. University of California Press, p.46.
xxxi Brecher, R. and Brecher, E.M., 1969. The Rays: A History of Radiology in the United States and Canada. Williams and Wilkins, pp.301-327.
xxxii Ailstock, L.K. and Nath, H., 1993. The First Radiology Journals. American Journal of Roentgenology, 160(6), pp.1216-1216.
xxxiii Eisenberg, R.L., 1992. Radiology: An Illustrated History. Mosby-Year Book, pp.559-578.
xxxiv Stevens, R., 1998. American Medicine and the Public Interest: Updated Edition with a New Introduction. University of California Press, p.xxxi.
xxxv Ibid., pp.xv-xvi.
xxxvi 1900. The Roentgen Society of the United States. The American X-Ray Journal, 6(3), pp.723-726.
xxxvii Eisenberg, R.L., 1992. Radiology: An Illustrated History. Mosby-Year Book, pp.561-562.
xxxviii Brecher, R. and Brecher, E.M., 1969. The Rays: A History of Radiology in the United States and Canada. Williams and Wilkins, p.305.
xxxix Kevles, B., 1997. Naked to the Bone: Medical Imaging in the Twentieth Century. Rutgers University Press, p.85.

xl Brecher, R. and Brecher, E.M., 1969. The Rays: A History of Radiology in the United States and Canada. Williams and Wilkins, pp.11-19.
xli Bishop, S., 1995. Radiology in New England: The First Hundred Years (1896-1995). The Massachusetts Radiological Society and The New England Roentgen Ray Society, p.10.
xlii Kevles, B., 1997. Naked to the Bone: Medical Imaging in the Twentieth Century. Rutgers University Press, p.85.
xliii Robarts, H., 1900. President's Address. The American X-Ray Journal, 7(6), pp.806-810.
xliv Brecher, R. and Brecher, E.M., 1969. The Rays: A History of Radiology in the United States and Canada. Williams and Wilkins, p.191.
xlv Kevles, B., 1997. Naked to the Bone: Medical Imaging in the Twentieth Century. Rutgers University Press, p.59.
xlvi Stevens, R., 1998. American Medicine and the Public Interest: Updated Edition with a New Introduction. University of California Press, pp.226-227.
xlvii Howell, J.D., 1995. Technology in the Hospital: Transforming Patient Care in the Early Twentieth Century. Johns Hopkins University Press, p.127.
xlviii Garland, L.H., 1938. The Interpretation of X-Rays in Court Hearings. American Journal of Medical Jurisprudence, 1, pp.19-21.
xlix Stevens, R., 1998. American Medicine and the Public Interest: Updated Edition with a New Introduction. University of California Press, pp.225-226.
l Moore, J., 2008. What Sir Luke Fildes' 1887 Painting *The Doctor* Can Teach Us About the Practice of Medicine Today. Br J Gen Pract, 58(548), pp.210-213.
li Friedlaender, L.K. and Friedlaender, G.E., 2015. Art in Science: The Doctor by Luke Fildes: Putting the Patient First. Clinical Orthopaedics and Related Research, 473(11), pp.3355-3359.
lii Gagliardi, R.A., 1990. Preston M. Hickey. American Journal of Roentgenology, 155, pp.235-236.
liii Fuchs, A.W., 1947. Edison and Roentgenology. American Journal of Roentgenology and Radium Therapy, 57(2), p.150.
liv Kevles, B., 1997. Naked to the Bone: Medical Imaging in the Twentieth Century. Rutgers University Press, p.33.
lv Eisenberg, R.L., 1992. Radiology: An Illustrated History. Mosby-Year Book, pp.51-52.
lvi Kevles, B., 1997. Naked to the Bone: Medical Imaging in the Twentieth Century. Rutgers University Press, pp.54-55.
lvii Brecher, R. and Brecher, E.M., 1969. The Rays: A History of Radiology in the United States and Canada. Williams and Wilkins, p.308.
lviii 1900. The First Annual Meeting of the Roentgen Society. The American X-Ray Journal, 7(6), pp.805-806.
lix Eisenberg, R.L., 1992. Radiology: An Illustrated History. Mosby-Year Book, p.563.
lx 1925. Supreme Court Decision: Judgment Affirmed for "Radiology." Radiology, 5(3), pp.264-267.
lxi Doub, H.P., 1964. The Radiological Society of North America. Radiology, 83(5), pp.771-784.
lxii Brecher, R. and Brecher, E.M., 1969. The Rays: A History of Radiology in the United States and Canada. Williams and Wilkins, p.64.
lxiii Kevles, B., 1997. Naked to the Bone: Medical Imaging in the Twentieth Century. Rutgers University Press, p.58.
lxiv Feldman, A., 1989. A Sketch of the Technical History of Radiology from 1896 to 1920. Radiographics, 9(6), pp.1113-1128.
lxv Eisenberg, R.L., 1992. Radiology: An Illustrated History. Mosby-Year Book, pp.525-526.
lxvi Lavine, M., 2011. The Early Clinical X-Ray in the United States: Patient Experiences and Public Perceptions. Journal of the History of Medicine and Allied Sciences, 67(4), pp.587–625.
lxvii Brown, P., 1908. The Roentgenologist and His Specialty. Transactions of the American Roentgen Ray Society, pp.232-239.
lxviii Morton, W. J., 1896. The X-Ray. American Technical Book Company, p.158.
lxix Kevles, B., 1997. Naked to the Bone: Medical Imaging in the Twentieth Century. Rutgers University Press, p.2.
lxx Brecher, R. and Brecher, E.M., 1969. The Rays: A History of Radiology in the United States and Canada. Williams and Wilkins, pp.301-302.
lxxi Rosner, L., 1988. The Professional Context of Electrotherapeutics. Journal of the History of Medicine and Allied Sciences, 43(1), pp.64-82.
lxxii Brown, P., 1910. Secretary's Report. American Quarterly of Roentgenology, 2, pp.248-260.
lxxiii 1905. The American Journal of Progressive Therapeutics, 16(2), front cover.
lxxiv Eisenberg, R.L., 1992. Radiology: An Illustrated History. Mosby-Year Book, pp.562-565.
lxxv Brecher, R. and Brecher, E.M., 1969. The Rays: A History of Radiology in the United States and Canada. Williams and Wilkins, p.304.
lxxvi Rosner, L., 1988. The Professional Context of Electrotherapeutics. Journal of the History of Medicine and Allied Sciences, 43(1), pp.64-82.
lxxvii Kevles, B., 1997. Naked to the Bone: Medical Imaging in the Twentieth Century. Rutgers University Press, p.38.

lxxviii Brown, P., 1908. The Roentgenologist and His Specialty. Transactions of the American Roentgen Ray Society, pp.232-239.
lxxix Hodges, F.M., 1930. Chairman's Address to the Section on Radiology. Journal of the American Medical Association, 95(12), 833.
lxxx Brown, P., 1910. Secretary's Report. American Quarterly of Roentgenology, 2, pp.248-260.
lxxxi Kevles, B., 1997. Naked to the Bone: Medical Imaging in the Twentieth Century. Rutgers University Press, p.58.
lxxxii Eisenberg, R.L., 1992. Radiology: An Illustrated History. Mosby-Year Book, p.61.
lxxxiii Brecher, R. and Brecher, E.M., 1969. The Rays: A History of Radiology in the United States and Canada. Williams and Wilkins, p.110.
lxxxiv Stevens, R., 1998. American Medicine and the Public Interest: Updated Edition with a New Introduction. University of California Press, p.77.
lxxxv Dreyfuss, J.R., 1969. Tufts and New England Radiology. Tufts Medical Alumni Bulletin, 28, p.9.
lxxxvi Eisenberg, R.L., 1992. Radiology: An Illustrated History. Mosby-Year Book, p.580.
lxxxvii Stevens, R., 1998. American Medicine and the Public Interest: Updated Edition with a New Introduction. University of California Press, pp.98-99.
lxxxviii Ibid., pp.133-139.
lxxxix Ibid., p.44.
xc Kevles, B., 1997. Naked to the Bone: Medical Imaging in the Twentieth Century. Rutgers University Press, p.92.
xci Anon., 1938. The Roentgenologist, the Pathologist, and the Anesthetist under Hospital Insurance Plans. Journal of the American Medical Association, 111(2), pp.158-159.
xcii Stevens, R., 1998. American Medicine and the Public Interest: Updated Edition with a New Introduction. University of California Press, p.227.
xciii Stevens, R., 1998. American Medicine and the Public Interest: Updated Edition with a New Introduction. University of California Press, pp.98-99.
xciv Chockley, B.A. and Emanuel, E., 2016. The End of Radiology? Three Threats to the Future Practice of Radiology. Journal of the American College of Radiology, 13(12), pp.1415-1420.
xcv Lozano, K.D.S., Hawkins, C.M., Rosenthal, S.A., Matsumoto, A.H., Ma, L.D. and Applegate, K.E., 2014. Driving Change: Taking Ownership of Our Profession and Its Future. Journal of the American College of Radiology, 11(4), pp.359-361.
xcvi Glazer, G.M. and Ruiz-Wibbelsmann, J.A., 2011. The Invisible Radiologist. Radiology, 258(1), pp.18-22.
xcvii Christie, A.C., 1956. The American Roentgen Ray Society. American Journal of Roentgenology, 76, pp.1-6.
xcviii Levin, D.C. and Rao, V.M., 2008. Radiology's Image Problem: Ponder the Words of Some Thought Leaders in the Field. Journal of the American College of Radiology, 5(5), pp.616-618.
xcix Bishop, S., 1995. Radiology in New England: The First Hundred Years (1896-1995). The Massachusetts Radiological Society and The New England Roentgen Ray Society, p.95.
c Eisenberg, R.L., 1992. Radiology: An Illustrated History. Mosby-Year Book, pp.409-477.
ci Thrall, J.H., 2009. Teleradiology: Two-Edged Sword or Friend of Radiology Practice?. Journal of the American College of Radiology, 6(2), pp.73-75.
cii Hosny, A., Parmar, C., Quackenbush, J., Schwartz, L.H. and Aerts, H.J., 2018. Artificial Intelligence in Radiology. Nature Reviews Cancer, p.1.
ciii King, B.F., 2018. Artificial Intelligence and Radiology: What Will the Future Hold?. Journal of the American College of Radiology, 15(3), pp.501-503.
civ Jha, S. and Topol, E.J., 2016. Adapting to Artificial Intelligence: Radiologists and Pathologists as Information Specialists. JAMA, 316(22), pp.2353-2354.
cv Margulis, A.R., 1981. Subspecialties in diagnostic radiology: the road to glory or disaster?. Radiology, 140(3), pp.837-838.
cvi Smith, G.G., Thrall, J.H., Pentecost, M.J., Fleishon, H.B., Knipp, H.C., Adams, M.J., Rumack, C.M., Blumberg, A.L., Hoppe, R.T., Sunshine, J.H. and Moser, J.W., 2009. Subspecialization in Radiology and Radiation Oncology. Journal of the American College of Radiology, 6(3), pp.147-159.
cvii Potts, D.G., 1981. The Division of Radiology. Radiology, 140(3), pp.839-840.
cviii Eisenberg, R.L., 1992. Radiology: An Illustrated History. Mosby-Year Book, p.584.
cix ESR Executive Council 2009 and European Society of Radiology, 2010. The Professional and Organizational Future of Imaging. Insights into Imaging, 1(1), pp.12-20.
cx Schnyder, P., Capasso, P. and Meuwly, J.Y., 1999. Turf Battles in Radiology: How to Avoid/How to Fight/How to Win. European Radiology, 9(4), pp.741-748.
cxi Muroff, L.R. and Williams, C.D., 2007. Apathy in Private Practice: "we have met the enemy and he is us". Journal of the American College of Radiology, 4(8), pp.512-513.
cxii Rubin, G.D., 2017. Costing in Radiology and Health Care: Rationale, Relativity, Rudiments, and Realities. Radiology, 282(2), pp.333-347.

cxiii Krishnaraj, A., Weinreb, J.C., Ellenbogen, P.H., Patti, J.A. and Hillman, B.J., 2013. Radiology in 2022: Challenges and Opportunities in the Coming Decade—Proceedings of the 12th Annual ACR Forum. Journal of the American College of Radiology, 10(1), pp.15-20.

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