Sir Ludwig Guttmann: his neurology research and his role in the treatment of peripheral nerve injuries, 1939–1944

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ABSTRACT Ludwig Guttmann spent five crucial years in Oxford between 1939 and 1944, carrying out fundamental research in peripheral nerve regeneration and the rehabilitation of patients with peripheral nerve injuries. He worked with Peter Medawar, John Zachary Young, Graham Weddell, Ernst Gutmann and others. He dismissed this period of his life, but the experience he gained was critical for his subsequent career in rehabilitating spinal injury patients.

KEYWORDS Ludwig Guttmann, peripheral nerve injuries, St Hugh’s Hospital, spinal injuries

DECLARATIONS OF INTERESTS JR Silver worked with Ludwig Guttmann from 1956 to 1957 and 1962 to 1965.

INTRODUCTION

Much has been written about Ludwig Guttmann (1899–1980) and his pioneering role in the treatment of spinal injuries and the use of sport to rehabilitate patients. Guttmann only started his work on spinal injuries at the age of 43 when he came to Stoke Mandeville Hospital as Resident Medical Officer to the Spinal Unit in 1944. He had spent the preceding five years at Oxford University, carrying out fundamental research into peripheral nerve injury. Despite having worked with a group of outstanding physicians, surgeons, scientists and Nobel Prize winners, Guttmann himself made little of this period of his life. This paper explores his time in Oxford and how this influenced his later contributions to medicine, particularly in the treatment of spinal injuries. (See Appendices following for a list of publications and collaborators.)

EARLY YEARS

Born in Upper Silesia in modern-day Poland, Guttmann grew up in a practising Jewish family. He studied medicine at the universities of Breslau and Freiburg. Upon qualifying, he wanted to work in paediatrics but there were no posts available; he was advised to ‘try the floor below’, the department of Otfrid Foerster (1873–1941), one of the foremost neurologists in the world.¹ Guttmann trained in neurology and neurosurgery under Foerster and subsequently became his first assistant in the summer of 1929. At that time, German medicine was highly regarded in the international medical community and doctors from all over the world came to further their training in Foerster’s unit (Figure 1).

Foerster had been taught to use physical methods of rehabilitation by Heinrich Frenkel, a spa doctor. A highly skilled neurologist and experimental physiologist, Foerster was interested in documenting nerve lesions. He had unique experience to draw on, having treated over 4,000 soldiers with peripheral nerve injuries during the First World War.² A pioneer in the development of...
rehabilitation, he advocated exercise therapy and had a reputation for ‘making the lame walk and the blind see’. He sought to understand the underlying physical basis of every patient’s disability before initiating treatment, a lesson Guttmann never forgot.

During his time working under Foerster, Guttmann made a significant finding. He realised that the clinical testing of sensation using pin prick, touch, hot and cold and electrical stimulation was too subjective. He observed the correlation between the recovery of sensation and the recovery of sweating. This had been measured previously using the starch iodine method, where starch turned blue when moistened by sweat. Guttmann developed a new and more sensitive method using quinizarin, a dye that also changed colour to purple when wet and he published his results in Germany.1

LEAVING GERMANY

Within weeks of Hitler coming to power in 1933, the new Nazi racial laws resulted in the dismissal of all Jews from official positions. Jewish doctors were dismissed from state hospitals and allowed to treat only Jewish patients; they were no longer called physicians but ‘Krankenbehandler’, a derogatory and demeaning term which effectively stripped them of professional status.4 Guttmann was expelled from his job as Foerster’s first assistant and his professorship was withdrawn. He took the post of neurologist and neurosurgeon at the Jewish Hospital in Breslau where he was able to continue his research work. He described how ‘we have become outlaws, outcasts of the community’.1 For Jews, life in Germany had degenerated into a nightmare.5

The 1938 ‘Kristallnacht’ heralded a violent pogrom against the Jewish community in Germany and many injured Jews were admitted to the Jewish Hospital in Breslau. Later that year, Guttmann, by now an internationally recognised neurosurgeon, was invited to Lisbon to treat a patient, but his family’s passports had been confiscated by the Nazis. Portugal’s dictator, Dr Salazar, personally intervened with the Nazi regime and Guttmann’s passport was returned to him by Joachim von Ribbentrop, Germany’s Foreign Minister. On his return journey, Guttmann went to London and met a representative of the Academic Assistance Council (AAC), known today as the Council for Assisting Refugee Academics (CARA), to discuss the possibility of leaving Germany for England. Guttmann had already written to Professor Hugh Cairns (1896–1952) (neurosurgeon and Professor of Surgery at Oxford University) and had been offered a voluntary (unpaid) research assistant position (Figure 2).6 The AAC agreed to support Guttmann with an initial grant of £250 per annum for six months on condition that Guttmann’s aunt, Mme B Tournel, who lived in France, would support the family thereafter. A year later, Guttmann and his family were granted a visa to go to England for three days. Guttmann realised that his only hope was to emigrate with his family. With the AAC’s assistance Guttmann left Germany on 14 March 1939 with his wife Else and their two children aged eight and four; with only a few German marks in their possession.1 A day after the Guttmann family reached Dover, Hitler marched into Prague and occupied Czechoslovakia.1

OXFORD: A CENTRE FOR NEUROLOGICAL EXCELLENCE

Oxford was a small city which, until the Second World War, did not have an undergraduate clinical medical school. Nevertheless, it had become the pre-eminent centre for neurological research and treatment in the UK. Servicemen with neurological problems were sent to Oxford for treatment. Clinical research was funded by the Medical Research Council (MRC) and the patients were observed, treated and followed to evaluate the benefits of treatment. This clinical work was reinforced by fundamental research carried out by a distinguished and internationally recognised team of physiologists and anatomists at the university’s Departments of Comparative Anatomy and Zoology and the Laboratory of Physiology. Many of the researchers came from Britain and the Commonwealth, while others were refugees from Nazi persecution.
During the First World War, 40% of serving soldiers sustained injuries, resulting in over 1.6 million casualties. Most locomotor injuries could not be treated on an ad hoc basis by general surgeons and many military orthopaedic centres were established across Britain under the direction of Sir Robert Jones (1858–1933), offering a high standard of treatment. Patients with peripheral nerve injuries were sent to these centres, but while the treatment was excellent, records and follow-up systems were inadequate and much valuable experience was never documented. Those units closed after the war, except for the Oxford Centre.

The lessons learned in the First World War about medical treatment were applied during the Second World War and medical provision was planned in anticipation of a large number of casualties. At the outset of the war George Riddoch (1888–1947), who had treated patients with spinal injuries at the Empire Hospital in London during the previous war, was appointed Chairman of the Peripheral Nerve Injuries Committee of the MRC (later called the Nerve Injuries Committee). It also had responsibility for spinal injuries. This committee advised the Emergency Medical Service.

Many servicemen with peripheral nerve injuries also had orthopaedic injuries and, for this reason, they were treated at three designated orthopaedic hospitals in England: The Nuffield Hospital in Oxford (Figure 3), Otley Park Emergency Hospital in Chertsey, Surrey, and Winwick Emergency Hospital in Warrington, Lancashire. Scotland was served by two units: Gogarburn, near Edinburgh, and Killearn, near Glasgow.

Neurosurgery

During the First World War, Percy Sargent (1873–1933) had performed surgical procedures for spinal injury. This ceased after the war and the small amount of neurosurgery performed in the UK was carried out by general surgeons. The subsequent development of the specialty of neurosurgery in Britain can be almost entirely credited to three men, Norman Dott (1897–1973) in Edinburgh, Geoffrey Jefferson (1886–1961) in Manchester and Hugh Cairns in London, who had all trained with the father of modern neurosurgery, Harvey Cushing in Boston. They were the only three specialist neurosurgeons in the country. As they had their own units they were the obvious choice as consultants to the Emergency Medical Service and to the Armed Forces. In this way they became responsible for neurological services for the whole of Britain. Cairns became Nuffield Professor of Surgery at Oxford in 1937, worked at the Radcliffe Infirmary and brought with him Joe Pennybacker (1907–1983) from the London Hospital. After Cairns’ arrival in 1937, Oxford became a leading centre for neurosurgery.

GUTTMANN’S ARRIVAL IN OXFORD

In his autobiography, Guttmann described how, when he first came to England in 1939, he and his son left for Oxford ahead of his wife and daughter who stayed in London for a few days. They were driven to Oxford by Professor Francis Simon who had left Breslau to work at the Clarendon Physics Laboratory. En route, Guttmann asked him what Oxford was like. Simon replied: ‘This varies naturally, but Oxford has one disadvantage, once you are here you don’t want to leave.’ AD Lindsay, Master of Balliol College, lodged the family for a few weeks and helped them settle into their new home. Through Lindsay, Guttmann met leading figures of the university and they and their wives made them feel welcome. Guttmann described how Lindsay helped him understand the ‘Oxford ways’ and guided him in his early days in the city. He mentioned how sympathetic Lindsay was to the plight of Jewish refugees. Guttmann soon began non-clinical work in the Nuffield Department of Neurosurgery at the Radcliffe Infirmary, under Hugh Cairns.

GUTTMANN’S RESEARCH AT OXFORD

When Guttmann arrived in Oxford, he could not practise neurosurgery because he did not have a registrable medical qualification. Foreign doctors were expected to take an examination in anatomy and physiology and undertake two years of clinical work before sitting examinations. Guttmann’s neurosurgical training under Foerster was not acceptable to Cairns because he had not trained under Cushing. Guttmann founded modern neurosurgery. His techniques and training were the recognised standard and virtually all neurosurgeons were trained by him directly and then in turn imparted this knowledge to their pupils so that all neurosurgery practised in the world today is in ‘Cushing’s
tradition of neurosurgery'. Guttmann was encouraged instead to take part in on-going research on peripheral nerve injuries. He had already received a thorough training in experimental physiology from Foerster and developed his quinizarin sweating technique which was essential to study the progress of nerve regeneration.1

St Hugh's College, Oxford

The treatment of head injuries was limited and required specialist treatment facilities. In 1940, Cairns, Riddoch (neurologist to the Army) and Sir Charles Symonds (1890–1978) (neurologist to the Royal Air Force) set up a neurological hospital for head injuries at St Hugh's College, Oxford; a women's college put at their disposal during the war. St Hugh's became a superb combined neurological/neurosurgical unit with 450 beds at its peak.13 It was staffed jointly by Army and Air Force personnel: Cairns (Army) was the neurosurgeon, Derek Denny-Brown (1901–1981) (Air Force) and William Ritchie Russell (1903–1980) were the neurologists and Dorothy Stuart Russell (1895–1983), the pathologist. Denny-Brown later became Professor of Neurology at Harvard in Boston. Denis Williams (1908–1990) and many other neurologists and neurosurgeons worked there. A total of 13,000 servicemen and women were treated there and it became the training centre for the mobile neurosurgical teams where surgeons and nurses were trained to treat head injuries close to the front line. Contemporary papers document the research that was carried out on the management, treatment and transport of patients with head injuries, the long-term studies done on epilepsy and the use of electroencephalograms (EEG).14

The Nerve Injury Centre, Wingfield Morris Orthopaedic Hospital

In 1940, because of his experience in working with Foerster treating victims of the First World War, Guttmann was invited by Mr (later Sir) Herbert Seddon (1903–1977), the director of the newly founded peripheral nerve injury centre at the Wingfield Morris Orthopaedic Hospital, to join the team, which included Ruth Bowden and Donal Brooks.1 The unit integrated all aspects of treatment: the diagnosis, surgical repair, subsequent rehabilitation by physio-therapists, followed by a full rehabilitation programme to enable the patients to return to work. The outcome of treatment was carefully documented with Riddoch's protocols. Seddon repeated Head and Rivers' work on cutting the lateral cutaneous nerve of the thigh crushed and Guttmann tested it for recovery of sensation.1 Guttmann was particularly interested in the unit's organisation and how patients' progress was documented (Donal Brooks, 2003). He brought his own clinical experience and carried out experiments on sweating at St Hugh's Hospital.

Experimentation

The main issues encountered by the physicians treating wartime injuries were the regeneration of peripheral nerves after injury, whether unmyelinated fibres grew faster than myelinated fibres, and neuroma formation and its inhibition. The team investigated the biochemical conditions which control nerve fibre growth and made useful surgical improvements to aid nerve regeneration. They sought to accelerate the repair of peripheral nerves severed by injury. In collaboration with Peter Medawar (1915–1987), JZ Young (1907–1997) developed a 'glue' from plasma to rejoin small peripheral nerves. This method was eventually modified and used during surgery.2

Guttmann used his experience in plotting sensory loss to follow the re-innervation of skin in rabbits in order to establish whether the first fibres grew in from adjacent areas or were regenerated from the main trunk.4 He worked with Young and Medawar on the rate of regeneration of nerve fibres and the chemical inhibition of regeneration and neuroma formation. With Ernst Guttmann (1910–1978), a refugee from Czechoslovakia (and no relation to Ludwig Guttmann), and Graham Weddell (1908–1990), he demonstrated the growth of fibres from surrounding areas.

Guttmann's work with Ernst Guttmann on the effect of denervation on muscle atrophy showed that, with stimulation of the nerve, the bulk of the muscle was preserved so that if recovery subsequently occurred, the muscle could be re-innervated and not suffer from fibrosis. Guttmann went on to use this technique with paraplegic patients. They also demonstrated that galvanic stimulation of the muscles, if started immediately after injury, reduced the rate of atrophy; he applied this technique to paraplegic patients when he came to Stoke Mandeville.5

Guttmann's expertise led Riddoch to invite him to lecture to the neurology section of the Royal Society of Medicine in 1941, where he set out his principles of rehabilitation, his experience with Foerster, and the methods he would later use to treat paraplegic patients. Riddoch was so impressed with Guttmann's work that in 1944 he invited him to set up the spinal unit at Stoke Mandeville.15

GUTTMANN'S RESEARCH AT STOKE MANDEVILLE AND THE OXFORD PHYSIOLOGY DEPARTMENT

Guttmann treated patients at Stoke Mandeville, but still wanted to carry out research. He requested three half-days a week to continue his studies on the physiology and pathology of sweating, using his quinizarin method. In his 1944 research application, he described how the segregation of spinal cord and spinal root injuries in a single centre would allow a systematic study of the correlation of the disturbance of sweating and sensibility...
during the various stages after injury as well as other functions such as heat regulation, mass reflexes and oculopupillary function.\textsuperscript{16} He described how his quinizarin method was used as an indicator of sweat gland activity and he designed a special chamber for the thermo-regulatory sweat test. Guttmann recognised that sweating was only one manifestation of autonomic function and he began to study blood flow and its control with Roger Gilliatt, then a medical student and later one of the most influential neurologists of his generation. Guttmann identified the correlation between sweating and blood flow but, at that time, blood pressure was not recorded, and so he was not yet aware of the significance of the overall cardiovascular changes.

However, as early as April 1944, Guttmann noticed that in three patients with lesions at T3, 4 and 5, when their bladders were washed out their faces and necks became flushed, their noses seemed to be blocked, their heart rates decreased and they complained of severe headaches. In order to study temperature changes produced by bladder distension in spite of complete cord lesions, Guttmann asked David Whitteridge (1912–1994), with whom he had been working in Oxford, to bring a multiple skin thermometer. Subsequently, a portable plethysmograph was used for recording blood flow and the volume of pulsation of the toe. In the first patient, the skin temperature went up as expected in the head and neck but went down in the legs and it was obvious that a major redistribution of blood flow had taken place. In the second patient, they measured blood pressure which rose from 90/60 mmHg to 220/140 mmHg.\textsuperscript{4}

Guttmann and Whitteridge set up a collaborative study to assess patients with lesions at all levels.\textsuperscript{17} They showed how, although vasoconstriction occurred in the toes of all patients, blood pressure remained steady in patients with lesions at and below T7, and rose sharply in patients with lesions above T6. This was a viscerocutaneous reflex triggered by distension of the bladder. This reaction could also be triggered by distension of the rectum, the intestine and the uterus. The stimulus spread as far as it could in the isolated cord and excited sympathetic vasomotor fibres in the lateral column. With low lesions, vasoconstriction occurred first in the legs followed by vasodilatation in the upper half of the body and slowing of the pulse. With lesions above T6, vasoconstriction occurred in more widely spread parts of the body and was evident in the hands. The regulatory mechanism still produced slowing of the heart, but the vascular territory was too small for effective vasodilatation. The effects observed are perversions of the homeostatic mechanisms controlling the circulation.\textsuperscript{4}

To study the overall cardiac output, Guttmann, Cunningham, Whitteridge and Wyndham (see appendix) used the conventional acetylene method, but the cardiac output did not change.\textsuperscript{2} These studies are seminal to our understanding of autonomic dysreflexia. Wyndham returned to South Africa where he studied heat regulation in miners. He returned briefly to Stoke Mandeville Hospital and collaborated with Guttmann and Silver in studying heat regulation in tetraplegic patients.\textsuperscript{18}

**CONTEMPORARY VIEWS OF GUTTMANN’S RESEARCH**

Guttmann’s research in Germany was industrious but not groundbreaking. His most important work was the development of the quinizarin method to detect sweating as a measure of peripheral nerve regeneration.

In November 1938, Cairns described Guttmann’s work as ‘very painstaking but not at all brilliant’.\textsuperscript{6} He would later change his mind and remark that he was ‘favourably impressed with Dr Guttmann’.\textsuperscript{6} In 1940, Cairns sought to obtain a grant to enable Guttmann to continue his research work. He succeeded in securing a £100 grant from the Nuffield Trust. Cairns asked the authorities not to intern Guttmann because of his vital research on peripheral nerve injuries.\textsuperscript{1} Guttmann’s son-in-law, Frank Loeffler, said that Cairns had even offered to adopt Guttmann’s children to protect them, should the Nazis invade Britain (Frank Loeffler, 2013).

Although Guttmann worked with Seddon at the Peripheral Nerve Injury Unit at the Wingfield Morris Orthopaedic Hospital, they were not on friendly terms.\textsuperscript{9} At a professional level, however, Seddon stated that Guttmann’s work was absolutely outstanding and he made numerous references to Guttmann in his textbook on surgical disorders of the peripheral nerves.\textsuperscript{9} Yet later he prevented Guttmann’s appointment to the National Orthopaedic Hospital because of what he described as his difficult personality.\textsuperscript{10}

While at the peripheral nerve injury unit at the Nuffield Hospital, Ruth Bowden, an anatomist also worked with Guttmann on the clinical examination of patients. She later became Professor of Anatomy at the Royal Free Hospital and remained a life-long admirer of Guttmann. George Riddoch, a great advocate of Guttmann’s, sponsored and supervised his early research, encouraged him to publish it, and was responsible for his appointment at Stoke Mandeville Hospital.

**GUTTMANN’S VIEWS OF HIS WORK IN OXFORD**

Guttmann was reticent about his time in Oxford. Despite working with him for more than 25 years, Guttmann only once mentioned his time there to Silver.
He stated that after six months of working on animals, they all died. Was this reticence personal or professional? Silver sought the views of 12 people who knew Ludwig Guttmann well, including his son and daughter. The authors also referred to his papers and analysed his autobiography. Those who knew him confirmed that he seldom mentioned Oxford apart from the fact that Guttmann was unhappy about not being able to carry out clinical work to such a degree that he contemplated giving up research and going into general practice. Personally he liked Oxford and said he was treated very well there.

At a professional level, he spoke well of Riddoch, Pennybacker, Whitteridge and Kremer but not of Weddell or Russell (L Guttmann, 1963). The only work that he quoted was his study with Ernst Gutmann on the treatment of paralysed muscle with electricity; he subsequently used this technique when studying the recovery of spinal injury patients.1

**WHY DID GUTTMANN NEVER MENTION HIS RESEARCH WORK AT OXFORD?**

Guttmann was a complex man whose motives and behaviour are difficult to understand, no doubt coloured by his history as a refugee from persecution and his hierarchical training with Foerster. Guttmann considered himself an outsider. When he came to England, he was an established neurosurgeon and researcher, but this carried little weight at Oxford where the scientific community was insular and patronising to foreigners. Guttmann wasn’t taken seriously at St Hugh’s where he was known as ‘sweaty Guttmann’ due to his experiments on sweating with quinizarin. He told Silver that he was disappointed and resentful that he was still not allowed to treat patients, but in later years he came to realise how they should be cared for; his use of sports as a means of rehabilitation; and his role in founding the paraplegic sports movement. His work on the speed of recovery of the nerve after suture (1 mm a day) is still quoted today. His work on the sympathetic system was not groundbreaking. He did not introduce new methods of investigation. Guttmann’s success in rehabilitation saved patients who would otherwise have died and enabled studies which elucidated the physiology of the autonomic nervous system in paraplegic patients.23

**CONCLUSION**

Nearing the end of his life and with the benefit of hindsight, Guttmann adopted a tempered and philosophical view of his time in Oxford. He was grateful to have had the opportunity to undertake clinical research and was glad not to have been inactive, like many others in his situation. While he would have preferred to have carried out clinical work, as evidenced by his family’s testimonies, he was grateful to his host country and did not believe that German refugees should complain publicly. He described how, at the outbreak of war, he had immediately rushed to the Radcliffe Infirmary to see Cairns and offer his clinical services to the Armed Forces, but to Guttmann’s disappointment, Cairns insisted he should continue his research on nerve regeneration. Cairns considered this research essential to the war effort, especially in view of the ongoing plans to set up a centre for peripheral nerve injuries at the Wingfield Morris Orthopaedic Hospital in Oxford. At the time, Guttmann was disappointed and resentful that he was still not allowed to treat patients, but in later years he came to realise that Cairns’ insistence that he should continue his research work in Oxford may have been providential. It eventually led to his appointment at Stoke Mandeville, where he could apply so successfully much of what he had learned, both in Germany and in Oxford, to the treatment and rehabilitation of spinal injury patients (Dennis and Eve Guttmann, September 2012).

Guttmann had great personal charm and a gift for empathy with the patients. In contrast to the practice at that time, he assumed absolute control of nursing, physiotherapy and all aspects of the medical care of his patients. He saw every patient himself and never took a holiday. The patients recognised his ability and when he cured their pressure sores and treated their renal infections, their health and wellbeing were immediately transformed. He was an authoritarian, but the patients accepted this and regarded him highly. He was recognised nationally and internationally for founding the International Sports Movement and he received

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**HISTORY**

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numerous honours, including the CBE, a Knighthood and Fellowship of the Royal Society.

Guttmann was at the centre of an extraordinarily creative and productive group of scientists at a defining period in time. He carried out outstanding work with Medawar, a future Nobel Prize winner, and worked with another world figure, JZ Young, and other outstanding research workers such as Ernst Guttmann and with good administrators, such as Riddoch and Cairns. Guttmann also came into contact with two future Nobel Prize winners, Howard Florey and Ernst Chain, who were working on penicillin. Guttmann was naturally preoccupied with the fate of his family in Germany and unhappy with the lack of clinical work for him in Oxford. He made little mention of his time in Oxford, but it clearly influenced him enormously and the benefit of working with such eminent people contributed to his subsequent achievements. In his autobiography, he acknowledged this:

Seen retrospectively, Cairns’ decision may have been yet another dispensation of Providence in my life, to be destined later in the war to start a new concept in the treatment and rehabilitation of soldiers and officers suffering paralysis as a result of spinal cord injuries…¹

Acknowledgements

We are grateful to Dennis Guttmann, Eve and Frank Loeffer, Trevor Hughes, the late Phillip Harris, Hans Frankel, Ida Bromley, Ruth Bowden, Waghi El Masri, Avi Ohry, Ruth Stone, Eric Nieman, Paul Kennedy and Sir Roger Bannister for helping us in our research, but the views expressed in this article are our own. We would also like to thank the staff at the Bodleian Library, the Wellcome Library and the Royal Society of Medicine Library for their assistance and CARA for their interest and help with our research. Finally, we are particularly indebted to Hugh Baron for his meticulous input and editing of this paper.

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19 Seddon HJ. Surgical disorders of the peripheral nerves. Edinburgh: Churchill Livingstone; 1972.
APPENDICES

APPENDIX 1 List of Ludwig Guttmann’s publications related to Oxford research

1 Weddell G, Guttmann L, Gutmann E. The local extension of nerve fibres into denervated areas of skin. J Neurol Psychiatry 1941; 4:206–25. http://dx.doi.org/10.1136/jnnp.4.3-4.206

2 Guttmann L, Medawar P. The chemical inhibition of fibre regeneration and neuroma formation in peripheral nerves. J Neurol Psychiatry 1942; 5:130–41. http://dx.doi.org/10.1136/jnnp.5.3-4.130

3 Guttmann L, Gutmann E. The effect of electrotherapy on denervated muscles in rabbits. Lancet 1942; 169. http://dx.doi.org/10.1136/jnnp.5.3-4.130


APPENDIX 2 Guttmann’s research collaborators

<table>
<thead>
<tr>
<th>Name</th>
<th>Dates</th>
<th>Institutions</th>
<th>Biography</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooper KE</td>
<td></td>
<td></td>
<td>Distinguished physiologist, went to Canada.</td>
</tr>
<tr>
<td>Cunningham DJC</td>
<td></td>
<td></td>
<td>Distinguished medically qualified physiologist. Did cardio-pulmonary work.</td>
</tr>
<tr>
<td>Ferres HM</td>
<td></td>
<td></td>
<td>Physiologist, not medically qualified.</td>
</tr>
<tr>
<td>Gilliatt G</td>
<td></td>
<td>Worked under Young at Oxford Physiology Department, then head of physiology department in Czechoslovakia</td>
<td>Medical student when he did the work but had degree in physiology. Served in war and received Military Cross for bravery; became Professor of Neurology, Queen Square.</td>
</tr>
<tr>
<td>Guttmann E</td>
<td>1910–1977</td>
<td>Worked under Young at Oxford Physiology Department, then head of physiology department in Czechoslovakia</td>
<td>Refugee from Czechoslovakia; worked with Young and did his PhD in his laboratory.</td>
</tr>
<tr>
<td>Medawar PB</td>
<td>1915–1987</td>
<td>Oxford Physiology Department (his tutor was JZ Young)</td>
<td>Physiologist who as a result of his subsequent research worked out the immune response and received Nobel Prize for Medicine in 1960.</td>
</tr>
<tr>
<td>Weddell G</td>
<td>1908–1990</td>
<td>Reader in Human Anatomy, University of Oxford</td>
<td>Distinguished work on peripheral nerves and conduction.</td>
</tr>
<tr>
<td>Whitteridge D</td>
<td>1912–1994</td>
<td>Oxford Physiology Department and teaching and research in Edinburgh. Became Professor of Physiology at Oxford</td>
<td>FRCS/FRCP. Autonomic control in paraplegia. Worked with Guttmann over the years.</td>
</tr>
<tr>
<td>Wyndham CH</td>
<td></td>
<td></td>
<td>Physiologist, went to South Africa and did studies on temperature regulation in coal miners.</td>
</tr>
<tr>
<td>Young JZ</td>
<td>1907–1997</td>
<td>Oxford Physiology Dept and Anatomy Department at University College London</td>
<td>FRS Zoology teacher, distinguished neuro-anatomist. Developed the technique of single nerve fibre in squid.</td>
</tr>
</tbody>
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