



Reflections on Churchill's Scientists-the first generation

By

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This presentation has the aim of demonstrating the great importance of the scientific and engineering material held in the Churchill College Archive. The great significance of the political archival material is well known. I want to emphasize the importance of the scientific material by recounting the achievements of the very early Fellows of the College, all of whom served under Winston Churchill, as Prime Minister. This note was composed for a Symposium dedicated to thanking Richard Keynes for his Chairmanship of the Churchill College Archive Committee from 1975 until 1998.

A list of Fellows of Churchill who are, or were, of an age to have served in World War II is given in Table 1 below. Some minor details still need to be inserted. The scientists or engineers were all Churchill's scientists (or engineers) in the sense of Churchill being their war time leader. They have all subsequently for long or short periods been Churchill (College)'s engineers (or scientists). This presentation will take a selection of those who served in the war and subsequently became Fellows of the College. Having delineated their war time service, it will note their subsequent activities which show relevance to Churchill (the war time leader)'s hopes for this institution named after him. Namely, to the stated aim of producing an institution in UK with similar strengths and claims to those of M.I.T. The presentation also aims to further the growth of the Archive Centre which, with the College, is the national memorial to Sir Winston Churchill.

On the occasion on which this material was first presented, during the Cambridge Science Festival 2007, a discussion took place after the presentation on how Churchill College was responding to its Founder's vision.

I call this presentation the first generation because I shall deal with those Fellows who served Churchill as our war time leader. The second generation which would include people such as Birch, Katritzky, Howie, Livesley, Ashburner, Gurdon, O'Connell and myself etc might be dealt with at some later time.

In the following list of Fellows there are two groups- those with established records as scientists before World War II- Cockcroft, Bullard- and those who served in the war in junior capacities and who came to prominence as scientists after the war, Bondi, Kendall etc.

The lives and activities of a small number of those listed will here receive special attention as the leaders of the first generation. These include Richard Keynes, whom we intend to honour, and Cockcroft, Roskill, Bullard, Hawthorne, Crick, Bondi, and Hewish. For all of these except Crick the archive contains the original material to which I shall refer.

Table 1

**Fellows of Churchill born before 1925
(except Overseas Fellows)**

Name	Assoc. with College	War service	Post-war Activity	
Cockcroft 1897-1967	Founding Master FRS 1936	ADRDE, MAUD Committee, Dir. Chalk River	Director AEA Nobel 1951	
Hamilton	F Fellow 1st Bursar	Army	Dir Operations War Office	
Roskill 1903 -1982	1961	Navy	Official Naval Historian	Litt.D Oxford, Cambridge
Bullard 1907 - 1980	F. Fellow FRS 1941	Admiralty Scientist	Notable Geophysicist	
Morrison 1913 - 2000	F Fellow- 1st Senior Tutor 1960-65	Navy-Brit Council Mid- East 41-45!!	Classical Scholar Tirremes	
Oriel 1896- 1968	F. Fellow		Director Shell	
Ashmore 1916-2002	F.Fellow 1 st Tutor Adv. Students	Balloon flammability Then RAF	Prof Phys Chem. UMIST	
Snow 1905- 1980	F.Fellow	Director, Tech. Personnel. Min. Of Labour		Noted Author The Masters
Young 1915 -2002	1961-66	Home Office? Polit.& Econ. Planning	Cr. Baron 1978	Founder of Which & Meritocracy
Crick 1916 -2004	F. Fellow FRS 1959	Admiralty 1940- 1947.	Discovered genetic code Nobel 1962	Nobel-phys. & med
Hywel George 1924-	Bursar 1972-90	RAF Navigator	Colonial Administrator	CMG 1968
Allchin 1923	1963-		FBA 1981	
Mallaby 1902- 78	1964-69			
St John Wilson 1922- 2007	F.Fellow	RNVR 42-46	Premier Architect RA 1991	Designer British Library
Squire 1920	F. Fellow	Army service In Russia	Russian Scholar	

Acheson 1921-2003	1977	Army 1940-45	Found. Prof. Commun.Med.	
Hahn 1924	F. Fellow	RAF-Navigator	Prof. Cantab. FBA 1975	
Hawthorne 1913	Master 1968-1983 FRS 1955	Sci. Officer RAE 40-44	Prof. Cantab. Energy Expert	
Tizard 1917-2005	F. Fellow	Sci. Officer RAE	NPL Computer Division	
Kendall 1918	1962	Exp Officer Admiralty	FRS 1964 Prof Cantab.	
Bondi 1920-2005	Master 1983-1990 FRS 1959	Exp Officer Admiralty	Dir. ESRO etc	
Menter 1921-2006	1966-72	Exp Officer Admiralty	FRS 1966 Tech Dir TI	
Keynes 1919	1962 FRS 1959	Exp Officer Anti submar.	Prof Cantab	
Hey 1917	F. Fellow	RAF		
Hewish 1924	1961	RAE Farnboro 43-46	FRS 1968. Discover. Pulsar. Nobel 1974	
Eshelby 1916-1981	1964-1966	RAF	FRS 1976	
Mc Quillen 1920-2005	F Fellow	C.O.		
Hugh Huxley 1924	1967-87 FRS 1960	Radar Off. RAF '39-45	Res. Sci. MRC	
Pole 1922-	1963-1979		FBA 1985	
Cockburn	1970-77	Govt. Scientist	Director RAE	

The War of 1939 – 1945

All of the Founding Fellows and those who joined the College in the early years were very familiar with the happenings of World War II. It was undoubtedly World War II which established Winston Churchill as the iconic figure that he is today. Without the triumph of his leadership of this country during the conflict, he would be remembered perhaps as a Chancellor of the Exchequer or as a controversial Home Secretary but more likely as a rather erratic maverick journalist politician – perhaps something like his unfortunate son Randolph.

War and things military were seen everywhere in this country in the lives of all those connected with the establishment of Churchill College and even the first undergraduates would probably have remembered the late 1940s and early 1950s – the Korean War, service uniforms often seen, one remembers the privations; until 1953 an undergraduate arriving here in Cambridge handed in his ration book to his College's Kitchen Office.

It is difficult for people not aware of these days, which must account for the great majority of the members of the College, to appreciate the almost ubiquitous presence of things to do with the war and the means by which it was thought the survival of the nation, the existence of the ‘sceptred isle’ was to be maintained. Armies, mines, bombers, air raid shelters, men and women in military uniform, new types of bomb and the idea of arming the nation for the fight, would I believe have figured in our Founder’s mind when he urged the creation of a rival to M.I.T.

Because these insights may well be so completely foreign or regarded as fanciful by members of the College now – indeed for most of the public in the country, I want to start by noting that among the first Fellows of whom there were 33 - all will either have experienced directly service in our armed forces or in a trade or profession to which they were directed, and if not that; each will have been considered for military service and either deferred or excused on health grounds or as a conscientious objector.

Of the 33 Founding Fellows, all had lived through World War II, the youngest being ten years old when it ended. All of these born before 1925 – there were 14 of them - served during the war in one capacity or another or were classified as conscientious objectors. Those who were Founding Fellows and those elected to fellowships in the early years and born before 1925 and who are engineers and scientists become our own special cadre of Churchill’s scientists.

The First Generation



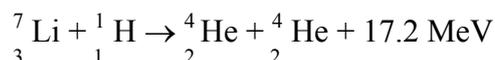
Sir John Cockcroft (1897 – 1967) the first Master of the College was originally trained as an engineer; his first degree was an MSc Tech from the College of Technology, University of Manchester in 1922, and although some subsequent Masters have claimed him as a scientist, he was as much an engineer as Sir William Hawthorne who succeeded him. Cockcroft was recognised as a great scientific achiever and had done his seminal work before World War II. He was elected a Fellow of the Royal Society in 1936 and had been an associate member of the Institution of Electrical Engineers since 1927. One must recall there was no Royal Academy of Engineering in those days.

Cockcroft’s Cambridge degree was a BA in the mathematical tripos obtained in 1924. His major work was the experimental demonstration of fission of an atomic nucleus by striking it with another nuclear particle given sufficient energy to enter the nucleus of the target atom by artificial means. Cockcroft and his collaborator Walton built an apparatus at the Cavendish Laboratory here in Cambridge capable of maintaining an electric potential difference of some 300,000 volts. They used transformers and rectifying tubes. Some of the rectifying tubes were still in use when I was a graduate student in the very early 1950s

Using this apparatus in April 1932, Cockcroft and Walton accelerated protons – the nucleus of the ordinary hydrogen atom (H) and after a check on the energy of the particles bombarded a target of the very light metal Lithium (Li). When they did this bright point scintillations were observed on a ZnS (Zinc Sulphide) screen placed

adjacently. These scintillations were due to particles emitted from the Lithium. From the nature of the scintillations and by subsequently passing them through an ionisation chamber these particles were found to be nuclei of the Helium atom (He). So the reaction of Li with hydrogen had produced helium – since all three are atoms – atomic disintegration had been observed. The papers describing the work refer to the experiments rather dryly as ‘Experiments with high velocity positive ions’.

What was also most important was the measurement of the energy of these nuclei of helium. In almost modern terms the reaction would be written down as



indicating that a lithium atom of charge 3 (i.e. atomic number 3) and of mass 7 units has on collision with hydrogen of charge 1 and mass 1 unit resulted in the production of 2 atoms of helium each of mass 4 and of charge 2 – note that the sums of the subscript and of the superscript balance on either side of the arrow sign. But of equal significance is the figure – 17.2MeV- on the right hand side of the arrow. This represents the energy and it is the measured energy of the alpha particles – split almost equally between them. This energy is very large indeed and it represents the energy of a single electron accelerated through 17.2 million volts. Now the mass of one lithium atom of mass number 7 and one proton of mass number 1 is greater than the mass of two ions of helium (α particles) and that difference in mass appears in the energy on the right hand side of the arrow.

Cockcroft and Watson point this out. The loss of mass appears as energy. And the exact equivalence between the two corresponds well within the accuracy of the measurement of energy and of mass in these experiments to that most well known of all scientific formulae, hallowed by the public and treasured by science:

$$E = mc^2$$

Where E is energy, m is mass and c^2 = the square of the velocity of light. Cockcroft and Walton’s experiment was the first direct experimental proof of Einstein’s famous formula. And that first proof of the fundamental iconic law of Physics is due to Churchill’s first scientist, as I am calling him – John Cockcroft. And the details are in our archive.

Cockcroft was elected a Fellow of the Royal Society in 1936 and the citation written by Rutherford read:

‘Distinguished for his investigation on nuclear transformations and on electromagnetic problems. In conjunction with E T S Walton, a high potential DC installation giving 800,000 volts was constructed in order to produce high speed ions for transformation purposes. These pioneering experiments showed that lithium and boron ions transformed on a marked scale by proton bombardment with the emission of swift α -particles. The nature of transformation both with protons and diplotons has been investigated and observations made on the production of artificial radioactivity. Results published in ‘Proceedings’. He also made calculations on skin effect in rectangular conductors at high frequencies (Proc. Roy. Soc.) and on design of coils for internal magnetic fields (Phil. Trans.)’

Cockcroft's essential genius had been to recognise that a calculation by Gamow (OS Fellow at Churchill in 1965) in 1929 indicated that nuclei could be split by accelerating ions with much lower energies than had previously been thought necessary. Cockcroft was awarded the Nobel Prize for Physics (with Walton) in 1951; one of the rather long delays between the date of the work and the prize: 19 years – Einstein was 17 and there have been periods of over 50 years. From Cambridge's point of view 1931-1932 was a marvellous year since during it not only was artificial disintegration achieved but also Chadwick discovered the neutron. Chadwick's papers reside in our archive.

For the interested non specialists one should remark that nuclear disintegration with the release of energy can be brought about by bombardment with energetic particles (as we have described) or by neutrons entering the nucleus – these being neutral particles cannot be accelerated by application of a voltage because each carries no electric charge – but being neutral they are not repelled by the nucleus. In the 1930s Fermi was perhaps the foremost user of neutrons to produce nuclear disintegration and so artificial radioactivity. And it is neutrons which cause fission of the really heavy elements e.g. uranium or thorium so as to produce atomic energy in an explosion or in a controlled manner in a pile.

Cockcroft was elected to the Jacksonian Professorship of Natural Philosophy from 1 October 1939 but spent the whole of his tenure until 1946 away from Cambridge. In 1938 he was informed by Tizard (Dick Tizard's Father) of the technique of detecting aircraft by radar and became the main scientist behind the use of radar by the army. After assisting Tizard in explaining our development of radar to the Americans, Cockcroft was made Chief Superintendent of the Air Defence Research Development Establishment at the height of the night bombing of this country by Germany in December 1940.

Cockcroft with others contributed to the development of the cavity magnetron which was necessary for the development of 10cm and 3cm wavelength radar. This instrument enabled the generation of appreciable power in the GHz frequency range (10^9 s^{-1}) which was not possible with the thermionic valves then used for radio reception and transmission. This instrument has been described as the single most important piece of apparatus which contributed to Britain's victory. That Cockcroft was able to help in real scientific detail is apparent from the reference in his citation for the Royal Society concerning the behaviour of conduction at high frequencies and the behaviour of ions in intense magnetic fields. As Chief of ADRDE he was the leader in the development of gunnery radar.

The development of an atomic bomb by the UK was not possible during the war but in Britain the first steps were taken that led finally to the Manhattan Project which produced the first bomb by the US in July 1945. Many British Scientists were involved and Cockcroft was one of the original MAUD Committee. An acronym for Ministry of Aircraft Production Uranium Development – which later became known (an intentionally misleading name) as the Tube Alloy Project. Tube Alloys was absorbed into the U.S. effort in 1943 after the Manhattan Project was established in June 1942 and Los Alamos founded – British scientists such as Peierls, Fuchs and Chadwick went to Los Alamos. Cockcroft was much involved in giving advice on all problems of the release of nuclear energy either in a bomb or in a reactor. During the war (and afterwards) cooperation with the US in nuclear matters was never easy. Between 1942 and 1944 discussions between USA, Canada and the UK were held

concerning the establishment of a nuclear reactor in Canada at Chalk River 130 miles northwest of Ottawa. He became its first Director.

Immediately after the war the United Kingdom had to investigate nuclear energy for itself either to develop a bomb or to provide useable power or both. Cockcroft was appointed the first Head of the Atomic Energy Research Establishment (AERE) at Harwell. And was extremely influential in the development of the British nuclear energy programme and the decision to build first a fission bomb and then a hydrogen bomb- see below.

The fission bomb was produced first at Fort Halstead and then at Atomic Weapons Research Establishment (AWRE) at Aldermaston. Cockcroft as Director of AERE, was reluctant to see Harwell involved in weapons work. He did assist in providing information to the bomb project which was available via Fuchs and Bretscher, both on the staff of AERE from their previous involvement in the Manhattan Project.

The detonation of our first (fission bomb) was followed quickly by an unexpected Russian explosion of an H bomb and Cockcroft helped to analyse the likely type of bomb. Penney, Director of AWRE believed that we should build an H bomb and Cockcroft echoed the opinion and with some, perhaps at the time, over optimistic opinions ‘Thermonuclear weapons are undoubtedly simpler to make than scientists thought – we believe the U.S. have successfully tested such a weapon– The weapon is comparatively cheap and easy to make’.

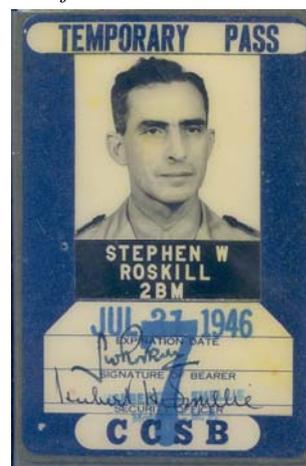
Though not a professional scientist, one must include the name of **Stephen Wentworth Roskill** (1903-1982) in this account because of his technical knowledge, his position as official naval historian of the war and his great support for the establishment of the Churchill Archives Centre. According to John Killen who initiated the idea of an Archives Centre it was Roskill who provided much of the enthusiasm and knowledgeability which was necessary to get the project started.

Roskill was educated at the Royal Naval College at Osborne and Dartmouth. His first posting was to the cruiser *Durban* on the China station where he came under the influence of Lieutenant Commander Stephen King-Hall who was at the time, or shortly afterwards, an influential columnist. Roskill acted as his research assistant in the 1920s – a post incidentally occupied by my late wife some thirty years later.

In the navy Roskill was a gunnery expert – gunnery was the elite branch of the naval specialist; he served in the carrier *Eagle* and battleship *Warspite* before World War II. In 1939 he joined the Admiralty for a time but saw active service in the Far East; his ship HMNZS *Leander* surviving a Japanese torpedo hit. In the same year he received the DSC.

In 1944 he was posted as chief staff officer weapons to the Admiralty delegation in Washington and as a result of this was appointed as the chief British observer for the first postwar US atomic bomb tests in the Marshall Islands. These took place after the passage of the McMahon Act by the US Congress which cut off collaboration

Reference: ROSK 2/20A



between the USA and the UK and Canada on atomic matters. Operation Crossroads was intended to assess the affects of (fission) atomic bombardment on warships and its effects in a marine environment; the only previous experience being of the detonation of the weapon over land.

These first tests revealed again the horrible and enormous destructive power of (even) a fission bomb and led to the conclusion that submarine warfare would be the most important naval war of the future between nuclear bomb possessing powers. Although Roskill was not the most senior member of the British delegation he made it clear that he was the boss and masterminded the writing of the report – the technical details were overseen by a serving naval submarine officer Arthur Hazlett (Later Vice Admiral Sir Arthur) and by the senior scientist. The British report was succinct yet comprehensive and Roskill claimed that the Americans were using his report rather than their own because of its quality and its style. It is said that the style also pleased our Admiralty and did much to bring about Roskill being nominated as official naval historian of the war.

Increasing deafness prevented Roskill rising further in the Navy. It was his distinction as an historian which led to his senior research fellowship at Churchill in 1961. He was awarded a CBE in 1991 and held a Litt.D from both Oxford and Cambridge.

The other scientist of well recognised stature at the foundation of the College was **Edward Crisp Bullard** (1907 – 1986) – known by all other Fellows as Teddy. Born exactly ten years after Cockcroft he was elected FRS in 1941; hence for work done essentially before the war. Bullard was trained as a scientist coming up to Clare in 1926 and reading Natural Sciences. Like Cockcroft he was under Rutherford in the Cavendish and in 1931 became the first demonstrator in the Department of Geology and Geophysics. His ‘boss’ subsequently asked Rutherford’s opinion of Bullard to which he received the reply ‘he’s a damn sight cleverer than you are’ – an oft told true story.



Bullard initiated geophysics at Cambridge and early work pioneered measurements of ‘g’ to investigate the origin of major geological structures, the investigation of rocks beneath the ocean – neglected by geologists because they could not see them. Doing this seems obvious since the oceans cover 75% of the earth’s surface and telluric rocks only a quarter. To my mind it shows his great originality. He also, very importantly, made measurement of heat flow within the earth.

His citation for election to the Royal Society mentions work on electron scattering, gravity determination, seismic surveys and the fact that his measurements threw much light on the structure of rift valleys.

It was fortunate for this country that Bullard was at the height of his powers and full of a characteristic self confidence and ‘can do’ belief in himself when war broke out. In November 1939 he was made Experimental officer at HMS Vernon – the Admiralty Laboratory concerned with mine warfare. In the months just at the beginning of the war, Britain was greatly threatened by the Germans dropping mines which detected a nearby ship due to its being made of steel and hence being

magnetised. The mines dropped in shallow water such as estuaries and near harbours where traffic is greatest caused maximum havoc. Bullard recognised what needed to be done and against initial formidable opposition was put in charge of developing counter measures. These involved fitting coils of wire on ships to reduce their magnetic field and such methods as ensuring that the ship carried little magnetic moment by passing a large counter current over the keel – the principal source of the ships' magnetism.

As a result Bullard was put in charge of the group concerned with sweeping all kinds of mines. And he was able to think ahead and to deduce what kind of mine the enemy might develop. This greatly assisted the Normandy Landings and when the Germans developed a new kind of mine to protect beaches, these were swept away within twelve hours of the first casualty. Bullard went on to join P M S Blackett who as Assistant Director Naval Operational Research was one of those introducing what is known as Operational Research – the rational and dispassionate evaluation of an operation's effectiveness – a striking result of this analysis was the prediction of the optimum number of ships in a convoy for maximum protection. Like all others in the group which I am discussing who worked on war-time problems Bullard was profoundly affected by the experience.

After the war Bullard became the most distinguished British geophysicist of his generation while holding a chair at Toronto 1948-50, being Director of the National Physical Laboratory 1950-55, and on his return to Cambridge at first as an assistant in research, then as Reader and finally a chair was created for him in 1964 – four years after Churchill College was founded.

Bullard was associated successfully with many advances in our understanding of the physics of the earth from the structure of ocean basins, heat flow through the sea floor and with the wonderful advance of the 1960s which proved that the continents move about on the surface of the earth. Bullard it was who fitted the continents surrounding the Atlantic Ocean in the most excellent way – he used the continental margins rather than the coastlines and hence obtained excellent fit.

This latter work was carried out while Bullard was a senior Fellow of this College. And it is interesting that the revolution in thought concerning continental movement and the adoption of the concept of plate tectonics took place remarkably quickly over a period of less than ten years in the 1960s and represents one of the most rapid shifts in scientific thinking from denial in 1960 to acceptance in 1970. It was said that in the mid 1960s no respectable department of geology in the US would consider teaching continental drift and that ten years later no respectable department would fail to teach it.

The second Master of the College from 1968 – 1983 **William (Rede) Hawthorne** (1913 -) came up to Trinity in 1931 and read Mathematics and Engineering.

He was a development engineer (graduate apprentice) at Babcock and Wilcox from 1937 – 1939; during that latter year he went to the U.S.A on a Harkness Fellowship. He was appointed Scientific Officer at the Royal Aircraft Establishment Farnborough from 1940 – 1944 and during this period he was seconded to work with Sir Frank Whittle as were other very promising young scientists and so became involved with Britain's first jet engine for aircraft propulsion. Whittle's activity went under

the name of Power Jets Ltd and was based at Lutterworth. Like Cockcroft, but at a more junior level, he was sent to Washington to exchange information with the Americans; in his case as a member of the British Air Commission. At the early age of 31 he was made Deputy Director of Engine Research for the Ministry of Supply and worked at Pyestock which establishment later became the National Gas Turbine Research Establishment.

In 1939 he had married Barbara Runkle the daughter of the President of M.I.T and Hawthorne became Associate Professor of Mechanical Engineering at M.I.T in 1946 and he remained there until 1951 when he returned to Cambridge as Professor of Applied Thermodynamics. His close relationship with M.I.T has continued all his life and he held various visiting Professorial posts from time to time.

Hawthorne was elected to the Fellowship of the Royal Society in 1955 and the citation speaks of his mastery of a combination of thermodynamics and fluid mechanics; the pair being necessary for the design of high speed heat engines – and refers to his extending the work of Froude one of the founders of marine hydrodynamics. Secondary achievements were understanding of the mixing of gas streams in combustion chambers and the flow of rivers round the piers of bridges showing how to avoid scouring.

Shortly after the war during the Suez crisis, Hawthorne invented the Dracone a device – essentially a long sausage like vessel – for transporting oil over long distances – it is used nowadays to move water to arid islands. In 1974 he was made Chairman of the UK Council for energy conservation shortly after the first oil crisis.

His contribution to the Archives Centre is enormous being Master when it first formally emerged and being instrumental in our obtaining the Whittle papers on the British development of the gas turbine for aircraft propulsion.



Professor Hawthorne standing on Draconella.



Francis (Harry Compton) Crick (1916 – 2004) was a Founding Fellow of Churchill, though he resigned his Fellowship very early in the life of the College. He later accepted an Honorary Fellowship and although having been a research student at Caius never accepted Fellowship of another College. When elected at Churchill he was very well known though had not at that time received his Nobel Prize. This occurred in 1962 when jointly with James D Watson and Maurice Wilkins he received the prize for Physiology and Medicine. He was elected FRS in 1959 – the same year as Bondi and Keynes.

Crick was trained as a physicist at University College London obtaining a 2nd class Honours degree with subsidiary mathematics in 1937. He believed the physics he had been taught at the time was old fashioned. He started some research at UCL under Professor E. N. da C. Andrade – a very determined and quarrelsome man who was for the time well known for his ideas on creep of metals. He assigned to Crick what Crick has stated to be the ‘dullest problem imaginable’.

Precisely like Bullard, whom Crick knew during the war, having been trained in and mastered physics, which was regarded as an extremely successful subject, gave him such confidence that he felt that he could make other sciences do likewise or, rather, solve any problems posed. As a young man in early 1940 he was given a job as temporary experimental officer at the Admiralty Research Laboratories adjacent to the National Physical Laboratory in Teddington and later transferred to the Mine Design Department. Bullard, it will be recalled, was in charge of research and development of mines. Crick’s quick intelligence must have been recognised since he was moved to Admiralty Scientific Intelligence. At the end of the war he became a permanent (scientific) civil servant as a result of his interview by a Board chaired by C P Snow another Founding Fellow of Churchill College. Crick held decided views on the organization of scientific intelligence and its application to military problems and had interesting correspondence with R V Jones immediately after the war’s end.

Crick and Watson’s deduction of the structure of deoxyribo-nucleic-acid and its inference as the bearer of genetic information has been hailed as the greatest scientific achievement of the 20th Century. Because of that and Crick’s unconventional career it is very interesting that he has described how he decided to enter a biological field. The great majority of the Fellows listed in Table 1, who were engaged as scientists during the war continued to pursue very similar disciplines afterwards. They had to find jobs, of course, and some had difficulty at first but none, so far as I know, other than Crick thought out systematically what scientific area he would attack and did this across the total scientific field.

Francis Crick describes the process in detail in his first memoir – imbued with the self confidence I have mentioned – he noted that at age 30 having no scientific published record was in fact an advantage. He spanned the whole field having read avidly in science and devised the ‘gossip test’ to tell what his interests were. The gossip test is a piece of self-analysis which consists of noting dispassionately what topic one has spontaneously introduced into conversation. The one you are ‘keeping on about’ is your real interest –rather like a person in love tries to steer the conversation toward

the topic of the beloved. Crick found that he wanted to investigate what he called the living – non living borderline.

Crick's major discovery made in 1953 with Watson - I remember well the party held just before the letter appeared in Nature – based on the experimental work of M H F Wilkins, Rosalind Franklin and E. Chargaff was the double helical structure of DNA; the substance which for most cells is the suppository of hereditary information – that information which determines the characteristics of the organism. Crick and Watson reasoned their way to the structure on rather meagre evidence but in Crick's case very good knowledge of crystallography and the kinematic theory of diffraction. He had published with Cochran and Vand the theory of X-ray scattering from helical chain molecules. The structure of DNA showed that it could carry long messages and the suggestion was that it would be neat if these messages described the chain of amino acids of which proteins are composed. The complications of translation of the message are still the essence of molecular biology research.

The recognised problem which Crick and Watson solved was how genetic material stored in the fibrous DNA of a cell could carry the information necessary to inform the production of protein molecules – amino acid sequences. The overall chemical composition of DNA is rather similar in most species so how could such diversity arise? The answer was in the base pairing between the twin strands of the DNA molecule and the suggestion that the strands could separate.

The deduction of the structure gave an immediate insight into what information might be stored and passed on from generation to generation and this was immediately recognised as perhaps the most important single contribution of the century to fundamental biology. Crick and Watson became instantly famous. Crick remained interested in Churchill College and its doings for the remainder of his life and in a letter to me toward the end of it rather regretted that he had resigned.

Richard Darwin Keynes was born in August 1919, the son of Sir Geoffrey Keynes, a brother of the famous economist Maynard Keynes. He came up to Trinity to as a scholar in 1938 and read natural sciences. His education here was interrupted by the war, he was a Temporary Experimental Officer first at H.M. Anti-Submarine Establishment and later at the Admiralty Signals Establishment - returning to Cambridge to graduate in 1946. He was successfully Demonstrator, Lecturer and the Head of Physiology Department. From 1965 until 1993 he was Director of the Agricultural Research Council's Institute at Babraham coming the few miles back to Cambridge in 1973 until retirement in 1987 as Professor of Physiology.



At the Admiralty Research Establishment at Fairlie on the Clyde he was concerned with anti submarine measures. He was not instrumental in the development of the Hedgehog anti submarine mortar which fired a spread of some 26 high explosive projectiles at the suspected position of a U-boat. However, the invention by a number of his colleagues was resisted by an importantly positioned older scientist and Richard Keynes was one of the young 'Turks' who, due to his own personal connections was able to get that particular individual moved so that the weapon could be introduced. It was very successful but Richard had to be relocated and went to the Admiralty Signals

Establishment in Surrey where he met Bondi again. They came up to Trinity together and were elected FRS in the same year 1959 (as was Crick). This ‘young Turk’ effect or the influx young men into the service scientific “establishment” who effected remarkable innovations was a common one and Bullard had to galvanise the ‘establishment’ at another admiralty research laboratory. Keynes continued to advise the Ministry of Defence after the war.

On return to Cambridge in 1945/46 he, with several other very notable Cambridge scientists determined to understand the basis of the nerve impulse. That nerves are sensitive to electrical impulses has been known since the time of Galvani (1737 – 98), one of the forms of electricity called animal electricity (before Faraday (1791-1867) unified the various forms showing them all to be manifestations of the same phenomenon). Hodgkin and Huxley used electrical recording measurements but Keynes employed radioactive tracer atoms. Radioactive materials were then becoming available in quantity. Keynes showed conclusively that the nerve impulse is connected with change in the concentration of sodium and potassium ions on either side of the nerve membrane. Besides contributing much to understanding human physiology Richard Keynes’s work explains much concerning the phenomenon of electric fish.

Although I am not aware that Keynes’s work for Admiralty during the war led directly to the prosecution of his researches after the war there can be little doubt that his experience with physics and electrical engineering while working for the Admiralty will have given him much confidence when using physical techniques to attack biological problems. Perhaps he will tell us later today.

In 1949 he was first Secretary of the Hardy club a seminal group of distinguished biophysicists named in honour of Sir William Bate Hardy (1854-1934) – the list of founding members includes Hodgkin, Huxley Kendrew, Crick (all Nobel Laureates) and other very distinguished biologists.

Richard chaired the Archives Committee of the College from 1975 until 1998 presiding over and greatly assisting successive keepers during the years the Archives Centre really established itself and including the acquisition of the Churchill papers.

Hermann Bondi (1919 – 2005) the third Master of the College (1983 – 2000) was trained as a mathematician. Born in Vienna in November of 1919, he has described in his autobiography, very dramatically, how he persuaded his parents to leave Austria and join him in 1938.

During the first years of the war he was an enemy alien and so unable to contribute directly to our war effort. This changed in 1942 when he joined the Admiralty Signals Establishment in Southsea later moved to Witley in Surrey and for most of the remainder of the war he worked, principally as a theoretician, on improvements in the design of radar equipment. In Surrey he worked with his later collaborators Hoyle (1915 - 2001) and Gold (1920 - 2004) on problems connected with noise, the improvement of aerial design and the proper detailed understanding of wave guides and, incidentally, met again Richard Keynes whom we honour today and who had known him at Trinity in



1938. Problems of scatter by water vapour and by sea water surrounding a target when the radiation was used to detect the periscope of a submarine were all investigated theoretically. But the need for trials led to Bondi setting up a radar generating and receiving station on top of Mount Snowdon. From there, 1100m high, transmissions were sent out and received to Aberforth in South Wales – a trajectory mostly over the sea. Bondi established the earliest reliable and comprehensive measurements of wave clutter of 10cm and 3 cm waves. He describes how he, during this period, realised the importance of practical ability and engineering intuition and how these talents are often more useful if not vital to success rather than accurate mathematics. This turned him from being an abstract mathematician into a real scientist.

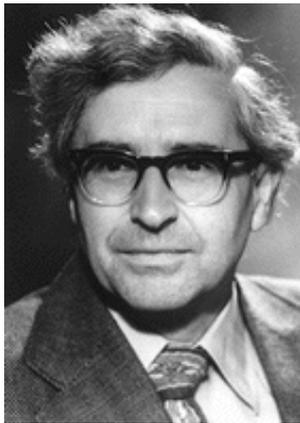
The interaction with Hoyle and Gold became the foundation of ‘my whole future’. After the war, while at Cambridge and London, a lecturer in mathematics here from 1948 – 54 and then as Professor of Mathematics at Kings College London from (1954) – titular from 1971 – until 1985, he became a most prominent astro-physicist (elected FRS 1959) and worked on problems such as how stars grow by accretion of matter. Here his wartime tasks particularly the study of how the powerful magnetron valve worked (the generator of radar pulses) with interpenetrating streams of electrons gave him vital clues to the study of accretion. The magnetron had been developed without a full understanding of how it worked. His subsequent most significant astrophysical work was in the field of Relativity and Cosmology – he published the book *Cosmology* which explains simply the clock paradox. This is that if one of a pair of twins goes off into space and returns, on return it would be younger than the sibling. Bondi also contributed to the understanding of gravitational radiation and is best known for a theory of the formation of the Universe known as the steady state theory which argues that matter is continually being created.

But apart from his scientific achievements after the war and his famous ability as a great teacher, Bondi went on to become Director of the European Space Research Organisation (ESRO) from 1961 – 1971 and then Chief Scientist to the Ministry of Defence from 1971 – 1977. He followed this by being Chief Scientific Adviser to the Department of Energy from 1977 – 1980 and after this was Chairman and Chief Executive of the National Environmental Research Council until he returned to Cambridge and to Churchill as Master in 1983. His war time experience had greatly aided his subsequent research. During Bondi’s period at the Ministry of Defence he invited Richard Keynes, whom we honour today to serve on a committee examining problems of target recognition and when Chief Scientist to the Department of Energy invited Anthony Kelly to assess the success of the United Kingdom Offshore Steels Research Project – concerned with the durability of drilling rigs in the North Sea.

Bondi served on numerous committees and was so well regarded that, although a complete outsider, he was asked at the suggestion of Solly Zuckermann to write a report on (1966) on the need for a flood barrier for London – this became finally the Thames Barrage constructed in 1982 at Woolwich.

The youngest of Churchill’s wartime scientists with whom I shall deal with and that only by a mere four years is **Antony Hewish**. Born in 1924 he entered Gonville and Caius College in 1942 and after a year there was directed to the Royal Aircraft Establishment at Farnborough as a temporary experimental officer and later was seconded to the Telecommunications Research Establishment at Malvern – his work concerned airborne radar counter-measure devices. Hewish met, while both were at

Malvern, Sir Martin Ryle (1918-84) who established radio astronomy work at Cambridge.



At TRE Hewish worked on a device called Airborne Grocer. This was designed to jam the radar used by German night fighter aircraft. It was installed in the tail of American B-17s flown by RAF 100 Group, Bomber Command. Later, back at RAE in 1945 he worked on the 'Talking Beacon', a navigational aid having a rotating beam which transmitted the appropriate bearing when received by an aircraft. On Hewish's return to Cambridge and after graduation, using techniques analogous to those developed for radar sensing and range finding in order to understand radio sources in the sky, was clearly a natural development. Radio Astronomy was born out of the development of radar techniques during

World War II in all of the leading countries, particularly Britain and Germany.

Ryle had developed a simple directive aircraft antenna, superior to a dipole which laid the foundation for the design of radio-astronomical antennae after the war. In addition his involvement in new measurement techniques at centimetre wavelength had an important influence on his later research. After war's end Ryle was supplied with large (captured German) aerials and other equipment.

So Hewish's later work flowed naturally from the wartime experience of him and of his supervisor Martin Ryle. His first investigation was to ascertain why radio stars twinkle, as do visible ones, and he discovered that the cause is the presence of clouds of plasma material in our ionosphere at heights of some 300km.

The citation for election to the Royal Society in 1968 refers to his establishing the electron content and other properties of the upper atmosphere, the outflow of matter from the sun, and credit him with the technique of 'aerial synthesis' i.e. using the reception of signals from many small aerials to simulate the properties of a large one.

In 1965 Hewish drew up plans for a radio telescope intended to carry out a survey of more than 1000 radio galaxies using a technique developed by Margaret Clarke and two of Hewish's colleagues Scott and Collins. This ambitious project could be likened to that of Flamsteed (1646-1719) who in the late 17th and early 18th century centuries produced the first star chart recording some of the characteristics of one thousand visible stars. Hewish, the latter day Flamsteed, required a receiving technique covering 18000m² and at a wavelength of 3.7m. In July 1967 a survey of the sky was started.

A record indicating fluctuating signals turned out not to be of terrestrial origin but was a source emitting regular pulses of radiation at intervals of time of just over one second. Difficulty was first experienced in proving that the signals were not due to electrical interference. They turned out to be keeping a constant period to better than one part in a million. Their sharpness indicated that the source emitting them was very small. An object with a diameter of no more than some 10 kilometres or so. Hewish at the time told Archie Howie that he suspected 'little green men' but other pulsing objects with periods of about a second were found by Bell and Hewish. It was Gold who taught at Trinity with Bondi when I was a research student, who first suggested that the phenomenon was due to a rotating neutron star (the rotation would arise from the conservation of angular momentum as the star collapsed and its radius decreased).

This provided the simplest and most plausible mechanism to explain the pulsar 'clock' Gold predicted that the pulse periodic time should increase with age and this was confirmed from the observation of other pulsars. Hewish was awarded the Nobel Prize for Physics with Ryle in 1994.

The importance of the discovery has been because it confirms theories of the life of stellar materials when the nuclear fuel is burnt and radiation pressure holding the star from collapse under its own gravitational field is no longer able to prevent collapse – so that protons and electrons no longer exist and matter consists almost entirely of neutrons. The density is enormous 10^{17} kg/m³ - normal solids on earth have densities of at most 25×10^3 kg/m³. The neutron star replaced the white dwarf as the final corpse of an aged star. At the time the supposed enormous density could not be directly verified because there was no independent measurement of the mass of the star. Stellar masses are most accurately found directly from the observation of the distance of separation of binaries and of the period of rotation of the binary star. The classical method follows directly from Newton's law of gravitation and the fact that the orbits are elliptical. However, in the case of pulsars relativistic effects have to be taken into account. Recent measurements (e.g. Lyne, 2006) yield values of close to about 1.4 times the mass of our sun or, expressed in terms of the same quantities which I have just used in quoting a value for the density, a mass of 2.8×10^{30} Kg.

The interest shown by solid state scientists deserves comment since the solid state is not one usually treated by astrophysics. But it is found that the mechanical properties are in some respects similar to the properties of ordinary matter. Howie and I have estimated the value of Poisson's ratio, a very well known property of normal solids. The value found is about one half – ordinary rubber on earth has a similar value!

Record of Scientific achievements held within the Churchill College archive

The story which I have just related indicates some of the richness of the material held within the College Archive Centre. This coupled with material which I have not dealt with in detail in this presentation comprises among many other things; the first demonstration of the validity of Einstein's famous equation $E=mc^2$, the discovery of the neutron, and the discovery of neutron stars (pulsars), the discovery of the wave nature of the electron, a major contribution to the establishment of continental movement, the theory and practice of jet propulsion, contributions to the biochemistry of nerve muscle interaction, development of the magnetron valve, development of the Scanning Electron Microscope, the discovery of monoclonal antibodies, original x-ray diffraction patterns of the double helical structure of DNA and many more.

See: <http://www.chu.cam.ac.uk/archives/collections/classified>.....enter subject e.g. chemistry

Churchill and our Bomb

Churchill was informed by Truman at Potsdam of the successful detonation of the first atomic bomb at the Trinity test site on July 16 1945. He was out of office when the bombs on Hiroshima and Nagasaki were dropped. He was intensely interested in the device and knew of its development almost from the start.

Britain's bomb was provided by British scientists working essentially in the Churchill era – hence by Churchill's scientists though among those who played an essential role either in its conception (Peierls, Frisch) or development (Chadwick, Fuchs) only Cockcroft who contributed to both stages was to become later a member of Churchill College

The British technical effort to produce atomic weapons, a fission bomb in October 1952 and a hydrogen bomb in 1957 has not been recognised and esteemed as the remarkable technical achievement that it was. The decision to go ahead with the latter – the hydrogen bomb (or the 'super' as it was known to the physicists attempting to make it) was taken by Churchill on the advice of Cherwell who, of course, consulted Cockcroft.

Cherwell at the time he was first consulted about the super in 1953 opined that the Russians might soon explode one. That "prophecy" turned out to be correct – the first true H bomb was exploded by the Russians in November 1955 almost exactly three years after the USA had exploded 'Mike' at the Eniwetok site in 1952 and this, though a thermonuclear explosion was not a deliverable weapon.

Although Lord Penney (1909-91) has been recognised as the leader of the project to produce our first fission bomb and was one of the leaders in the production of our first H bomb in 1957 – other scientists have hardly achieved adequate recognition and the names of Corner, Bruce, Pilgrim and Willows who worked on the fission bomb or Cook, Roberts and Taylor for the fusion bomb are hardly known.

The Soviet scientists such as Kurchatov and Sakharov were made heroes of the Soviet Union and the Americans such as Alvarez and Serber (the latter incidentally wrote the Los Alamos Primer the introductory text made available in a highly secret first briefing to scientists recruited to Los Alamos) both received Nobel prizes for related nuclear studies. Oppenheimer, of course, is exceedingly well known as are Carson Mark, Teller, Ulam and others.

There is a strong echo of this in the 1970s in the way in which major encryption discoveries necessary for the secure use of all our credit cards, made by British scientists – notably James Ellis, Clifford Cocks, and Malcolm Williamson working secretly for our government at GCHQ are little if ever referred to. The usual names recorded are American.

Whether or not one believes that Britain should be in possession of nuclear weapons and able to deliver them against a target - there has been no doubt about this in the minds of members of the Cabinet and of all British Prime Ministers since the end of World War II.

It was Clement Atlee who authorized the production of Britain's first bomb in January 1947. In August 1945 soon after the first explosion in July of that year, he saw international control of the weapon as the best hope for mankind. The McMahon Act passed by the US Congress cut off essentially all atomic collaboration with its wartime ally despite the US/UK/Canadian collaboration on the Manhattan Project.

The first British bomb was not tested until 3 October 1952 off the northwestern Australian coast. When Churchill returned to power in 1951 he was struck by Atlee's concealing the costs from parliament (that work was in fact going on was admitted in May 1948 in a guarded and terse reply to a planted parliamentary question).

And it was Churchill and not Atlee who had to give final permission for the first test to proceed (The electrical timing, so important a technical part was controlled by my later boss Sir Ieuan Maddock). On 7 November 1953 the R.A.F. took delivery of its first true fission weapon named Blue Danube ; initially of 10kton but later of 30kton.

Churchill was somewhat ignorant of the technical situation since he suggested soon after his return to power in late 1951 that Britain did not need to make its own bomb and that President Truman should be asked to give Britain part of the US arsenal – presumably by purchase. Though this may have appeared silly at the time it was not, since if Jock Colville is correct Churchill had persuaded Roosevelt to initial a paper in September 1944 to the effect that all atomic bombs produced in the US should be shared between the two countries.

Churchill's valedictory address to parliament was formally presenting the 1955 Defence White Paper and it contained the key announcement that the government had decided to manufacture a British hydrogen bomb. Churchill, like Macmillan later, was quite obsessed with the importance of the weapon. Winston told Lord Moran in the spring of 1954 that he was more worried by the hydrogen bomb than by all of the rest of his troubles put together.

The USA detonated a hydrogen fusion device named Mike on the island of Elugelot in Eniwetok Atoll, part of the Marshall Islands on 1 November 1952 – but it was not a deliverable weapon – it involved a building two storeys high – but it did meet the definition of a super by producing a yield of the equivalent 10.4 megatons of tnt– 1 megaton is the accepted lower limit for a fusion device.

In fact it was the knowledge imparted to Churchill concerning the destructive power of the H bomb which was one of the most potent factors in his clinging onto power after his stroke because he believed that he was uniquely the person who could bring about some 'easement' as it was called of the tension between the US and Soviet Union and hence prevent the use of H bombs in anger. Easement was the term used to forestall any accusation of appeasement.

Malenkov had announced that the Soviet Union had successfully completed a thermonuclear test – Joe 4 exploded on 12 August 1953 – it has been questioned whether this was a true H bomb or merely a boasted fission device. On 22 November 1955 the Soviet Union did show that it had a fully fledged hydrogen bomb. And it has been argued that the Soviet team produced the first useable thermonuclear weapon ahead of the Americans.

The Soviet announcement in 1953 and the second American thermonuclear tests in March 1954 – the Castle series also in the Marshall Islands – this time at Bikini Atoll – hence the bizarre appellation of the scanty two piece swim suit – was of a weaponised device and this announcement led to intense worry around the world. Anxiety was enhanced at about the same time by the effects of fall out on the crew of the Lucky Dragon – a Japanese fishing vessel.

That Britain intended to make an H bomb was revealed in the Defence White Paper published in February 1955 as I have said. Britain's first true H bomb exploded off Christmas island with a force of 1.8 megatons on 8 November 1957. France did not test its first fission bomb until doing so in the Sahara on 13 February 1960 and exploded its first fusion device in 1968. China's first bomb came in 1964 and an H bomb in June 1967.

The McMahon act of 1946 was extremely effective in cutting off information on US weaponry to all other nations. The restoration of information sharing with Britain in 1958 – brought about because, among other things Macmillan was very importantly able to claim that we had developed a true hydrogen bomb, led quickly to sharing of war head designs and – joint target choosing by the US and ourselves for the US B52 and the RAF V bombers Vulcan and Victor and later to the Polaris and Trident submarine forces of the US and of our Royal Navy.

In late 1957 Eisenhower ordered that the most stringent application of the McMahon act be put aside and authorized the resumption of technical talks concerning collaboration on nuclear weapons. This required the UK to demonstrate its indigenous, wholly owned capacity to produce an H bomb. This it could do but only in terms of strict chronology **after** the Eisenhower directive.

Throughout the 50s and 60s into the 70s possession of the H bomb has seen by successive British governments as providing entry into the highest counsels of the world. Even the quintessential socialist Aneurin Bevan, father of the National Health Service poured scorn at a Labour party conference on October 1957 of the idea of Britain unilaterally renouncing the H bomb – ‘do not send me naked into the conference chamber’. At the precise time he spoke we were still a few weeks away from successful detonation of a fusion bomb.

Possession of an H bomb and the ability to deliver it remains a necessity for a country aspiring to be counted as of influence in global questions. Both Gordon Brown and Tony Blair joined anti-nuclear demonstrations in their youth. Having assumed power each will have realized that without the H-bomb their world-wide influence as the government of great Britain would be greatly diminished and the British seat as a permanent member of the Security Council of the United Nations would be put at risk.

Table 2 is, an abridged summary of the nuclear weapon tests of the 1940s and 50s and demonstrate how, starting essentially from scratch, we caught up with the USA and USSR

Table 2**Nuclear Weapon Tests**

DATE	USA	USSR	UK
July 1945	Trinity 21kT		
June 1946	Crossroads 21kT		
1948 April	Sandstone 49kT		
1949 Aug.		Joe 1 22kT	
1951 Jan	Ranger 22kT		
May	George 225kT		
Sept.		Joe 2,3 40kT	
1952 Oct.	Mike 10.4MT		Hurricane 25kT
1953 Aug/Oct		Joe 4 400kT	Totem 10kT
1954 Feb.	Castle 15MT		
Sept.		150kT	
1955 Nov.		Joe19 1.6MT	
1956 Feb.		1.5MT	
June	Redwing 6MT		Mosaic60kT
Oct.			Buffalo 15kT
1957 Nov.			Grapple 1.8MT
1958 Feb.		8 shots in MT range	
Apr.	8 shots in MT range		Grapple 3MT
Aug			2shots MT range
Oct.	22k		

Our bomb was produced by our scientists and their names and achievements need to be more fully recognised.

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Bibliography

Nobel Lectures of Cockcroft, Crick and Hewish

Royal Society of London Library and Archive: citations for election: Cockcroft, Bullard, Hawthorne, Keynes, Bondi and Hewish

Biographically Memoirs of the Royal Society-Vol 14 Cockcroft (1968), 32 Ryle (1986), 33 Bullard (1984)

Oxford Dictionary of National Biography 2004 Roskill

Cambridge contributions Chapter 10 Geophysics in Cambridge H.E Huppert-S.J. Ormrod Edit.

Churchill Review Vols 37-43

J. Colville Footprints in Time William Collins 1976
B. Cathcart Test of Greatness J.Murray 1994
R.V. Jones Most Secret War Hamish Hamilton 1978
H.Bondi, Science Churchill and Me Pergamon 1990
G.Hartcup The Challenge of War David and Charles 1970
G.Hartcup and T.E. Allibone Cockcroft and the Atom Adam Hilger 1984
L. Arnold Britain and the H Bomb Palgrave 2001
P. Hennessy Having it so good Allen Lane 2006
F.H.C.Crick What Mad Pursuit Weidenfeld and Nicholson 1988
J.G. Crowther and R Widdington Science at War HMSO 1947
S.Singh The Code Book Harper Collins 1999
Kaufmann W.J.III Discovering the Universe 2nd edit Freeman and Co (1990)
A.G. Lyne The double-pulsar binary J0737-3039. Advances in Space Research 38,
2716-2720, (2006)

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