"No Mean Society"

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200 Years of
The Royal Philosophical Society
of Glasgow

1802 2002

On 9th November 1802, twenty-two citizens of Glasgow met to establish a "Society for the discussion of subjects connected solely with the Arts and Sciences". The world has changed beyond recognition during the intervening centuries, and many of those changes - in public health, in transport and communications, in commerce and industry, in architecture, as well as in the arts and sciences - were the subjects of the Society's discussions.

Glasgow was indeed "no mean city"; it was known both as "the second city of the Empire" and as "the workshop of the world". In an era when knowledge has become increasingly specialised and fragmented, this collection of essays reviews and celebrates those two centuries of contribution across the breadth of the intellectual life of our city, our country, and indeed the world.

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The Royal Philosophical Society of Glasgow
PO Box NAT 8268
Glasgow
G46 7BR

www.royalphil.org
info@royalphil.org

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Contributors

David Primrose

David Primrose is a Doctor of Medicine, a Chartered Accountant and a graduate in Law. He is currently treasurer of The Royal Philosophical Society of Glasgow, having served on its Council for several years.

W. Hamish Fraser

W. Hamish Fraser, Professor of History, University of Strathclyde has written extensively on aspects of labour history and social history. His most recent book is Scottish Popular Politics (Edinburgh UP, 2000).

Bill Cranston

Emeritus Professor Bill Cranston is a civil engineering graduate of the University of Glasgow to where he returned to complete his PhD after National Service. Following a 25-year career in the United Kingdom cement industry's research laboratory in Berkshire, he joined the Department of Civil Engineering at the University of Paisley. Since 'retiring', he has been researching into engineering education.

T. S. Wilson

Dr T. S. Wilson was the City of Glasgow's last Medical Officer of Health. He subsequently became a Community Medicine Specialist with the Greater Glasgow Health Board focusing on environmental health and infectious diseases.

George Wyllie

Dr George Wyllie was Senior Lecturer in the Department of Natural Philosophy mainly in the University of Glasgow from 1943. In his retirement he pursues interests in environmental physics, statistical theory and sundials

Peter A. Reed

Peter Reed is Professor Emeritus of Architecture and a former Vice-Principal of the University of Strathclyde. He has been Chairman of the Charles Rennie Mackintosh Society and Convenor of Glasgow Conservation Trust.

Leslie Barr

Emeritus Professor Leslie Barr was President of the Royal Philosophical Society of Glasgow from 1993 until 1996. A former Professor of Physics at the University of Paisley, he maintains an active interest in physics and in the history and philosophy of science.

Foreword

Ephraim Borowski
President, 2000–2003
The Royal Philosophical Society of Glasgow

History is always humbling, peopled by the great men and women of the past in whose footsteps one feels unworthy to walk; but equally daunting is the road ahead, uncharted and perilous, on which one treads only with circumspection. Not for nothing did Janus require two heads, to survey both past and future, and if that is true of years, how much more so of centuries!

Thus it has been a great challenge as well as a great privilege to have been at the helm of this venerable Society at this turning point, as we too have looked both back and forward. We closed our second century with a lecture series reviewing 100 years of change, and we opened our third with a series looking to the future. It is extremely gratifying that this programme has built the Society to its strongest for more than half a century, and that it continues to flourish, as our city's motto exhorts.

It is difficult for us to imagine the world in which, as Mercury crossed the Sun on 9th November 1802, twenty-two of our fellow-citizens met in the Price of Wales Tavern to establish a 'Society for the discussion of subjects connected solely with the Arts and Sciences'. Our cities were not yet lit even by gas nor connected by railways; steam power, both in navigation and in industry, was barely in its infancy; our rivers were sewers and our water was drawn from wells; and another forty years would pass before either anaesthesia or antisepsis came to the aid of medicine. Dalton's atomic theory was not yet fully articulated, thermodynamics had yet to be formulated, and electricity was virtually unknown.

This was truly 'no mean society', a fellowship of citizens of no mean city, indeed the proud 'Second City of the Empire'. What is perhaps most remarkable is how many advances in both theory and practice are associated with the early members of this Society. Many of these eminent individuals provided the ideas which stimulated the advances in science and engineering that were to fuel the industrial growth of Scotland and to give Glasgow its reputation as 'the workshop of the world'. The intellectual genius which inspired individuals like Graham, Kelvin, and Lister brought Scotland to pre-eminence as the source of advances in chemistry, ship-building and engineering, medicine and public

The bicentenary dinner held in November 2002 in the magnificent setting of Glasgow City Chambers.

health that were to underpin economic and social progress for future generations.

Clearly, whatever the intentions of our founders, the arts never had parity with the sciences amongst the Society's early interests, and it was not until the 20th century that literature, sociology, history, architecture, economics, and psychology became increasingly common subjects. Paradoxically, to our ear, philosophy in the modern sense almost never featured in the Society's diet, although increasingly in recent years our speakers have eschewed the technicalities of their own work to address broadly conceptual questions about their disciplines.

Where once eminent practitioners presented their latest discoveries, now equally eminent advocates of their subjects make them accessible to a wider public. It is not surprising that a professor of 'the public understanding of science', speaking in this bicentennial year, brought us our best attendance for almost a century. As knowledge has fragmented, and there are increasingly more learned societies with increasingly narrow scope, we are all lay observers of most of human endeavour. It is by adapting to this change and retaining its breadth of vision, perhaps, that the Society has survived to flourish again.

So it is with great pleasure and pride that we take our first step into our third century, on a day when Mercury retraces the path it followed on the day of our first meeting, by presenting this brief memoir of the intervening two centuries.

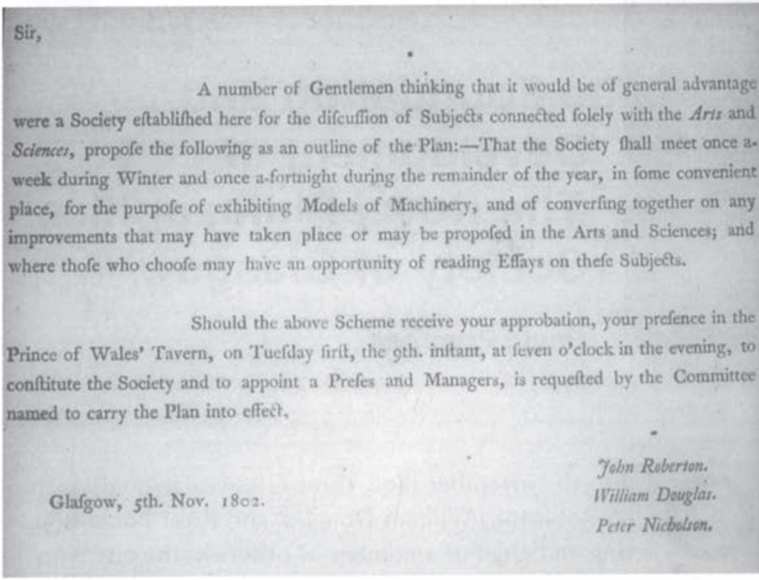
7 May 2003

The Foundation and Development of The Royal Philosophical Society of Glasgow

David Primrose

On the 5th November 1802, three Glaswegian gentlemen, John Roberton, William Douglas, and Peter Nicholson, acting on behalf of a number of others in the city who were 'interested in the prosperity of the Trades and Manufactures of their country', and anxious for 'the improvement of the Arts and Sciences' sent a circular letter proposing a meeting to discuss the establishment of a society for this purpose. Interested parties were requested to attend a meeting to be held four days later at the Prince of Wales Tavern in Brunswick Street. Twenty-two individuals duly attended and appointed a committee 'to draw up an outline of the principles of the Society' to be presented at the next meeting which was held on 16th November. Sixty persons met and subscribed to the setting up of the Glasgow Philosophical Society. Included in the 'principles' were a private meeting room and the creation of a library of scientific books.

One month later on the 8th December, the first council of four officials and twelve directors was elected, with an entrance fee of three guineas to join the Society and an annual subscription of 10/6 also being agreed. The first officials were William Meikleham (President), John Roberton (Vice President and also membership certificate no.1), James Laird (Secretary) and John Lindsay (Treasurer).



Sir,

A number of Gentlemen thinking that it would be of general advantage were a Society eſtabliſhed here for the diſcuſſion of Subjects connected ſolely with the *Arts* and *Sciences*, propoſe the following as an outline of the Plan:—That the Society ſhall meet once a-week during Winter and once a-fortnight during the remainder of the year, in ſome convenient place, for the purpoſe of exhibiting Models of Machinery, and of converſing together on any improvements that may have taken place or may be propoſed in the Arts and Sciences; and where thoſe who chooſe may have an opportunity of reading Eſſays on theſe Subjects.

Should the above Scheme receive your approbation, your preſence in the Prince of Wales' Tavern, on Tueſday firſt, the 9th. inſtant, at ſeven o'clock in the evening, to conſtitute the Society and to appoint a Preſes and Managers, is requeſted by the Committee named to carry the Plan into effect,

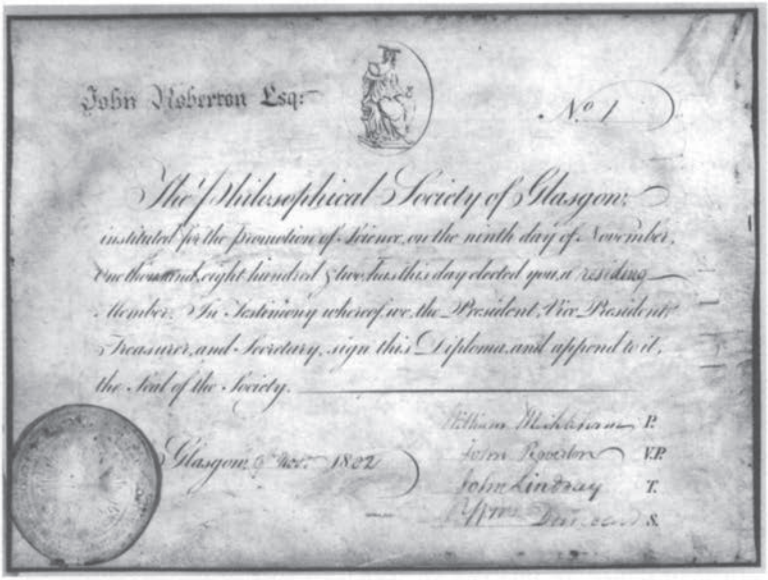
Glaſgow, 5th. Nov. 1802.

John Roberton.
William Douglas.
Peter Nicholson.

The original letter proposing the establishment of the Society.

Meikleham was then the professor of astronomy at Glasgow University but in the following year he was translated to the university's chair of natural philosophy (which he occupied until his death in 1846, being succeeded by William Thomson, later Lord Kelvin). Roberton was an ironfounder and the election of these two illustrated the close connection of 'town and gown' as well as emphasising the importance of science and industry for the future prosperity of the city. By the end of 1802, 31 had paid their dues and subsequently all except one of the original 60 became members. The membership certificate was designed by an engraver, James Haldane (member no.51)

At the first anniversary William Duncan succeeded as secretary and he was later to become the first Librarian. There were 67 members and £100 had been deposited in the bank. In 1804, new officials were elected, including an accountant, James Boaz as Secretary, an office he was to hold for almost 30 years.



The Society's first membership certificate.

From the beginning it was intended that meetings would be held weekly in the winter and fortnightly in the summer and that members would present papers and exhibit models, artefacts, etc. However, attendances soon dropped off as many members had not prepared anything and on such occasions there was only general discussion. In fact, throughout the early years of the Society, membership fluctuated widely. (Membership at ten-yearly intervals is shown in the table in Appendix 4). There continued to be a steady trickle of new members but others dropped out, or did not renew their subscriptions. In 1806, only 36 members had paid their annual fee, while in 1810, 114 paid up members were listed. By 1820, the loss of members was a worry and it was decided to reduce the entrance fee to one guinea. This had little effect and by the 30th anniversary in 1832, membership had fallen to 47 which included six of the original members. However, the variety of occupations of these 47 members does shows how wide the range of interest in the Society was at that time: academic, accountant, architect, baker, calenderer, chemist, cotton spinner, commission merchant, engineer, engraver, firemaster, glass maker, hat maker, iron master/founder, ironmonger, manufacturer, merchant, silversmith, spirit dealer, steelmaster, superintendent of works, surgeon, tallow chandler, teacher and yarn merchant.

One of the Society's problems had been the difficulty of finding a suitable meeting place for there was a general shortage of available places in Glasgow. The first meetings were held in the Assembly Rooms in Ingram St (subsequently the site of the Central Post Office) and then in 1806, a three-year lease was obtained from the Faculty of Physicians and Surgeons, for premises in the Surgeons Hall on the east side of St Enoch Square (later to be the railway station). There was talk of building a laboratory for experiments on spare ground behind it but, although the lease was renewed for a further three years, this did not materialise. In 1812 the Society leased premises in Smith's Court, 53 Candleriggs but being 'cold within, obscure outside and difficult of access', in 1816 the Society moved to 34 Virginia St and then again for two years to the south side of the Trongate. In 1820, a lease was obtained from the Glasgow Annuity Society, at Pratt's Court, 109 Argyll St for a more suitable room which had a gas fire and was large enough to be partitioned. This was the year in which a presentation of silver plate was made to Mr. Boaz 'for his valuable services as Secretary for 16 years'.

Membership and consequently, finance, continued to cause anxiety and at one meeting in 1831, although there was a membership of 47, only the president and secretary attended. The situation was precarious and dissolution was considered.

Anderson's University

In the meantime, discussions had been taking place with the recently completed university founded by John Anderson. It was agreed in December 1831 that this University would provide a life-

rent right to the use of its library and reading room for all of the paid-up members as well as the free use of a room for meetings. In return, the Society would transfer all of its property (including its library and £40 in cash) to the university. The use of the Andersonian facilities was a turning point for the Society and by 1840, membership had increased to 80. The library was again built up by the purchase of journals and books as funds permitted.

In 1845 the free use of a meeting room in the Andersonian was

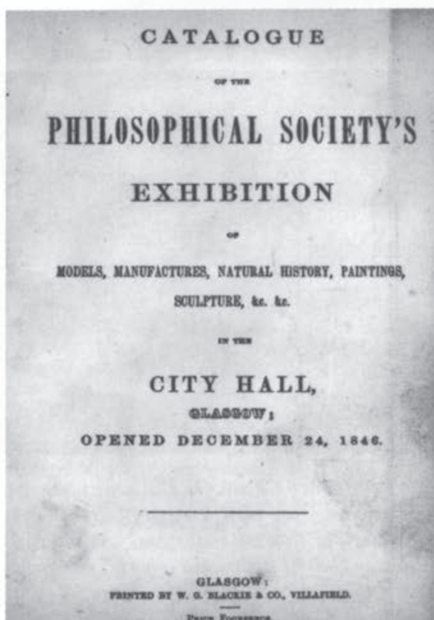
The President's Chair. On the headpiece, Minerva (representing both science and the arts) sits beneath a sunburst, her left hand on the Society's original logo, itself sitting on books and a compass. On the opposite side is the Glasgow coat of arms and a scroll containing the city motto, 'Let Glasgow Flourish'. The profiles on the left are probably William Meikleham and behind him, John Roberton, the first President and Vice President; the figures on the right are identified as 'Smith' and 'Simson'. The chair is presently in the safekeeping of the University of Strathclyde.

changed to the lease of a hall there and the Society spent £118 on fitting it out. This included the creation of a president's chair to be made from an approved design. The chair was later described as being made 'from oak from the beams of Glasgow Cathedral'. In 1868, the university required the hall for its own use and the Society was fortunate in being able to lease a hall in the new Corporation Art Gallery (latterly the McLellan Galleries) in Sauchiehall St.

In 1869, the membership situation was eased when the Sewage Association amalgamated with the Society and later that year, the Glasgow Architectural Association did likewise; members of both associations who were not already members of the Society were encouraged to join it.

Exhibitions

From time to time the Society held private exhibitions to which members and their scientific friends were invited. In 1845, the Society had joined with the City Council to bring to Glasgow an exhibition of 'works of Art from Paris' which had been bought by the Government and had been on show in London. These were shown in the Government School of Design in Ingram St and the exhibition was so successful that the Society decided to hold another over the


CATALOGUE

OF THE

PHILOSOPHICAL SOCIETY'S

EXHIBITION

OF

MODELS, MANUFACTURES, NATURAL HISTORY, PAINTINGS, SCULPTURE, &c. &c.

IN THE

CITY HALL,

GLASGOW;

OPENED DECEMBER 24, 1846.

GLASGOW:
PRINTED BY W. G. BLACKIE & CO., VILLAFIELD.

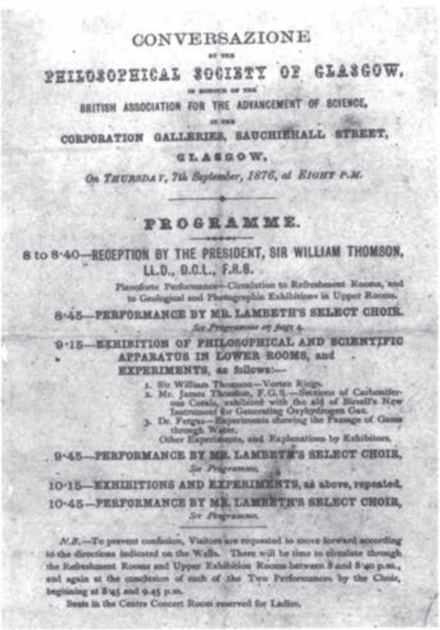
PRICE FOURPENCE.

The catalogue of the Society's 1846 Christmas extravaganza.

Christmas holidays with the primary object being 'to interest the working classes'. This was opened in the City Hall on Christmas Eve, 1846 and ran for 17 days. There were free days and it was open on some evenings with the result that attendances reached almost 100,000. A surplus of £462.6.2 was realised and this was invested with the Corporation as the 'Exhibition Fund'. This was at the core of the Society's increasing solvency, to the extent that in 1852 on its 50th anniversary, general funds amounted to £346 16/- and in addition there was over £570 in the Exhibition Fund; ten years later, it had increased to over £900.

The British Association

In 1855, as a result of an invitation from the Society, the British Association for the Advancement of Science met in Glasgow. Over 2,100 persons enrolled for the meeting. There were eight different scientific sections and in total 349 papers were presented. The British Association met again in the city in 1876 when Sir William Thomson (later Lord Kelvin) was president, and the Society held a Conversazione and Exhibition in the McLellan Galleries in honour of the occasion. When the planning of this was being discussed by the Society, it was suggested that as part of the social programme



CONVERSAZIONE

PHILOSOPHICAL SOCIETY OF GLASGOW,

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE,

CORPORATION GALLERIES, SAUCHIEHALL STREET,

GLASGOW,

On THURSDAY, 7th September, 1876, at EIGHT P.M.

PROGRAMME.

8 to 8·40—RECEPTION BY THE PRESIDENT, SIR WILLIAM THOMSON, LL.D., D.C.L., F.R.S.

Pianoforte Performance—Circulation to Refreshment Rooms, and to Geological and Photographic Exhibitions in Upper Rooms.

8·45—PERFORMANCE BY MR. LAMBETH'S SELECT CHOIR.

See Programme on page 4.

9·15—EXHIBITION OF PHILOSOPHICAL AND SCIENTIFIC APPARATUS IN LOWER ROOMS, and EXPERIMENTS, as follows:—

1. Sir William Thomson—Vortex Rings.
2. Mr. James Thomson, F.G.S.—Sections of Carboniferous Corals, exhibited with the aid of Birrell's New Instrument for Generating Oxyhydrogen Gas.
3. Dr. Fergus—Experiments showing the Passage of Gases through Water.

Other Experiments, and Explanations by Exhibitors.

9·45—PERFORMANCE BY MR. LAMBETH'S SELECT CHOIR,

See Programme.

10·15—EXHIBITIONS AND EXPERIMENTS, as above, repeated.

10·45—PERFORMANCE BY MR. LAMBETH'S SELECT CHOIR,

See Programme.

N.B.—To prevent confusion, Visitors are requested to move forward according to the directions indicated on the Walls. There will be time to circulate through the Refreshment Rooms and Upper Exhibition Rooms between 8 and 8·40 p.m., and again at the conclusion of each of the Two Performances by the Choir, beginning at 8·45 and 9.45 p.m.

Seats in the Centre Concert Room reserved for Ladies.

The programme from the Society's 1876 Conversazione.

there should be a steamboat trip down the Clyde, at which another member volunteered that if this took place he would arrange to put on, as the boat passed the quarry at Furnace, 'one of the largest blasts which has yet taken place'. Prior to this in 1868, Dr F. H. Thomson had dwelt in his presidential address on a new explosive, invented by Nobel, called dynamite and discussed its relative safety. Sadly, however, in 1876 there was no official boat trip and thus no explosive display.

Incorporation

In 1879, the Society was incorporated under the Companies Acts of 1862, 1867 and 1877 as a company limited by guarantee (up to 5/- per member), and named The Philosophical Society of Glasgow. There was a new constitution, though the new articles generally repeated the regulations of the old Society. Honorary and corresponding members (see page 43 and Appendix 2) were continued and a new drive was made to encourage members to compound their annual subscription into a life membership. There was an increase of 100 members in that year, 25 of which were life memberships.

The new library and reading room.

New Building

For some time there had been a desire to have more permanent premises, a desire given impetus in 1878 by the Corporation's termination of the Society's lease of the McLellan Gallery. In conjunction with the Institute of Engineers and Shipbuilders, ground was purchased in Bath St on which to erect a three-storey building with a library and reading room on the ground floor and a large hall and council room on the first floor. There were also meeting rooms for the Sections. On the staircase landing there was a three-part stained glass window with the centre panel representing the City of Glasgow and on either side panels representing the Society and the Institute. There were living quarters in the basement for a caretaker as well as two large rooms and two fireproof safes. The architects were Thomas Watson and William Miller and it was completed in 1880 for a total cost of £7,987, shared equally with the Institute of Engineers. The Society took out a bond for £3,000 on the building. The annual accounts had been showing a reasonable surplus and in 1897, £300 of the bond was repaid.

Royal Charter and Centenary

In 1899, the Microscopical Society united with the Society. With the approach of the new century and the Society's centenary in 1902, there was renewed activity, particularly amongst influential members of the society to raise its profile. As a result, a Royal Charter was granted on 23rd August 1901 and the Society's name henceforth became The Royal Philosophical Society of Glasgow. In that year there were 365 new members. The Centenary was celebrated with a Conversazione and Exhibition in the new Kelvingrove Art Gallery, which was attended by over 3000 people, and by a civic dinner the following day. The remainder of the property bond was paid off in this year.

The Engineering Institute had been finding the building too small for both societies and it was agreed in 1906 that the Society would buy out the Institute's interest in it for £4,000. The Institute would pay a rent to continue part use of the premises until it had built new premises. A new bond for £3,250 was taken out to help to pay out the Engineers. Reserves at this time amounted to almost £5,750.

Lady Members

The question of admitting women to the Society had been raised in 1902 when it was decided by the Council, after discussion, that ladies 'be not eligible for membership'. It was raised again in 1914 and the Council, having sought advice, decided that as membership under the Constitution was restricted to 'persons', this term did not include females! It was also stated that there was no objection in principle but that some members were likely to resign if women were admitted. However, it took another 14 years before the Council agreed unanimously to admit women, with the first being Miss Muriel Gray in November 1932, followed by Miss Elizabeth Stewart, Miss Anne Fyfe, Miss Hannan Watson and Dr Violet Roberton.

Financial Challenges

During the First World War, the membership total remained relatively stable although the annual accounts showed a modest deficit each year from 1915 onwards until 1925. The exception to this general pattern was 1920 when there were 208 new members and the accounts showed a small surplus.

In 1932 the membership was holding up at 968 but almost a quarter of these were life members and so did not pay the annual subscription. The cash situation was getting serious and there was a mounting bank overdraft. In 1938, the situation was eased by transferring the Exhibition Fund into the general funds, and £1500 was also transferred from the Graham Medal and Science Lecture Funds. The bond was repaid and the bank account was again in credit.

During the war years from 1939 to 1945, many members were on active service and by 1940, the overdraft had already reached £700. In 1945, the annual subscription was doubled to two guineas bringing an immediate cash benefit but at the cost of membership which fell steadily over the next few years: at the 150th anniversary in 1952, there were only 325 out of 500-odd members paying the subscription. The net assets were a little over £11,000 but this included the cost of the building at just under £8,000 and the cash prospects did not seem to be improving.

In the 1959–60 session, it was decided that it was no longer financially prudent to remain at 207 Bath St and in 1961, it was sold for £23,000. Thereafter, Society meetings were held at various places including both Glasgow and Strathclyde Universities, the Royal Colleges, Rankine House (183 Bath St) and the Mitchell Library. Since 1994–95, they have been held in Strathclyde University.

In 1981–82, the remainder of the Science Lecture Fund, amounting to £284 was transferred into the general funds and the accounts then showed a net assets value of £31,552. There had been a change in the investment policy and the net asset value had risen to £44,856 in the 1991–92 Accounts.

Early Records

When the Society was founded, the age of steam was just beginning and coal-gas and electricity had not yet come out of the laboratory. At that time Glasgow covered 1864 acres, all on the north of the river and the population was about 100,000 persons. It did not extend to the south of the river until the Gorbals was annexed in 1846.

There is no extant record of the details of most of the papers presented to the Society until the publication of *The Proceedings* from 1841. In the early minutes it is recorded that two books were to be kept, one for the minutes and one in which to write approved essays given by members. An essay book was purchased in February 1803 and the minute for 26th December 1804 states that the essay given on 19th December. by Dr Watt (later President of the Society 1808–09) on *Piped Water into the City* was to be engrossed into the Essay book. The minute books record the topics and their authors, and there are also Council minutes but there is no trace of the book for the essays. In the first 25 years, many of the matters raised were of observations from nature and practical suggestions to assist industry, rather than laboratory and experimental science.

Topics Presented

The first paper was given on 5th January 1803 by the vice president, John Roberton, on *The advantages to be derived from heating cotton works, drying houses etc. on an improved plan …* . Heat came up again in 1807 under *On heating buildings by steam*, and again in 1820 when in *On heating churches*, it was argued that it would be better to keep them heated throughout the week rather than intermittently. The second paper to be delivered in 1803 was on *Roofing*.

Water Supply

This was a recurring topic for the Society. In the 1801 census, there were 30 wells in Glasgow for a population of about 100,000. At that time, water came from the river and from a few wells and springs and was distributed about the streets by water carts. In 1806 a paper was presented which proposed the piping of water from the river into the city. In 1810, when the Glasgow Water Company was building a water-works at Dalmarnock, Dr Watt proposed that an extensive area of low flat land (a holm) on the south side of the river should be used as a natural filter. This was accepted by the water company and a pipe was carried across the river bed to the holm. In 1822, Thomas Hall, the manager of the water company, described his fuel-saving invention which heated water in an insulated boiler during the night. Concern about the water supply continued until the building of the Loch Katrine scheme which was advocated by members of the Society (Professor L. Gordon and Mr L. Hill) in 1845 and again in 1852 (Professor Macquorn Rankine and Mr J. Thomson). In December 1852 the Corporation appointed a civil engineer from London to advise on the best water supply for the city and some months later he advised that it should be Loch Katrine. Work began on the scheme in 1856 and there was an address to the Society that year on *The mode in which the water of Loch Katrine may be obtained of uniform temperature at all seasons.*

The Forth and Clyde Canal

The Forth and Clyde Canal had been opened in 1777 between Grangemouth on the Forth and Maryhill in Glasgow, and then to Bowling on the Clyde by 1790. It was of importance not only for the bringing of farm produce into the city but also for imports from Europe which entered the country via the port of Leith. In 1803, there was a paper on the saving of water from canal locks and in 1811, there was a description of a proposed construction for raising and lowering canal boats at changes of water levels. This was to be by means of a semi-circular watertight wooden frame which the boat entered, and the height was then changed by means of a lever and fulcrum system. In 1817, when the junction of the canal at Camelon with the Union Canal was projected, the Society received a communication and reports on the subject from Hugh Baird, who was the civil engineer in charge of the work. The joining up of the canal from Edinburgh was completed in 1822.

The River Clyde

As there were no railways in 1802, transport by water was important but at that time no ships of more than 100 tons could reach the Broomielaw. As a result, and because of the importance of imports of tobacco, cotton and sugar, the possibility of deepening the Clyde to allow larger vessels to reach the city came up repeatedly in Society presentations. In 1805, Thomas Telford had just been commissioned by the City Council to make proposals for deepening the river. These were discussed by the Society with suggestions being made for modifications. The following year, Mr. Fleming gave a lecture, with illustrations, *On the means of rendering the Clyde navigable for large vessels to Glasgow.* Amongst the schemes contemplated was the formation of a lock and dry dock at Govan, the building of a quay on the south side and widening the river at the Broomielaw. In 1807 Dr. Watt had proposed that a large basin be made on the Clyde where the water could rise and fall with the tide and floats on the water could be connected to a system of wheels and ratchets to provide power for cotton mills and similar industries. Tidal wheels which were attached to the old London Bridge gave a practical example of tidal power (although a 1948 lecture on this topics showed how impracticable the Clyde plan would have been).

Also in 1807 there was a talk on how the Molendinar burn could be made 'navigable for small and fishing craft' as far as St Andrew's Square but this was not acceptable. At this time, the memory of the severe flood of 1795, which had flooded the merchants' warehouses, could have been an adverse factor. Mr. K. Mathieson was one of the original members (no. 30) and was a builder of many prominent buildings and bridges in Glasgow as well as further afield. He gave an early talk on widening the Glasgow Bridge over the Clyde.

Heating and Lighting

The production of coal-gas was still in the laboratory stage when in 1805, Mr. Lumsden gave a practical demonstration of heating coal in a cast-iron retort to produce gas; this was collected under water and then passed through a jet and ignited. Professor Thomas Thomson, who became president in 1834, recalled that in 1808 when he was a medical student at Edinburgh he walked to Glasgow to see the Tontine Hotel being illuminated by gas. Oil lamps were used for most domestic lighting and in 1814 a talk, illustrated by models, was given *On how to get better lighting from the* *use of less oil.* In 1818, gas lighting was generally introduced into Glasgow, but condensation occurred on the surrounding glass bulbs and this was discussed at a meeting in 1821. Experiments with different shapes for the glass bulbs showed how the condensation could be reduced, but if the bulbs were overheated they might shatter in a shower of rain. Methods proposed for improving the illumination of the clock on the Tron steeple by means of reflectors were accepted by the City Council.

Electricity

In 1804, Mr Boaz gave a demonstration of his telegraph, which he had patented, and the members 'approved of the invention and of the ingenuity of Mr. Boaz'. In the following year, there was a practical demonstration of a galvanic apparatus and in 1822 there were various experiments with 'a powerful electric machine'. In 1845 'Mr Smith, late of Deanston' offered to write to Mr. Wheatstone 'to obtain an electrograph to be showed and explained', but the electric telegraph is not mentioned again until 1850. Electric light using a galvanic battery and a carbon arc was demonstrated in 1849 but the first local public demonstration of electric lighting was not until 1879 when six carbon arc lamps were installed in the newly built St Enoch's railway station. In 1881 there was a paper on *Electric and Photometric Tests of Swan's Incandescent Lamps*. The first electricity supply to the public was in 1884 and the subject came up-to-date in May 1888 when a member described how, in his country cottage, he had adapted an old windmill to charge batteries and run his electric light from them.

Printing

Another topic brought up in 1804, which helped to show the wide range of commercial interests of the members, was that of printing. At least two of the early members had print works. In 1805 there was a demonstration by a chemist, (and former engraver) Mr John Thomson, on bank notes and for this he used United States dollar notes to illustrate the use of different colours to make forgery more difficult. His advice had been sought by the Bank of England who subsequently made use of it, but only after it had been shown by the bank to a London printer who had then patented it. Another member showed a banker's cheque which had five lines printed on one side using an acid medium and on the other side, lines printed with an alkaline medium, thus making attempts at alteration more easily detected. In 1820 a member showed a much improved self-inking machine which he had developed. The following year Andrew Smith, a Mauchline maker of snuff boxes, demonstrated his instrument for tracing drawings onto them. In 1822 one of the topics was *Calico-printing and Turkey-red dying*. In 1823, lithographic prints were shown in which the ink had been made by the member from coal tar. Another development was shown in 1844 in which a printing machine produced the letters as raised dots to enable the blind to read.

Armaments

There was still a state of war with France when the Society was formed and the battles of Trafalgar and Waterloo had still to take place. In 1806, a member proposed a naval gun made with two conjoined parallel barrels and a common explosive chamber. The barrels were then to be loaded with two cannon balls joined together by a chain which was intended to catch in the rigging of an enemy ship. In 1808, Mr Roberton (who may have invented the lathe) demonstrated different riflings of gun barrels which he had made, and how by elongating a musket ball it would travel further and more accurately. This led to the development of the bullet.

Pollution

Other early topics included ventilation in coal mines, the reduction of smoke in factory chimneys, and the design of a tobacco pipe which would reduce the amount of fumes produced in the room. On the smoke pollution of the atmosphere, it was observed that this was just as bad on Sundays when the factories were closed because of domestic coal fires and because gas , which was less polluting, at that time cost ten times as much as coal.

Astronomy

Papers on astronomical topics had been few in the early years of the Society but with the building of a new observatory for Glasgow University at Horslethill (Dowanhill) in 1845, more interest began to be shown in astronomy. In fact, from the mid 1850s, there was a flood of papers from this field. In 1855, Professor Macquorn Rankine spoke on *The Azimuth of a Star* and the following year, there was a talk on *The Application of Photography to Meteorology*. In 1857, there was an evening on *The Gyroscope, the Precession of the Equinoxes and Saturn's Rings* and in that same year James Bryce gave the first of his lectures On the recent progress and present state of the sciences of meteorology and terrestrial magnetism. In 1859, Professor Thomas Thomson gave an account of *Recent Investigations on the Motion of Mercury by M. leVerrier*. (In 1860, M. leVerrier was one of the first Honorary Members to be elected). He also gave a talk *On the variation of the periodic times of the Earth and inferior planets, etc.* and *Sun Spots* was also a topic in 1860. In 1867 Professor Herschel was a regular speaker at the Society, addressing members in 1867, 1868, 1869 and 1871. Professor Grant's presidential address in 1871 was entitled *The Astronomy of the Nineteenth Century* and in 1874 Professor Forbes gave a lecture on *The Transit of Venus*. In 1876 Dr Muirhead spoke on *A Kinetic Theory of the Cosmos*, having spoken the previous year on *The Genesis of Atoms, Worlds and Sunspots*. In 1884 there was an address on the motion of the stars.

The Science Lecture in 1898 was given by Sir Robert Ball on *A Universe in Motion*. Such was the anticipated demand for places that the St Andrew's Hall was booked for the occasion and members of the public were also admitted for a small charge. Professor Archibald Barr, in his centenary address on 5th November 1902, recalled that the insignia of the Society commemorated a transit of the planet Mercury on the day when the Society was founded. An eclipse of the Sun was described in 1906 and, as 1909 was the tercentenary of the invention of the telescope, this was a topic that year. In 1910 there was a paper on comets, in 1930 the discovery of a new planet named Pluto was reported and in 1937 the Astronomer Royal spoke about the building of a 200-inch telescope, which would increase the amount of visible space eightfold. *The Stratosphere* was a topic in 1942 as was physical cosmology in 1948. In 1965, there was a paper on the origin of the constellations but the real excitement was the exploration of the moon in 1966. After this in 1968 there was a discussion on *Space*.

Geology and Botany

In the early years of the Society, geological interest was exemplified by the fossilised branch of a tree from the quarry at Sauchiehall and by fossil leaves from a coal-pit at Rutherglen. In 1814, a member showed several 'beautiful specimens' of dry rot from his house and amongst other early botanical demonstrations were specimens of fern leaves from Bute. At other meetings specimens of geological, or entomological interest from abroad were also exhibited. In 1917, Professor Bower stated 'The University of Glasgow can claim the distinction of having supplied, during the nineteenth century four professors of Botany to her sister University of Edinburgh, and to Kew the first two directors of the Royal Gardens'. The second of these professors was Sir William Hooker who went to Kew and his son Joseph was a member of the Society. Joseph sailed on the *Erebus* as surgeon and botanist on her voyage to the Antarctic and in 1842 gave the Library a copy of his *Notes on the Botany of the Antarctic Voyage*.

Mensuration

There were several presentations on weights and measures. A paper was presented in 1822 by Mr R.Wallace, editor of the *Glasgow Mechanics' Magazine*, which discussed the relative merits of duodecimal, decimal and binary systems and he concluded in favour of the last of these. Also that year, Mr Allan Clark 'exhibited his arithmetical machine making it perform addition, subtraction, multiplication and division. It consisted of 8 wheels, one for pence having 12 pins, or teeth, and one turn made a shilling. The second wheel had 20 pins, or teeth, so that one turn made a pound and there were 6 more wheels so that it could count up to £999,999 19/11'.

In a paper in 1910 on *The Proposed Compulsory Adoption of the Metric System in the U.K.*, Lord Kelvin is quoted as having a letter from James Watt from 1783 in which Watt advocates a decimal system, some seven years before it was adopted by France. In 1855 when the Ordnance Survey was producing a 6-inch-to-1-mile map of Glasgow, the Society petitioned the Lords of the Treasury to extend the survey to include parts of the counties of Lanark, Renfrew and Dunbarton.

Public Welfare

The condition of the poor in Glasgow was a matter of concern to many members and Dr Birkbeck, who was professor of Natural Philosophy and Chemistry at the Andersonian University, had been amongst the first to give lectures to a class of working men. However, when Robert Owen's scheme 'to ameliorate the condition of the poor' at New Lanark came up for discussion, it was decided that it would be impracticable. In 1826, there were several meetings on unemployment and benefit societies and there was much discussion on a scheme to resettle some of the unemployed in a coastal area where they could become self-supporting on fishing and agriculture. In 1840 'cheap and nutritious food' was advocated, whilst in 1886 Dr Glaister said 'vegetables when used should be thoroughly boiled'. In 1893 a minimum family 'living wage' of 24/- per week was proposed.

Transport

In 1818 and again in 1820, 'beautiful models' of Dr Stirling's patent hot air engine were exhibited and in 1829, it was proposed that heated steam should be used rather than hot air. High pressure and rotary steam engines were discussed as was steamboat machinery. Modifications to valves and pistons were suggested as well as the use of dried compressed peat as a fuel. In 1828, Mr Burstall and his son showed a quarter-scale model of their patented steam carriage which had a double boiler, one inside the other. A steam-boat was again suggested for the Forth and Clyde canal and this was to come into service in 1832 carrying goods from Port Dundas.

The railways began in Scotland with the opening in 1831 of the Glasgow to Garnkirk line. In 1838 there was great enthusiasm for a proposal made to the Society from America to show 'a locomotive engine on a railway with cars attached, propelled by electromagnetism'. However, it was felt that this was outwith the scope of the Society and it was declined.

The uses of the hydraulic pump were described in 1844. There were several lectures relative to ships and in 1862 John Napier spoke on *The Sections of Least Resistance for Ships ...* (which came up again in the Kelvin Lecture of 1972).

Physics and Chemistry

After the initial enthusiasm for the Society wore off, attendances at meetings dwindled, and a change of direction was necessary for the survival of the Society. Fortunately, this was achieved by developing from 1831 direct links with the Andersonian University, and by men of exceptional ability such as Thomas Thomson, Professor of Chemistry at Glasgow University who became President of the Society in 1834. At the same time Thomas Graham, Professor of Chemistry at Anderson's University became Vice-President of the Society. Graham subsequently became Professor of Chemistry at University College, London and some years later, one of his pupils was Joseph Lister who became Professor of Surgery at Glasgow. The development of Sections in 1840 (see page 42) did much to stimulate interest and the publication of *The Proceedings* from 1841 gave a much more informative account of the progress of the Society.

Natural philosophy was becoming more scientific and technical, and more dependent on experimental evidence and less on speculation. In 1823 there had been a talk on the atomic theory of gases and in January 1825, Mr Archibald Burns gave an address in which he said, 'matter composed as it is of original molecules, or atoms, can be divided the same as the roe of a fish to the last pellet and is no longer divisible without destroying their nature or consistence'. In 1834 Professor Thomas Graham gave an innovative lecture on *The Modern Doctrine of Isomerism* and demonstrated this using different crystalline forms of the same substance. Some of the other topics discussed at this time were the distillation of wood, and weather forecasting. In 1838 Mr Griffin exhibited cheap chemical apparatus adapted to promote the introduction of the teaching of chemistry into schools. In 1840 the President gave an essay on *Acetone, Chlorine and Caffeine*. In 1868 in On a new plastic material, the speaker described a plastic material he had made by compressing under heat a mixture of sawdust and rubber. Plastics came up again in 1945 in *The Future of Synthetic Plastics*.

In 1878 a fund had been established to honour Thomas Graham by the award of a medal and the giving of a Science Lecture. The first Science Lecture was given the following year by W. C. Roberts on the subject of molecular mobility.

Public Health

From its beginning, medical members had been active in the Society and public health was a general concern, especially because of epidemics such as typhus, typhoid and cholera. The general vaccination of children for smallpox had only recently started under the Faculty of Physicians and Surgeons at their premises in St Enoch's Square when the Society met there in 1806. The prevention of disease by getting a cleaner water supply and by trying to improve ventilation have already been mentioned and in 1834, a member demonstrated his apparatus for fumigating clothing by steam.

Sewage

In early 19th-century Glasgow, sewage was carted to open fields and then used as manure while liquid waste soaked into the ground or was carried by open drains into the river. Between 1842 and 1844, experiments were described using different manures for different crops. In 1885 a prominent member, Professor Ebenezer Duncan, gave a paper on *Manure Poisoning* which showed how recurring outbreaks of fever at a farm was related to the years when it used Glasgow manure and not farmyard manure.

After the Loch Katrine scheme provided piped water to the city from 1869, the City Council had passed a bylaw requiring the owners of tenements to provide water-closets, but this made matters worse by blocking such drains as there were. In 1868 there was a paper on the purification of sewage water by ammonia 'so as to sustain fish'. In 1869, the Sewage Society amalgamated with the Society and the following year, there was an essay by E.C.C. Stanford, a future recipient of the Graham Medal, on the action of house sewage on lead pipes which showed that this could produce a poisonous gas. In 1872, there was an essay on *The Drainage and Sewerage of Towns* and the next year there was one on *The Removal of Sewage*. In 1875, Dr William Wallace spoke on *The Germ Theory of Putrefaction*. Dr. Russell, the Medical Officer and a future President of the Society, said in an address on *Air and Water*, 'those who have visited the Glasgow Fair on a hot, calm July day or evening will have a vivid recollection of the abominable effluvium ... and that it was worse indoors'. This was followed in 1879 by the architect James Buchan on *House Drainage and Ventilation* and also by James Sellars in his Presidential address to that Section in 1882. He quoted Dr Russell when he said that

> on some 4700 acres are congregated some 566,000 human beings, with thousands of the lower animals ...

> Three-fourths of the population live in a house of one or two apartments ... so arranged as to exclude the sunlight, ... and a large proportion are hollow squares of stagnant air, ... and inside these are ash-pits and privies. It means that the mass of our excretions is so enormous, in relation to the earth and air space, that to get them removed from our house and precincts water carriage must be employed, and therefore our rivers and streams are loaded with the foulest refuse ... .

In 1878 there had been a paper on *Purifying Glasgow Harbour* and the next year another on the purification of water. In 1880 there was a paper which proposed three sewage purifying plants, which would be able to deal with the needs of half of the population. It was not until 1894 that the first sewage purification works was built at Dalmarnock and a similar plant was built at Dalmuir in 1904.

Cremation

The increasing population, which had exceeded 500,000 by 1880, and the increase in the death rate in Glasgow meant that the cemeteries were rapidly filling up. In 1887, Professor Duncan presented a paper on the relative merits of burial and cremation and two years later, the architect James Chalmers said that, 'If the western brow of the necropolis, or the site behind the Ramshorn Church (Ingram St) could be obtained, a crematorium of this character (described) would be one of the places of interest in Glasgow'. The Western necropolis had been opened in 1882 and the first crematorium was opened there in 1895.

Fires and Explosions

One of the early members was the city firemaster and the subject of fires was discussed from time to time. A kind of fire-escape consisting of a ladder with pulley and bucket attached to be placed against the wall was proposed in 1830. The danger of inflammable clothing was emphasised in an address shortly after several children wearing crinoline dresses had died in a fire. In 1841, there was a paper on *Fires in Factories* and the design of buildings to include consideration of fire danger was stressed by the president of the Architectural Section in his address in 1883. In 1898, the City Medical Officer, Dr Russell, in an analysis of the causes of accidental deaths, gave building fires as the most frequent cause.

Explosions of boilers was an early theme in the developing steam age and the increasing industrial use of gas in furnaces with the need for the prevention of explosions was also brought to the attention of members. Ventilation in coal mines was discussed in 1816 and a safety lamp was described; this was just when Sir Humphrey Davy invented his lamp. The average numbers of deaths of coal miners from 'firedamp' had halved from 1 in 219 in 1851 to 1 in 425 when a Royal Commission on accidents in mines reported in 1881, but this still caused great concern. In 1886 Joseph Swan described an electrical safety lamp which he had invented for use in mines, and he felt it would not be too expensive for the mine owners to introduce.

Safety on Railways and at Sea

Safety in the development of railways and the prevention of disasters such as when trains collided, or brakes failed, led to many papers. The first brakes had been mechanical ones on each carriage and various modifications were proposed. In 1848 a self-acting brake was described and in 1875 a paper was given on compressed air brakes and a vacuum brake was recommended. At this time there was a Royal Commission on railway accidents and the Society petitioned the Queen 'to instruct the Commission to inquire into Continuous Brakes ... and to recommend that they be applied to the whole railway system of the United Kingdom'. It was not until 1904 that there was a paper and discussion on electric signalling on railways.

A paper in 1850 described the electric telegraph and in 1858 the President, Professor. William Thomson, gave a paper about *The Atlantic Telegraph* and his invention of submarine conductors for the cable. However, mechanical methods of 'on the spot' signals were still needed at sea and on land when in 1886 George Buchanan gave his paper on *A New Signal for River Piers and Railways* which proposed a mechanical arm the position of which indicated 'stop' or 'go'. Other suggestions for safety of vessels were a masthead light and signs at the entrance of harbours to indicate the depth of the water.

Gas and Electricity

In 1880 the Society held a large 'Exhibition of Apparatus for the Utilization of Gas, Electricity, &c.,' in the Burnbank Drill Hall and Grounds in Great Western Road. It was planned to last for four weeks but such was the demand that this was extended for another week. There were 84 exhibitors and almost 40,000 visitors were recorded. Although there was a financial loss of £675/10/-, which was met out of the 1846 Exhibition Fund, it was felt that it had been an overall success as the amount of business generated in the city was likely to be considerable.

There had been trials of low temperatures for the preservation of food and in 1883 the installation of electrical refrigeration in a Clyde ship, so that food could be imported, was described for the first time. This was recalled in the 1965 Kelvin Lecture. It was not until 1881 when Swan's Incandescent Lamps were shown to the Society that practical electric domestic lighting became a possibility, and in 1894 an address was given on using an electric dynamo for lighting a house. In 1897, a paper on the various methods of propulsion for tramcars came down decisively in favour of the electric dynamo. *Hydro-Electric Development in Scotland* was the subject of a lecture in 1946 and nuclear electric power in 1949.

Radioactivity and the Atom

Electric discharges in rarefied media was the subject of a talk in 1860 and there were addresses on electric sparks in gaseous mixtures with explosive results, and also on inert gases. The latter led on to mercury vapour and neon lamps as well as to the discovery of X-rays. Roentgen discovered X-rays in November 1895 and he sent a copy of his paper to Lord Kelvin who passed it on to Dr John Macintyre in Glasgow. On 5th February 1896, Dr Macintyre and J. T. Bottomley addressed the Society on *The New Photography* and showed the shadows made by X-rays produced with vacuum tubes. One month later, Dr Macintyre opened the world's first X-ray department in the Glasgow Royal Infirmary. Ultra-violet light and the discharges from uranium were demonstrated in 1897.

The century was ending having sown the seeds of vast scientific advances, with the knowledge and development of subatomic particles and energy probably of the greatest significance. In 1903, there was a centenary lecture on *The Electromagnetic Theory of Light* as well as one on *Experiments on Radioactivity* showing some of the effects of electrons. In 1907, Lord Blythswood spoke on his research with X-rays while two years later, the Graham Lecture was on the properties of uranium and radium. In 1913 the address was about the constituents of matter and in 1919, there was a paper on the *Liberation of Electrons by Light*.

Einstein's theory of relativity was the subject of an address in 1921 and the quantum theory was discussed in 1925 in *On the Atom and Radiation*. The Science lecture in 1933 was to be by Lord Rutherford and because of the occasion the question of renting the St Andrew's Hall and admitting the public was discussed but it was decided to restrict it to the Society and its guests and to hold it in its own premises. The subject was an illustrated lantern lecture on *The Transmutation of the Elements* and the overflow had to stand in the corridors. (Einstein and Rutherford were both elected Honorary Members in 1926.) In 1940, there was a paper on recent advances in atomic physics, in 1946 there was one on *The Release of Atomic Energy* which discussed fission and fusion while in 1964 a paper was presented on the atomic bomb. In 1949, Professor Gunn spoke on *Fundamental Particles* and this was followed up in 1951 by *On the Glasgow Synchrotron*. Professor Higgs, who gave the Kelvin lecture in 1999, brought matters right up to date with *The Search for Fundamental Particles*.

Education

The Society had from its early days shown an awareness of civic responsibilities, one of which was education. In 1879, there had been a paper *On the Present Position of Scientific and Technical Education in Germany* and in 1884 there was a plea for the teaching of Higher Chemistry in Scotland. In 1901 there was a paper on the training of teachers in Scotland and in 1904, on *A Theory of Education*. There had also been occasional papers such as on the teaching of deaf-blind children and in 1905, *On the Examination of the Eyesight of over 3,000 Glasgow Schoolchildren*.

In 1906, there was a paper on 'social derelicts', and the following year, the Factory Surgeon deplored the wastage of skills when boys left school aged 14 but could not begin an apprenticeship until they were 16-years-old. Training schemes up to age 17 were advocated and the problem of juvenile employment came up again in 1910 when training in 'commerce' was proposed. There was a related plea in 1913 for university training for commerce and administration.

At the end of the war in 1918, Professor Graham Kerr spoke on *Science and Education*, but it took until the next war for the universities to be invited to emphasise the importance of education in science. In 1940, Sir Hector Hetherington spoke on this and in 1947, there was a resumé of education in the last 100 years. The importance of the post-war universities came up again in 1951 and again in 1964 when the teaching of science was emphasised. There were papers on the teaching of science in other universities in Europe and in the USA and in 1968, the subject was *The University of the Air* (later to become The Open University). The Christmas Lectures for Young People were started in 1930 and continued regularly until 1964.

Moral Philosophy

In addition to the predominance of science as a topic in education, there was an increasing interest in economics and moral philosophy including theism and religions. When the Glasgow University Adam Smith Chair had been founded in 1897, the Society had shown a special interest and had sent a letter to Andrew Stewart, its founder, to place on record 'their appreciation of his philanthropic, wise and patriotic action'. Smith was the topic in 1923 and 1993, Hume in 1950, 1974 and 1994, Nietzsche in 1952 and 1970, Jung in 1967, Sartre in 1970, Hegel in 1974 and Schopenhauer in 1977. In 1965, the Society sponsored a project to give philosophy lectures to schools and colleges of further education, and in 2001 the Society initiated prizes to the best pupils in the school certificate philosophy examinations.

Sociology

The legal framework of society was another recurring theme. In 1899 there had been a talk on punishment and in 1906, there was one on *The Social Reformation of Criminals.* In 1907, there was *Punishment and the Prevention of Crime* and the next year there was a paper on the causes of crime. In 1910, there was a talk on 'inebriates' and in 1911, the legal framework came up under *Lunacy.* In 1916, there was *Ethics of Advocacy*, in 1924 there was *Unemployment* and in 1925, *Citizenship.* In 1931 *Criminal Punishment Past and Present* started from old biblical times and was followed by a paper on the difference between *God's Law and Man's Law.* This led on to *Law and the Citizen* in 1936. Science and crime detection came in 1944, the history of Scots law in 1945 and sheriff courts in 1947. In 1950, women's prisons was a topic. The Kilbrandon Report on Law Reform was discussed in 1968 as well as censorship. In 1976, children's rights and in 1977, children's hearings were addressed.

Modern Medicine

In its first 100 years, the health of the community had been a frequent topic with special reference to infections and epidemics, which could be related to a bad water supply, poor sanitation and overcrowding. Improvements were advocated for these conditions. The importance of mass vaccination and of antisepsis had also been established but in the 20th century medical science became more concerned with the individual. The production of better scientific instruments helped in both diagnosis and treatment. Developments in chemistry and biochemistry resulted in purified chemical products in place of crude botanical extracts and then therapeutics became a reality. The subjects of lectures started to reflect this progress. In 1923 there was an address on diet and vitamins, some of which were known to be necessary for health, but none had by then been identified. Similarly in 1936, the subject was viruses which were known to be so small as to pass through filters which would stop bacteria but could not be seen by the ordinary microscope. The electron microscope was described to the Society in 1941 and this contributed greatly to the study of viruses and to the subjects of genetics and of the changes to the cell in cancer. Cancer research was a topic in 1942 and there was *Genetics Today* in 1945 and *Cell Structure* in 1950.

Another topic addressed in 1945 was therapeutics which was developing rapidly with the recent discovery of penicillin, and there was a lecture on antibiotics in 1950. The Kelvin Lecture by Sir James Black in 2002 gave an overview of the developments in therapeutics with which he had been involved in the preceding half century and for which he had been awarded a Nobel prize. The 1939–45 war had led to a great increase in the need for blood transfusion and there was a talk on this in 1940 and on blood groups in 1945. The lecture on Joseph Lister in 1965 was a reminder of the progress which had taken place not only in surgery but also in anaesthetics. The first successful heart transplant had just been performed in 1970 when there was a talk on transplantation by Paul Bacsich who had spent some years in research on the prevention of organ rejection using corneal grafts.

Communications

Transport was another sphere which had made rapid progress in the 20th century. There was a railway network over the country but there was no adequate system of trunk roads and the demand for motor transport was increasing. In 1924 road transport was a topic and roads-versus-rail transport was discussed. In 1925, there was a paper on railway electrification and in 1932 on *The Economic Aspects of British Railway Transport*. The motor car had come of age when in 1926 there was a talk on the *History and Evolution of the Motor-car*. Air travel was an early interest for in 1904 there was an address on *The Stability of Flying Machines* while in 1919, there was a talk on modern aircraft developments. In 1931, Handley Page addressed the Society on *Lift and Stability in Aircraft Design* and in 1934 the inventor of the autogyro, de la Cierva, spoke on rotary wing aircraft. In 1951, there was a lecture on aeronautical research. *Science and Telecommunications* was one of the topics in 1949 and the global significance of the developments from this culminated in an address on *The Death of Distance* in the year 2000.

The Fine Arts

Apart from the professional and academic members, most of the early members were involved in industry and commerce and the fine arts only occasionally entertained them. On 24th December 1821, Mr Henderson exhibited 24 very fine Chinese coloured drawings, then Mr .Buchanan exhibited an ivory box 'beautifully turned', which had belonged to Graham of Gartmore. In 1822 in an essay on architecture, Mr Watt said, 'this City is much deficient in all that belongs to the intellectual sciences particularly those connected with the Fine Arts' and he went on to praise the government for the purchase and free exhibition of the Elgin and other marbles. One of the first members was John Geddes (no.68) of the Verreville Glass Works and there was a thriving pottery industry in Glasgow at that time. In 1829, there was a talk on the stained glass windows of York Minster and in 1840 on *The Art of Pottery*, and on the Caledonian Pottery in Delftfield Lane.

In 1870 Architecture was recognised as a separate Section and in 1887, Francis Newbery, the head of the Glasgow School of Art, spoke on the training of architectural students. History and Literacy became a separate Section and the Sections provided many talks such as *Standing Stones* and *Greek Thomson* (both in 1888). In 1865, it had been agreed that there could be occasional lectures on fine art. Music was the theme in 1871, when Herschel read the paper by his friend Helmholtz, on the vibrations of violin strings. In 1888, Thomas Machell demonstrated his new invention, the dulcitone, which he had based on tuning forks. In 1894, there was a paper on Italian art and in 1900 on the art of Florence. In 1918, there was a paper on *The Language of Poetry* and in 1927, the subject was *Mediaeval Music in Scotland.*

The Section on Fine Art and Architecture was formed in 1938 when James Bridie gave the address with a plea for the development of a national theatre. In 1941, a topic was *The Glasgow School of Painting*. In 1946, there was *The Orchestra*, in 1947, *Portrait Painting* and in 1949 *Drama*. In 1972, there was a lecture on the restoration of works of art and the annual Arts Lecture started in 1978 with Roger Billcliffe speaking on *The Furniture Designs of Charles Rennie Mackintosh*.

Variety of Interests

Members were encouraged to bring and exhibit 'natural or artificial Curiosities, Antiques, Models etc.' In 1821, Mr Ian Duncan brought an oil painting on wood supposed to be of Queen Mary 'which had been found when removing rubbish when building the cavalry barracks at Stirling Castle'. It was said to be well done and in a good state of preservation. Sometimes articles from the latest journals were read, such as Livingstone's travels in Africa or Captain Peary's journey towards the North Pole. Members produced meteorites and curiosities from South America. There was a description of a mammoth's skeleton from Philadelphia and in 1826, members were told of a village near Lake Erie which was lit by gas escaping from a crevice in the ground. In 1828, there was an address on the eruption of Vesuvius while in 1848, Dr R. D. Thomson gave an account of his expedition into Thibet which detailed his successful attempt to reach the Karakoram pass.

The Library

When the Society started in 1802, the only public library in Glasgow was that founded by Walter Stirling on his death in 1791. He left a bequest of £1,000, his house and a collection of 804 books to found a reference library with free access to the public. The finance to continue this was totally inadequate and the great need for a scientific library in the city was emphasised at the initial meeting to form the Society.

In furtherance of this, John Roberton, the vice president, purchased 71 arts and science journals while on a trip to London in 1803 and followed this with another consignment in 1804. By 1811 journals taken by the Society included *The Philosophical Journal, Retrospect* and *The Repertory* (or to give it its full title: *The Repertory of Arts and Manufactures consisting of Original Communications and Specifications of Patent Inventions and a Selection of Useful Practical Papers from the Philosophical Societies of All Nations etc., etc.).* In 1831, when shortage of money led to a reduction in the purchase of books, the only one to be continued was *Repertory*. Many of the members were engaged in the developing industries and were involved in inventing new machinery and improvements to processes and parts of machines. They looked to patenting those with financial prospects and hence the need for *Repertory* and up-to-date scientific journals. That this was a continuing interest is shown in 1875 when a proposed new act 'relating to Letters Patent for Inventions' was under discussion in Parliament. The Society petitioned the House of Commons to reject it as they felt the existing legislation was better and in the following year, when the Patent Acts Amendment Bill was being discussed, they submitted 19 detailed amendments.

In 1812 the Regulations provided for a Librarian to be an additional member of Council, ex officio, and William Duncan became the first librarian. That same year it was decided by a majority to purchase *Rees Cyclopaedia* as each volume came out, in preference to the *Encyclopaedia Britannica*, though the latter was added later. It is interesting to note that Thomas Thomson who became president in 1834 had succeeded his brother as editor of the *Encyclopaedia Britannica* in 1796. Thomson's *Philosophical Annals* was added in 1814. Each year, additions were made to the Library as funds allowed. The catalogue of 1829 had 300 volumes of which 69 volumes were a complete set of *Repertory* from 1794 and another 68 volumes were of the *Philosophical Magazine* from 1798. 'General Works' included *Brewster's Dictionary* and *Hedderwick's Reference Book*.

In 1831, when the Society made the arrangement with the Andersonian University, all of its library was taken into the Andersonian library. It is likely that many of them would be included in the 500 books and other journals bought by the Society from the Andersonian library in 1840 for £45. By 1845 the total number of books was 750 miscellaneous volumes and 550 journals.

In 1853, the total had risen to over 2,000 volumes. This included over 260 journals from 110 other learned societies with which journals were exchanged, many in Europe, the USA, Canada, Australia and India. By 1869 the total was 4,831 volumes and the Library was insured for £2,000. In December of that year, when the Architectural Society amalgamated, their books were added to the Library. In 1871 the Society complied with a request from the University of Strasburg for a replacement set of the Society's *Proceedings* as their library had been destroyed by fire 'in the recent siege'. In 1873 the Astronomer Royal presented a set of the Royal Observatory's publications to the Library, some 114 in total.

When the new building in Bath St was completed in 1880, there was a separate room for the library. By 1903 the insurance value of the books had risen to £4,900 plus £500 for the books which had been handed over by the Architectural Society when it amalgamated with the Society. In 1947–48, some books were sold for £750.

In 1961, when the building was sold, temporary accommodation for the library books was found in the Mitchell Library and in the Royal Technical College (the Andersonian Library). The books were sold in 1968–69 and the Andersonian Library paid £300 for a selection, with the rest going for sale by Thin's in Edinburgh (£500) and Sotheby's, London (£4,564).

The Proceedings and Journal

The Proceedings, which since publication in 1841 had been sent to every member of the Society and to many kindred societies, was discontinued in 1952 because of the cost. A new *Philosophical Journal* was published from 1964 and Dr John Lenihan who was Honorary Secretary from 1965 to 1975 had much to do with the success of this. In recognition of his contribution to the Society, he was elected Honorary Vice President. With mounting editorial problems and the difficulty of getting transcripts of the papers presented the *Journal* was discontinued in 1977.

The Sections

The Sections, which began in 1840, contributed very significantly to the success of the Society. Initially, there were four: Chemistry, Engineering, Physics and Natural History. Each Section had a leader and its own executive. As well as their own meetings, as the *Proceedings* show, their members frequently gave addresses to full meetings of the Society. Sections multiplied as interests developed, until in 1857 the 16 rather loose Sections were reduced to seven, covering Astronomy and Mathematics; the Mechanical Applications of the Principles of Physics; Engineering and Practical Mechanics; Theoretical and Applied Chemistry; Mineralogy, Metallurgy, Geology and Geography; Meteorology;

Zoology, Botany, Agriculture, Anatomy and Physiology; Economical, Educational and Social Statistics . In 1869, a Sanitary section was included with Statistics when their association amalgamated with the Society. In the same way in 1869 Architecture came in as a Section, to be followed by Archaeology. In 1873, Engineering and Shipbuilding was also formed into a separate Section. The Microscopical Society joined in 1899 to represent still another interest.

As interests changed and as national societies developed the only Sections still active by 1914 were Architectural; Geographical; Sanitary and Social Economy; Historical and Philological; and Mathematical and Physical. By the time the war was over in 1918, only the Historical and Philological had survived and Economic Science soon started again. The Biology Section was revived in 1922 and the Geography in 1929, but the latter was discontinued three years later, when it was also decided not to revive Architecture. In 1938, a Fine Art and Architecture Section was formed and the History Section was still meeting. The end came after 100 years when in 1940 all Sections were discontinued.

Honorary Membership

Provision for Honorary and Corresponding Membership is included in the first Regulations of 1802 and repeated in the first printed constitution in 1812. Persons nominated for Honorary Membership had to be of outstanding merit or to have given eminent service to the Society. This seems to have been awarded to local personages, or to deserving members when they moved away from Glasgow. Such were James Hunter (1818) when he moved to a chair in Edinburgh University, James Clelland (1822), the City 'Statist', who presented several volumes of his *Annals of Glasgow* to the Society, Sir John Sinclair (1822) having presented the Society's loyal address to George IV that year, was also made an Honorary Member. In 1829, Honorary and Corresponding Members totalled 13 which had risen to 47 by 1831.

In 1859 the Council agreed that Honorary Membership should also be awarded to 'distinguished men of science belonging to any part of the world' and the total number of these was not to exceed 20 at any one time. In 1860, 16 persons were elected under the new provisions as Honorary Members. There were six from the UK, three resided in Paris, three in the USA and one in each of Bavaria, Heidelberg, Leipzig and Wurzburg. The last person to be elected in this capacity was Professor F. O. Bower from Yorkshire in 1931. Between these years there were eminent people from all over the world: France, Germany, Russia, Australia, the USA, Canada, South Africa and India as well as from the UK. Of these the last survivor was Sir Chandrasekharan Raman who died in 1970. In 1965, the Principals of Glasgow and Strathclyde Universities were elected Honorary Members.

Corresponding members had to be resident outwith Glasgow. Existing members could be elected to this when they moved away, but it was also open to persons resident abroad. When Mr. Roberton returned from London in 1803 he proposed that Alex Tillich, the editor of the *Philosophical Magazine* be made a member, and this was agreed. He is shown as Member no.67. Alexander Johnston, a civil engineer was also elected when he moved to Dublin, and Andrew Smith from Mauchline was a Corresponding member. Overall the numbers were small and only four are recorded in 1874. One of these was A.S. Herschel on his departure to Newcastle.

Moving with the Times

In 1930, Dr James Knight, the Honorary Librarian of the Society, pointed out in a book on Glasgow and Strathclyde, that the prosperity of Glasgow had depended on the nearby coalfields and the Clyde. He wrote that '... the material advantages of the Clyde are long past, or are passing rapidly ...', and stressed that the future would depend more and more on non-material assets, including the character of the inhabitants. The Second World

War only delayed the decline in the heavy industries and the Society's activities reflected the changes. Service industries were represented more often in the programmes but the Graham Lectures on chemistry, which had started in 1879, and the Kelvin Lectures in physical sciences (from 1959–60) continued. Astronomy or another science such as botany, geology or geography was usually included. There were more social and ethical subjects and in addition to the 'Arts' lecture there was often another 'artistic' topic or a visit to a local centre of interest. Having reached its bicentenary, the Society has become an important part of the cultural life of the city with an annual syllabus of addresses by eminent speakers. However, the original concern for 'the prosperity of the Trades and Manufactures' is no longer evident but the 'Arts and Sciences' are still well represented.

Economic development in Glasgow 1802–2002

W. Hamish Fraser

The ending of the French Revolutionary War in the summer of 1802 was not necessarily widely welcomed by Glasgow merchants as the war had proved to be profitable for many. However, conflict was soon resumed, government orders were to be got, prices were good and there were huge profits to be made with a bit of risk-taking. Scottish goods still found their way, by devious means, into Napoleon's Empire. With the British Navy in control of the seas after Trafalgar, trade with the West Indies also expanded rapidly. Sugar came in to the refineries in Greenock and Glasgow, cotton and linen textiles went out, as did a range of other manufactured goods made in a growing number of small workshops around the rapidly expanding city.

Merchant City and Cotton Town

Cotton had arrived in the 1760s with technological developments allowing factory production in spinning thread. The spinning mills were near the water supplies at places like New Lanark and Catrine. Weaving was carried out by the 30,000 or so handloom workers scattered throughout the city and region. The coming of steam power allowed spinning mills to develop in Glasgow itself where labour was more easily and more cheaply obtained than in the villages. But steam power was less easily applied to the fine weaving in which Glasgow specialised and so, although the power-loom was steadily making inroads, the demand for good hand-loom weavers remained high into the 1820s. The textile industry also required a multitude of support industries. Shuttle-makers and pirn-makers proliferated in the streets and alleys off the High Street. There was calico printing at Thornliebank, dyeing at Barrowfield and in the Vale of Leven, and soap- and bleach manufacturing at St Rollox.

The years immediately following the end of the Napoleonic wars with France in 1815 were difficult ones, with high costs and tens of thousands of demobilised soldiers seeking work. Unemployment, distress and discontent were widespread with threats of revolution around, but the city continued to grow and new textile firms continued to emerge. Yet even as growth was continuing, there were signs that Lancashire was beginning to pull ahead of Scotland as the main cotton textile region: markets there were larger, port facilities better, and machine-building skills more available. The decision of Henry Houldsworth of Anderston to switch from textiles to the iron industry and machine-making in 1837 is often taken as significant turning point, while the bitter industrial unrest at that time is a sign of a malaise in the industry created by over-expansion. Nevertheless, textiles were to retain great importance in the west of Scotland well into the 20th century, with the number working in the industry continuing to rise to over 40,000, until the 1860s. The decline was a slow one and J. & P. Coats and J. & J. Clark of Paisley were for long able to dominate the world market in thread.

The Engineering City

Domestic more than manufacturing needs had stimulated a demand for coal and the desire for access to the Lanarkshire fields had led to the construction of the Monklands Canal in the 1780s and the early development of railway networks. An iron industry had been slow to develop because of low-quality iron-ore and poor-quality coking coal. However, the invention of the hot-blast process in 1828 allowed the rich blackband iron ore of Lanarkshire to be utilised and Glasgow money rapidly found its way into the expanding industrial heartland of Lanarkshire. The really significant thing about the hotblast and other subsequent technological developments was the dramatic reduction in costs which it brought. Cheaper iron stimulated new industries and had implications for everyone. Machines could be built more cheaply, iron-frame buildings could be erected, and wrought-iron decoration could replace the expensive intricacies of wood carving.

Foundries spread, producing the extensive range of pipes, fittings, axles, nuts and bolts needed for machines. By the mid-19th century, Glasgow was well-placed to become the workshop of an expanding empire, providing the heavy machinery that was to speed industrialisation in other parts of the world. Firms like Arrol & Co. at Dalmarnock produced the piers for Brighton and Blackpool and the bridges across the Thames, the Forth and the Tay. Locomotive manufacture began to develop in Springburn and Polmadie. Macfarlane's Saracen works produced the ornamental cast-iron fittings for balconies, fireplaces, conservatories. The manufacture of pumps and steam-engines also added to Glasgow's reputation as a major engineering centre.

Shipbuilding

It was application of steam engines to ships which turned the Clyde from a minor to a major shipbuilding area. After all, a narrow, comparatively shallow river is not the most obvious place to build ships. In 1812, Henry Bell's Comet – designed to transport guests to his hotel in Helensburgh – was powered by an engine made in John Robertson's engineering works in Dempster Street and with a boiler from Robert Napier's Camlachie foundry. It was the Napier family which more than any saw the new opportunities. In 1821, David Napier set up a combined engineering and shipbuilding yard and began building sea-going steamers to ply to Belfast and Liverpool and, from the 1840s, across the Atlantic with Cunard. It was men trained in the Napier yards who led the expansion over the next 30 years. James and George Thomson set up a yard at Mavisbank in 1847 before moving to Clydebank in four years later. Charles Randolph and John Elder founded the Fairfields yard at Govan and were succeeded by another Napier product, William Pearce. Between the 1850s and the early 1870s, the Clyde launched two-thirds of British steamship tonnage.

New engine development, much of it on Clydeside, culminated in the application of the screw propeller, the introduction of the compound marine steam engine and the use of Howden's Scotch boiler. These developments did two things: it made a switch to iron-built ships essential, since the speed and vibration of the screw would shake apart wooden-hulled vessels, and it brought dramatic reductions in use of energy. The Clyde had easy access to the necessary iron and by the early 1850s, iron hulls were cheaper to build than wooden ones. Cheap shipping encouraged more trade which in turn increased demand for more goods and for yet more ships. By the 1870, 24,000 people were employed on shipbuilding on the Clyde, more than half the total number in the whole of Britain. Such a figure took no account of the hundreds of contractors employed in producing the elaborate cabin and stateroom fittings in the ever larger liners plying the oceans.

Signs and Omens

At one level, there is no doubt that the story is one of great success. The west of Scotland had shown itself to have enterprise and skills. New opportunities had been seized and new directions taken. There was a good supply of labour augmented by Highland and Irish migration. However, there were also worrying signs. The financial system, concentrated in Edinburgh and London, showed itself less than sympathetic to the needs of industry. Many firms were vulnerable to downturns in the economy and the failure rate was high. Many remained relatively small, dependent upon family money or on bank loans as credit for manufacturing was relatively expensive. A further potential weakness derived from the fact that markets were often narrow and quite specialised. Glasgow firms prided themselves in being able to produce one-off items exactly to the customer's specifications but sadly, such commendable pride in craft did not always make the most economic sense.

Yet there were also some competitive advantages in the area: raw materials were accessible, business networks were well-established, labour was relatively cheap, trade-union organisation was poor,and people seemed willing to tolerate poor housing and working conditions. Such conditions perhaps encouraged a complacency, and certainly a conservatism amongst Glasgow's business community but the economic climate was about to change and the response of many firms was slow and ultra-cautious.

The extraordinary boom years of the early 1870s had given a boost to trade unionism and the gap between Glasgow wages and those of the other parts of industrial Britain narrowed. Moreover, by the 1870s raw materials were running out, with the rich black-band seams close to exhaustion and ore having to be imported. Scottish pig-iron production also peaked in 1870 as Cleveland and South Wales proved more efficient, more modern and less costly. Markets were also closing as mainland Europe and America set about protecting their own nascent industries with high tariffs. Yet in spite of such developments, there was a tardiness in moving into steel production. Only the Steel Company of Scotland at Hallside, near Cambuslang was in existence by the end of the 1870s and even this was on the initiative of the Tennant family and of engineers like William Arrol and Henry Dubs, rather than on that of the iron masters. Growth did come in the 1880s and for a brief period, Scottish steel dominated. However, none of the steel plants was integrated with pig-iron producers, leading to higher costs and lower efficiency than in England and it soon became cheaper to build ships with Cleveland and even German steel plate than that of Lanarkshire.

Throughout this period, shipbuilding retained its dominance. A third of new British shipping tonnage came from the Clyde slipways: a quarter of a million tons each year in the 1870s to over three quarters of a million tons in the peak year of 1913, with some 55,000 workers employed in the industry. Iron eventually gave way to steel in ship construction after 1879 when William Denny in Dumbarton launched the *Rotomahana*. J & G. Thomson also started on a run of famous Cunarders at Clydebank.

Yet here too there were signs of changing times. The new technology of steam turbine and diesel engines which were to revolutionise marine engineering was not coming from Clydeside firms and a failure to develop an expertise in diesel was eventually to prove crippling. In a fiercely competitive environment, what were, in many cases, relatively small firms were battling for orders. Prices were cut to the bone just as shipowners were laying down tighter specifications and many ships were built at a loss. In other cases, there was an excessive reliance on admiralty orders. At the same time, the very dominance of shipbuilding meant that other, often huge, parts of the regional economy were dependent on its fate and demand for ships was always volatile.

But so much of this was largely hidden from view. A look at the buildings of Glasgow erected in the 30 years before 1914 shows the prosperity, the confidence, the pride in itself which the city exuded, despite myriad social problems. There were new entrepreneurs around taking advantage of the opportunities created by rising living standards and cheap imports. Thomas Lipton, for example, expanded his business from a single shop in Stobcross St in 1871 to become the acknowledged 'King of the Dairy Provision Trades' by the end of the 1880s, with branches in every significant city. Templeton's, Massey's, Cochrane's and Galbraiths followed in his wake. Elsewhere, Bilsland Brothers supplied the bread and Macfarlane & Lang and Gray & Dunn the fancy biscuits for the now fashionable tea-rooms of Sauchiehall St, Buchanan St and beyond. Department stores from Anderson's Royal Polytechnic in Argyle St to MacDonald's and Fraser's in

Buchanan St to Copland's 'Caledonian House' in Sauchiehall St set the fashions for the middle class. The co-operative societies were also reaching their peak and the SCWS supplied food, clothes and furnishings from its huge works at Shieldhall to the skilled working class. Prosperity and confidence oozed from every corner of its new headquarters in Morrison St, which opened in 1897. Other businessmen were also catering for the growing passion for sport, particularly football with investment in grounds and professional players at Ibrox and Parkhead, while others met the demand for either temperance outings or boozy trips 'doon the water'. Scores of companies set out to make motor cars after 1896. Some eighteen major theatres were built in the city and the Glasgow Rep was at the forefront of dramatic experimentation. Wealthy business men patronised the bold new French Impressionists and Glasgow-based artists challenged the conservatism of the academies. Glasgow proudly showed off its industry, its culture and its progress to the world in the great exhibitions of 1888 and 1901.

War and Crisis

The First World War brought a huge demand for the products of heavy industry with firms once producing machines for peaceful purposes being transformed into armaments companies. There was also a brief post-war boom, and the *Glasgow Herald* in 1919 was confident that the motor car industry would soon develop on a large scale in Scotland. But the world had changed. Other countries were now producing their own ships, locomotives and heavy machinery while new coal mines in Germany, Poland and America were producing cheaper and better coal than the old, exhausted pits of Lanarkshire. Glasgow had long relied on export markets for its machines and consequently, the post-war decline in world trade was disastrous for the city. For example, The North British Locomotive Company in the years between its formation in 1903 and 1914 produced on average 450 locomotives a year, mainly for export. By 1924 this figure was down to 74 and none at all was produced in the darkest year of 1932.

Shipbuilding too suffered a dramatic downturn in its fortunes. By 1923, the effects of wartime production and the post-war boom meant that there was a surplus of ships, a situation that lasted throughout most of the inter-war period. Defence orders also dried up as the government embarked on naval disarmament.

Inevitably, with so much of the west of Scotland's industry linked to shipbuilding, the ripples spread widely. Producers of boilers, pumps, cranes, wire, cables, ships furniture, paint all felt the effects and paid off their work forces, with the result that demand for consumer goods also tumbled. Hopes that a reduction in wages and then prices would be enough to revitalise the markets for Scottish ships and machinery proved to be misguided.

With an over-valued pound, Scottish manufacturing could not compete effectively with its American and German competitors, even before other countries, in the face of world depression, began to push up subsidy and tariff protection for their own industries.

Two factors came together in the inter-war period. A very large part of the west of Scotland economy was dependent on shipbuilding. It became worse, indeed, in the interwar period as shipbuilders strove to maintain their supplies by buying into steel companies. At the same time, the west of Scotland failed to attract new growth industries. Car production had disappeared by 1928 and ominously, Stewart and Lloyds, the successful, specialist steel-tube makers moved their business from Mossend in Lanarkshire to Corby in Lincolnshire, taking many of their work-force with them. Population was falling as migration exceeded the rate of natural increase and, with unemployment levels topping 20 per cent, real incomes were growing much more slowly in Scotland than in the rest of the UK. The fast expanding new electrical industries producing the increasingly 'necessary' refrigerators, radios and washing machines went close to the biggest and most prosperous markets of the English Midlands and South-East.

All the evidence called out for a reorganisation and rationalisation of Scottish industry, but remarkably little happened. Shipbuilding on the Clyde slimmed down only marginally while firms, always hopeful of imminent recovery, were wary about losing their skilled workforce. Re-organisation in steel was rather more vigorous. By 1936 Colvilles controlled nearly 90% of Scottish steel capacity and became a highly-efficient producer, with good productivity, but there was not a substantial re-siting and integration of plant. Iron manufacture was separate from blast furnaces which in turn were separate from the steel plants. The result was that Scottish steel costs remained higher than those in other areas. Rearmament at the end of the 1930s once again generated a demand for the ships and munitions of the west of Scotland and the long-awaited growth seemed to have returned. With it, the pressure for new products and new technologies faded.

The New Economy?

Despite the world economic boom of the post-Second World War period, Glasgow and the West of Scotland were not too successful at tapping into it. The Scottish Council for Industry still believed that 'the mainstay of the Scottish prosperity would always be the heavy industries'. But, the small yards on the Clyde with their limited space for manoeuvre could not compete with the huge new ones appearing in Germany and Japan. The Clyde could not produce the tankers necessary to meet the world's demand for oil or the huge container ships. There were labour shortages – the Clyde had rivetters, not welders – and there were labour disputes as a score of unions battled over the demarcation of new processes. Yards closed with increasing momentum although valiant attempts to salvage something brought about the Fairfield's experiment of collaboration between private enterprise, trade-union and government, and then the merger of Fairfields, Browns, Connells, Yarrows and Stephens and others into Upper Clyde Shipbuilders. Within three years, however, UCS was bankrupt and although something was temporarily salvaged by the famous, high-profile work-in at UCS, the respite was short-lived: 77,000 were employed in the industry in 1951; 40 years later, it had fallen to 14,000 and the downward spiral continued.

Inevitably, the steel and coal industries felt the brunt of any downturn but with government help, there were attempts to diversify. Always keen to attract vehicle construction, the Scottish Office successfully persuaded the Macmillan government to force Rootes to open a plant for the new Hillman Imp at Linwood in 1963. But, it was far from the supply of components and Scottish firms were slow to seize the opportunities to produce them. Strikes and poor management did nothing to help. Political pressure also brought a steel strip mill to Ravenscraig to supply the light steel for the new consumer industries which it was hoped would appear, but it proved a short-lived chimera. By 1967 Colvilles was to all intent bankrupt and the state stepped in. The new British Steel Corporation took up a plan that had been around since the 1930s for a fully-integrated iron and steel works linked to an ore terminal at Hunterston. But demand for steel was already falling by the time the terminal was completed and there was no 'glorious resurrection' of the Scottish steel industry as was hoped. The closure of Ravenscraig in 1991 marked the end of an era.

Some new industries were appearing with the coming of largely American-owned branch factories after the war. IBM came to Greenock, Hoover to Cambuslang, Honeywell first to Blantyre and then to Newhouse, Burroughs to Cumbernauld and Goodyear Tyres to Drumchapel. The main thrust of public policy was to encourage outside firms to invest in Scotland rather than to stimulate home-grown enterprise. The danger of such a branch economy is that it is vulnerable to changes in the company and the market and this proved to be the case in the late 1970s and early 1980s. Goodyear closed in 1980; Honeywell was down to half the size; Hoover barely clung on; and Singer went from Clydebank after more than a century. The decision of the now

Chrysler-owned Linwood to build their new model in France in 1975 was the beginning of the end and when Peugeot took over, it was closed in 1981. Significant manufacturing was rapidly disappearing from the west of Scotland. The Scottish Development Agency (later Scottish Enterprise) tried with some success to attract clusters of high-technology firms and the west of Scotland, but not Glasgow itself, gained something from the growth of 'Silicon Glen'. Glasgow set about creating a new image as 'City of Culture' and 'City of Architecture'.

In the new century, Scotland, on the periphery of Europe has had to struggle hard to face the challenges of globalisation, market liberalisation, deregulation and the advances being made in information- and communications technology. Highly creative young people have developed niche markets in software products, but have struggled to break into export markets. It is still proving difficult to translate innovative ideas into commercial success and to integrate an excellent IT base in the city's many institutions. The hope has to be that a well-educated workforce will attract inward investment and generate innovation, but much is going to depend also on maintaining an attractive environment and a decent infrastructure and getting the necessary integration of services, supplies, workforce and transport. Glasgow has still much to do to become the 'Knowledge City', the 'Creative City', the 'Communicating City', the 'Liveable City' to which its development themes aspire.

Engineering: Rising to the Modern Challenge

Bill Cranston

Some years ago I read a 1970s study of professional education. It contained the following assertion: 'society wants, and needs, what the professions of medicine, law and engineering can confer – health, justice and comfort.' I was shocked. I had never thought of my profession in that way. Why was that? I've realised since that I, and most engineers, get engrossed in what they are actually doing, rather than thinking about what it is for.

When I think of what I have done as an engineer, I remember the sites I worked on, or the time spent subsequently in the research laboratory, or on full-scale tests of actual structures. Times spent on sites like Luichart Dam, for example, in the Highlands of Scotland: the calculations using seven-figure logarithms, surveying out in the sun – and the rain – ensuring the dam was being built 'to line and level', of concrete beams being bent to failure and then the feeling of achievement, on returning years later, to see the completed dam, and that thrill, when experiments turned out to fit the theory, or computer predictions fitted with experimental results. Such thoughts and feelings are sometimes shared with a fellow-engineer but very rarely with anyone else.

This failure to describe first what we do, and more importantly, what we do it for, is a major reason why very few people, even in our sophisticated and technological Western society, under-stand our role. It's also why engineers, unlike doctors and lawyers, are virtually never the stuff of drama on screen or stage. Doctors and lawyers nearly always relate directly to people one-to-one – and often about intimate and personal problems. Not many engineers are in this position.

A key result of this 'invisibility' is that society appreciates very little of the comfort we provide. That's not too serious (although it does mean that we lose some good recruits). What is serious is that we are beginning to be seen in a negative way, especially by the ecological and environmental movements. This is a key challenge.

To trace the development of this challenge, we need to go back some way into history. We need to probe why it is that this negative image has developed and then to examine how we might begin to meet the challenge. But first some history.

History

Engineering has a long and proud history, much of which remains to be discovered, recorded, and assessed. We will start in 1802, when there were already significant numbers of professional mining engineers, civil engineers and military engineers. Mining engineers made decisions about where shafts were to be sunk, and tunnels extended. They devised drainage, and later, pumping systems to remove water. Their main interest were in the coal and ores from which metals could be smelted. Civil engineers designed, and supervised the construction and maintenance of bridges, roads, canals and harbour works, to facilitate travel and trade (the provision of reservoirs for piped water supplies and of sewage treatment systems hadn't really started at this time). Military engineers, as they had been doing for millennia, were devising fortifications for defence and war engines for attack. For example, the foundries in the Carron valley in Scotland were busy casting carronades (as they had been for many years prior to 1802), for use in both navy and merchant shipping, helping to assure British supremacy in both sea warfare and trade.

What sort of physical comfort was being supplied? The aristocracy and other wealthy townspeople of Glasgow had certainly become much better housed and clothed. Coal fires provided warmth, and lots of hot water, improving hygiene and health for them (although improvements in the training of doctors, where Scotland was leading the world, take credit too). While it must be accepted that many people in Glasgow were living in less healthy environments than if they had stayed in the country, a trend to a general increase in comfort for everyone had been established.

As far as professional education and training for engineers was concerned, the first civil engineering school had been founded in 1750, in pre-revolutionary France, and the first mining engineering school in 1765 in Saxony. Military engineering had been organised well before this; for example the Corps of Engineers of the British Army was created in 1716, with some formal training involved, but falling well short of a full degree or diploma course.

An Early Engineer: John W. Macquorn Rankine (1820-1872)

The first engineering school in Scotland was set up at Glasgow University under Professor Lewis Gordon in 1842. It had limited success, mainly due to severe opposition from professors in other faculties. Only when John William Macquorn Rankine was promoted to professor in place of Gordon in 1855 could the course be described as properly established. Rankine went on to develop both a local and an international reputation (his text-books were translated into French, German and Italian, and English versions were widely used in American colleges). He also served as president of the Glasgow Philosophical Society (GPS) and was a prime mover in the setting up of the Institution of Engineers and Shipbuilders in Scotland in 1857 which continues today as the only Scottish professional engineering institution.

Rankine had exceptional abilities. At the age of 14, he was given a copy of Newton's *Principia* in the original Latin and he recorded later that he 'had read it carefully'. During his two years at Edinburgh University (he left early because of straitened family circumstances), he studied metaphysics and the theory and practice of music, alongside the scientific subjects of chemistry and natural philosophy (the equivalent to our present-day physics). In his career and public life, these initial wide interests served him well and he was prolific in both the scientific and engineering worlds. He was instrumental in the appointment of a Glasgow graduate to head the first college of engineering in Japan in the 1870s (which was before Oxford or Cambridge had accepted engineering as a subject for study).

Alongside this he continued an active life in Glasgow society, not least through his musical talent – he was in frequent demand at social functions to sing songs of his own composition. It is clear that he was a well-known and well-loved figure in the Glasgow of his time and there were other engineers of calibre who were similarly known, and as active in local affairs and society. There were, for example, many papers related to engineering presented to the GPS in the first 50 years of its existence and we can conclude that in Rankine's day, engineers had an assured place in Scottish society: that society knew what they did, and appreciated it.

Moving Forward to Today

In the course of the 20th century, engineers became more specialised, and began to concentrate more and more on engineering. That specialisation has been encouraged by the development in both the UK and the USA of at least twenty separate professional institutions, each devoted to a particular type of engineer (mechanical, electrical, and so on), and within these types there is further specialisation. Each institution, with its own official charter or constitution, has tended to guard jealously its independence and in such circumstances, no clear unified voice emerged to speak for the profession as a whole. UK engineers who prospered in the period around 1900 tended to buy country estates, and their sons were not encouraged to continue in their father's profession. Few engineers have ever gone into politics, and of those that have, none have made any serious mark.

Nevertheless, throughout the 19th century and up until the 1940s, the work of engineers continued to be known to society at large, and appreciated. The profession was portrayed as attractive (but only, of course, for boys). I recently presented a volume from the early 20th century entitled *Victories of the Engineers* to Paisley University library. It deals with projects ranging from the construction of the Panama Canal to the building of battleships, and communicates something of the sense of excitement and achievement that can be achieved from careers in engineering.

However, since the 1940s, engineering has steadily lost its appeal. Surveys of school-leaver opinion about career choice has shown a steady increase in a negative attitude to the subject. At least one writer traces this back to Hiroshima and Nagasaki while others attribute it to the rise of the environment and ecology lobbies, identifying Rachel Carson's *Silent Spring* as a major influence. I agree with those influences, but think it probably has as much to do with the seemingly unstoppable and uncontrollable growth in technology, and its growing influence on more and more of our lives. It appears out of control and we feel uneasy as a result.

Furthermore, the word 'sustainability' has entered the language. It is not a reassuring word. It makes us think of things running out, with potentially catastrophic effects and in so far as global capitalism is seen to be the cause, engineers are seen as willing accomplices by the environmental and ecological lobbies.

Engineering Reactions to Sustainability

What are engineers doing about sustainability? To make an assessment of this, I made a review of material (as of December

2002) on the Internet websites of the US National Academy of Engineering (NAE), the UK Royal Academy of Engineering (RAE), and the Verein Deutscher Ingenieure (VDI Association of German Engineers). Part of the remit of these three senior engineering organisations is to advise their respective governments.

I looked at recent papers, articles, or substantial news stories and classified them under three headings: firstly, items simply describing engineering projects; secondly, items describing engineering projects where sustainability was at least mentioned; finally, articles with a substantial element on sustainability.

A report satisfying the last category was about establishing a 'hydrogen economy.' It was stated that the technology had now been developed, all that was now needed was 'the political will to get it going.' Another example was the RAE's response to the UK government's 2002 statement on the future of UK energy supply.

Altogether a total of some 50 items were reviewed. A total of five were in my final category, indicating a significant effort to look not just at what to do and how to do it (our usual pre-occupation), but also giving arguments as to necessity, with discussion of alternatives.

But with regard to the specific engineering projects from all three national organisations, I found nothing that was really radical, and serious issues were often avoided. For example, there was virtually nothing in the RAE's recommendation to the government on nuclear power about how engineers might help in allaying the strong public concern about disposal of nuclear waste.

What do I mean by radical? Scientist Theodore von Karman said, 'Scientists find out what is: engineers dream of what never was before.' Here are three of my engineering dreams.

Ocean Farming

At the moment, we simply hunt food from the oceans, taking a proportion each year of fish and other creatures, leaving nature itself to replenish the stock. We gave up this grossly inefficient principle on land over 10,000 years ago. Switching from hunting to farming in the sea will, as on land, increase the yield by a factor of more than a hundred. It's not a new idea. Already in the 1970s, it was being argued that unless we developed ocean farming, there would be widespread famine throughout the world in the year 2000. Developments in agriculture up till now have meant that hasn't happened, but with our still rising population ocean farming should now be receiving serious study.

The engineering problems are considerable. To control cattle on the range in the American West the only technology needed was barbed wire, although it should be noted that the engineering of its production called for real talent. The floating structures to 'fence in' growing fish will be several orders more complex. They will need to cope with severe storms. But these same structures will offer further opportunities. They could carry wave and wind power installations which in turn could support significant industrial production. The experience of the offshore oil industry will be invaluable.

Controlling the Climate

All but a few people accept that the increase in the percentage of carbon dioxide recorded over the last 150 years in the Earth's atmosphere has come from the coal we have burnt over that same 150 years in our fires at home, and in power stations to produce electricity. It's also agreed that this has at least contributed to an overall increase in Earth temperature, and that there is more of this to come – the so-called greenhouse effect. Thus, say many people, we must control carbon dioxide release to keep down this temperature increase. But what about going even further and accepting control of the climate, via an International Climate Control Commission?

American scientists and engineers have looked at the idea of controlling global warming by adjusting the amount of sunlight reflected back out into space by introducing quantities of fine white dust into the stratosphere. The reaction of many people to this suggestion will be one of 'shock-horror' with a fear of what might happen if it gets out of control? I don't actually think it would be a serious problem; there would be ways of getting the white dust back down again and there would be trials in any event with larger dust particles which would settle to a lower level and be finally brought to earth again by rain.

But what about organising reflection of the Sun's energy at ground (or sea) level? Many of us do this already during the summer by adding a mild whitewash to the outside surface of our greenhouses to prevent overheating. I have a vision of a billion of us volunteering to put out 1 m^2 panels on our garden paths, or on our roofs, white side up or black side up as instructed for that day and/or night via the internet from 'International Climate Control HQ.' It could be organised on a voluntary basis – many of us in Western Europe already put out waste for collection once a week, having spent a considerable time and effort sorting it. Yes, a number of us keen volunteers would make mistakes, putting out black instead of white, as well as forgetting to tell Climate Control that we are going to be on holiday and can't find anybody to take over our responsibilities, but satellites will be checking us out, issuing reminders about our responsibilities, and more important, adjusting for 'no-shows' in exactly the same way that airlines currently do.

The engineering here is not rocket science, and will be much more about organisation, planning and control. But that's just what engineers who direct large projects do, ensuring all the bits and pieces are brought together in proper order and in due time.

Dealing with Sea-level Rise

This is linked to the previous problem. What we do about the climate will affect the degree of sea-level rise. My dream here is that we engineers emphasise that we can deal with sea-level rise directly. To highlight what could be done, I first take an extreme hypothetical example.

Let's assume all the ice in West Antartica melts in the next 50 years, which will produce a sea-level rise of 5 metres (an extremely unlikely scenario: it's estimated that by 2050 the sea-level rise from global warming will be around half a metre at the very most). But let's assume that we knew it definitely was going to happen. A third of Florida would face flooding – what would the people there do?

A large portion could be surrounded by dykes, designed by Dutch engineers and life there would continue as before. The city of Miami would be a bit of a challenge. But over the next 50 years, large areas of it are going to be rebuilt in any event and buildings could easily be built either with a flood-resistant first storey, or on raised ground. As for the high-rise structures on the waterfront, they could be temporarily evacuated, and jacked up 5 metres, using the same technique applied to a North Sea oil production platform that subsided far more than expected after installation. And there would even be a benefit, since the massive investment currently planned to re-establish large parts of the Everglades Swamp area would not be needed.

Quite simply, investment would be forthcoming to conserve the capital value of that area of Miami, in exactly the same way that investment has been forthcoming over the last six centuries to preserve and extend the productive land area in Holland. The Dutch could easily, had they wished, emigrated en masse to America in the 1900s and abandoned their land (as many in Ireland and Scotland were forced to do in the previous century). But they chose to stay. I think Miami people would want to stay too.

Other areas in the world do not have the investment potential of Miami. But over the next 50 years the accuracy of short- and even medium-term weather forecasting will become much higher. Rather than provide expensive fixed protection like dykes, it may be sufficient to organise emergency evacuation procedures of both people and their more valuable belongings, combined with high-level flood refuge structures at suitable intervals for those who refuse initially to leave their homes or businesses. Such refuges installed in Bangladesh have already significantly reduced loss of human life in floods.

Discussion

There are serious global, political and legal issues with the first two of the proposals just outlined. For example, how much of the ocean might the USA get to farm, and how much would Iraq get? Does land-locked Switzerland get any at all? And how much of the ocean are we going to leave as marine reserves, to preserve existing marine species for future generations (whether as a genetic bank, for contemplation, or as a source of wonder to our great-grandchildren)? The idea of climate control will be scary to many, but is it scarier than the prospects offered by genetic engineering? The third proposal is hypothetical but even the modest sea-level rises which are foreseen are going to affect countries all around the world.

It is quite clear that these issues cannot be tackled by engineers alone. But somehow or another we must ensure our voices go in to the debate. In recent discussions about the impact of flooding due to expected sea-level rise, many scenarios suggested by the Inter-governmental Panel for Climate Change specifically exclude any consideration of increased coastal protection. Even a minimal engineering voice would have shown the stupidity of this.

However, it is not that the voices of engineers are deliberately excluded. I discovered in the websearch mentioned earlier that the US National Academy of Engineering had only recently amended their constitution to allow them to take a pro-active role in advising government. Their previous constitution allowed them only to respond to requests from the US government. The current NAE president, William Wulf, in his explanation of this expanded role to the newly elected members for 2002 took pains to point out that it could be controversial. But he was equally emphatic that the rough and tumble of debate had to be accepted. He himself, along with the NAE chairman, have taken a lead in speeches following 9/11. For example, alongside a pledge to support research into improving national security, there was the observation that the roots of terrorism had to be tackled as well. There was also a quiet observation about the role humanitarian aid might have played in an Afghanistan which the US had abandoned after the withdrawal of the Soviet Union. We are learning to speak up.

Concluding remarks

Engineers need to be seen in society not just as people who 'do technology', but as serious joiners in the debates about what should be done. We should be pro-active in our advice to society and more international in our thinking. The 21st century needs our advice. I am confident it will get it.

Acknowledgments

The Royal Philosophical Society of Glasgow has vigorously broadened my thinking over the last decade via the many and varied topics covered by their speakers. The library staff at the University of Paisley have been assiduous on my behalf. Many people whom I met on a recent visit to the USA have helped me to assess the current state of the engineering profession in that country, and something of its history.

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Public Health in Glasgow

T. S. Wilson

In his book, *A Tour Through The Whole Island Of Great Britain*, published in 1724–26, Daniel Defoe described Glasgow in very favourable terms: 'Glasgow is indeed a very fine city; the four principal streets are fairest for breadth, and the finest built that I have seen in one city together; ... in a word it is the cleanest, and beautifullest and best built city in Britain, London excepted.' Even in such 'idyllic situations', housing conditions could be poor. Across Scotland, infectious diseases were rampant and there was a high infant mortality rate. Deaths in childbirth or from infections associated with childbirth were common. In Edinburgh, for example, Sir Walter Scott's parents resided in College Wynd. The place was foul-smelling and disease-ridden with a high infant mortality rate. The first six children born to Scott's mother died in infancy. Walter was the middle of the next five boys that were born. There was one girl, Ann, never very robust, who died in her thirties. Scott himself developed poliomyelitis at the age of 18 months.

Most people at this time lived in the country and were engaged in agricultural pursuits, or in service activities. The towns were small and the work was largely about government or the support of agriculture. In the early 18th century, trade was with the continent and the West Indies. 'Tobacco lords' produced large fortunes that were invested in the city or in estates nearby. The sugar trade and the tanning of leather also produced large fortunes for the merchant class. However, this great period of commercial activity in Glasgow and Scotland was brought to an end by the American Declaration of Independence in 1783.

The next great development came with the manufacture of cotton goods, which was followed in turn by the coal, iron and steel era. James Watt with his improved steam engine paved the way for massive economic, social and demographic changes. People came in droves to Glasgow and to other Scottish towns where employment was readily available. This rural exodus was driven by the Agricultural Revolution, which was lessening the need for labour in the fields, and by the Highland clearances for sheep farming. Railways were also expanding throughout in this period which acted as a source of employment and also increased people's mobility. Following the Irish potato famine of the mid 1840s, the cities were also swollen by large numbers of migrants from across the water.

Consequently, Glasgow's population expanded rapidly during the 19th century, increasing from 414,000 in 1863 to over 724,000 in 1898. Those who could afford it tended to move out westward to better housing, leaving poorer quality and greatly overcrowded accommodation for those who could not. Housing conditions in these poorer districts were dreadful and proved fertile breeding grounds for infection and disease. Dry water closets, with no running water available were the norm, resulting in waste being dumped into the streets. Consequently, epidemic diseases such as cholera, typhus, smallpox, scarlet fever and whooping cough were rampant and while they could affect all social classes, they were most prevalent amongst the poor. Furthermore, because of smoke pollution (which reduced the preventative action of sunlight) rickets was a common occurrence amongst the populace, as was chronic bronchitis and lung cancer amongst younger people.

While the 19th century witnessed an explosion in public health problems, it also saw a gradual change in the community's approach to dealing with them. By the end of the century, the old negative approach involving the isolation of obvious sources of infection and spasmodic attempts to abate nuisances was replaced by one based on the recognition of the benefits of attacking systematically the conditions which promoted ill health.

The 1860s had seen cities such as Edinburgh and Glasgow appoint Medical Officers of Health (MOH), but smaller areas were slower to follow and by the 1870, it was apparent that many local authorities were not able themselves to develop sanitary reform. The Local Government (Scotland) Act 1889 created district committees and county councils (to whom the powers and duties of the old parochial authorities were transferred). The act required the new authorities to employ both a Medical Officer of Health and a Sanitary Inspector whose powers and responsibilities were to be prescribed by the Board of Supervisors. The problems in smaller burghs were alleviated by the passage of the Burgh Police Act of 1892, which required all burghs to appoint Medical Officers of Health and Sanitary Inspectors. The Act laid down requirements relating to the laying out of streets, stairs and houses, the erection of new buildings, the height of ceilings, the lighting and ventilation of rooms, and the provision of water supplies and sewerage. At this time, seven or more inhabitants could apply to the sheriff to have their area declared a police burgh, and if the population was found to be in excess of 2000, the sheriff was compelled to grant the application. Dr John C. McVail, the MOH of Dunbartonshire argued that with the creation of huge sanitary areas under the 1889 Local Government Act, the need for the formation of small burghs had disappeared. These criticisms by McVail were to go unheeded until 1929.

Furthermore, the Public Health (Scotland) Act 1897 authorised the Local Government Board of Scotland to instruct local authorities to provide hospital accommodation for those suffering from infectious diseases and made mandatory the provisions of the Infectious Diseases (Notification) Act of 1889. As a result, cases of smallpox, cholera, diphtheria, membranous croup, erysipelas, scarlet fever, and other fevers including typhus, typhoid, enteric, relapsing and puerperal, were to be notified immediately to the MOH in order that action might be taken to prevent the spread of disease. The reports of the Medical Officers of Health annually detailed the many problems still to be tackled. How some of these problems were dealt with in the city of Glasgow will now be dealt with.

Water Supplies

In the early 19th century, Glasgow received its public water supplies from two water companies which obtained water from the Clyde, and from numerous wells around the city. In the 1850s, the city fathers decided to develop the Loch Katrine supply which became operational by 1859. This large civic enterprise largely corrected the cholera epidemics, which periodically occurred about this time.

However, the extent to which public water supplies can be further managed to provide health benefits to their users has been a hotly contested issue throughout the second half of the 20th century. In 1939 as a wartime precaution against bacteriological warfare, the water was treated with chlorine and in the post-war years, the medical authorities resisted attempts to stop this treatment.

In the 1950s, the Scottish Department of Health initiated an investigation into the effect of fluoridation of water supplies upon dental health in Kilmarnock and Ayr with Kilmarnock's water being fluoridated while the Ayr supply was not. The tests proved successful but in spite of this the town council discontinued fluoride treatment due to pressure from the anti-fluoride lobby.

In the 1960s, Glasgow and Edinburgh rejected proposals to treat its water supplies with fluoride. Glasgow Corporation in the early 1970s agreed to fluoridation but no action was taken as neighbouring authorities disagreed. In the late 1970s, agreement was reached between Strathclyde Region and the four health authorities concerned but anti-fluoride activists halted the work. The case came before Lord Jauncey who, in spite of evidence that the proposed concentration of fluoride carried no risk to health and would reduce the dental caries rate, judged that local authorities were not permitted by the Water (Scotland) Act to fluoride the water supplies. Although this was overturned by the passing of the Water (Fluoride) Act of 1985, no action was taken so that people who regularly brush their teeth with toothpaste containing fluoride benefit, but those who do not suffer as before.

Reservoirs in Glasgow from the 1980s had trouble with seagull guano, which resulted from a population explosion of these birds. This problem was contained by chlorination of the supply, which dealt with bacteriological contamination

In 1988, the first outbreak of cryptosporidiosis traced to the mains water supply was recorded in the United Kingdom. This protozoan was first recognised as a human pathogen in 1976 and is now the most frequently identified protozoan cause of gastro-intestinal infection in the UK. This organism is found in cattle in sheep and chlorination does not block off this infection; filtration of water is required. The Loch Katrine supply is not filtered and in 2002, an outbreak of the condition occurred within the loch's distribution area, caused by contamination at the Milngavie reservoir. Plans for a new filtration centre are under way but have met with local opposition.

A further problem facing Glasgow's water supplies was found in the pipes actually carrying it to the populace. The Loch Katrine supply had a pH of 6.5 which made it aggressive to the lead pipes which were commonplace in domestic plumbing prior to the 1970s. In 1973 the city council decided that all municipal houses undergoing refurbishment should have lead pipes and tanks replaced and in 1980, the government offered grants to private householders to replace lead pipes and tanks. The use of calcium and phosphate has greatly reduced the plumbo-solvency of Glasgow's water source. The pH of the Loch Katrine water supplied now is 9.

Drainage and Sewerage

In Glasgow, the sewerage works at Dalmarnock and Shieldhall that opened in 1894 and 1910 respectively both employed the chemical precipitation method. In the 1970s the Corporation of Glasgow decided to rebuild Dalmarnock Sewage Works and introduce a complete activated sludge plant that opened in 1968. This has also been done at Shieldhall. Sludge disposal at sea has been abandoned under EC regulation in favour of land disposal. One major problem of sewage works is the pronounced odour in the adjacent districts, particularly in good summer weather.

Housing

Poor housing was associated with the prevalence of many infectious diseases and in particular, with pulmonary tuberculosis. External toilets with faulty drains were a common source of bacilliary dysentery and other bowel infections. Dr James Burn Russell, the city's Medical Officer of Health (MOH), delivered a lecture entitled *Life in One Room* to the Park Church Literary Institute, Glasgow on 27th February 1888. This lecture shocked the good people of the district about the dreadful conditions of the populace residing barely a half-mile from their own houses.

In Glasgow, the proportion of households without fixed baths and exclusive access to water closets fell from 56% and 37% respectively in 1951 to 4.7% and 0.8% in 1982. At the same time, the percentage of one- and two-apartment houses fell from 11% and 36.3% respectively in 1951 to 2.3% and 16.1% respectively in 1981. These figures have greatly improved since.

Atmospheric Pollution and Clean Air

The 19th century industrial revolution, which was largely powered by steam and fuelled by coal, resulted in a great increase in the levels of atmospheric pollution. James Russell in 1895 had emphasised the necessity of clean air and administrative action was first taken against industrial pollutants. In Glasgow, measurements of solid deposits from the atmosphere were made and persistent offenders were prosecuted. Boiler firemen also received instruction on efficient methods of stoking while smoke inspectors (who were usually marine engineers) were appointed.

Subsequently, the problem became the domestic fireplace rather than industrial furnaces. The Clean Air Act of 1956 tightened controls on industrial smoke emissions and authorised local authorities to issue orders declaring the whole or any part of their district a Smoke Control District. The success in Glasgow has been dramatic.

The problem of air pollution is tending to return, but this time due to the exhaust gases from motor vehicles. More efficient engines and filter systems are being developed.

Food and Milk Supplies

For centuries, the supply of unwholesome foodstuffs had been considered a criminal offense and in the 19th century, with advances in medical knowledge, surveillance became much greater. The Public Health Acts in the 19th century allowed local government officers to inspect animals and foodstuffs and to destroy those foods unfit for human consumption.

Tighter regulations were brought in over the years to govern the preparation and supply of foods. Parliament passed the Food and Drugs (Scotland) Act in 1956 which authorised the issue of food hygiene regulations. Food poisoning became notifiable and hygienic handling of food became obligatory. Adequate washing facilities were to be provided for food handlers and for equipment and utensils used in commercial food premises. The Poultry Meat (Hygiene) (Scotland) regulations of 1976 required poultry only to be slaughtered and cut up in premises licensed for the purpose. Crown immunity for kitchens in hospitals and other publicly owned premises was abolished. Various milk and dairy Acts over the years gradually improved the quality of milk on sale. Between

1946 and 1956 the proportion of tuberculin tested and certified milk rose from 56.8% of total milk sales to 96.4% while by 1956 75% of all milk sold in Scotland was pasteurised. In 1980 the Milk (Special Designation) (Scotland) Order made pasteurisation obligatory for all milk sold in Scotland after August 1983. Scotland was well in advance of England in this matter.

The Control of Infectious Diseases

Outbreaks of infectious diseases such as cholera, typhus, and smallpox were commonplace in 19th-century Glasgow. The product of unclean water, poor housing conditions and general hygiene problems, they resulted in many fatalities. In the city, Belvedere, Ruchill and Knightswood hospitals were available for the treatment of infectious diseases. Bacteriological services were available in Glasgow, Lanarkshire and Aberdeen. Tuberculosis dispensaries and sanatoria for early cases and hospital accommodation for the isolation of advanced cases were provided. Treatment centres were also provided for venereal disease cases. The infectious disease service had made a significant contribution to the health of the people of Glasgow but improvements in housing conditions, nutrition and general standards of living also helped greatly.

Diphtheria immunisation became available in the 1920s and was tried for a period in 1924 in Aberdeenshire and Edinburgh on children who had been Shick-tested and found to have no immunity to the disease. Yet little progress had been made nationwide in spite of encouragement by the central authorities. It took the dramatic rise of diphtheria between 1939 and 1940 to change the attitude to immunisation. In Glasgow in 1939, there were 3,144 cases with 193 deaths, in 1940, 5,910 cases with 226 deaths, and in 1941 4,039 cases with 155 deaths. The campaign was started in Glasgow in 1940 and by 1956, diphtheria had been eliminated from the city. These campaigns were later extended in 1949 to whooping cough and tetanus with great success.

Whooping cough immunisation met with considerable public unrest and Scotland was again very slow in adopting BCG vaccination. In 1951, 52 of the 55 local health services took powers to undertake BCG vaccination. In 1952 the scheme was extended to children approaching school-leaving age. Later, the scheme was extended to infants, students and hospital workers. BCG assisted greatly in bringing about the decline in tuberculosis mortality.

Mass radiography was introduced in the mid 1940s because of the high occurrence of pulmonary tuberculosis during the Second World War. Between 11th March 1957 and 12th April 1957 the Glasgow X-ray campaign against tuberculosis took place. During this period, 714,915 people were X-rayed by 37 MMR units; 2,842 active cases of tuberculosis and 5,379 cases requiring observation were discovered. The campaign was organised by the Corporation of the City of Glasgow and the Western Regional Hospital Board in co-operation with the Department of Health for Scotland.

The development of streptomycin in 1944 and other chemotheraputic agents also greatly helped in eradicating TB. The work of Professor Sir John Crofton at Edinburgh University in devising drug treatments for the disease received international recognition. Also, the compulsory pasteurisation of all milk supplies in Scotland and the tubercular testing of cows eliminated TB derived from bovine agents.

Prior to the Second World War, Britain did not have a high incidence of poliomyelitis. However, major epidemics occurred in 1947, 1950 and 1955. In 1956, vaccination using the Salk vaccine was started in Glasgow, and in 1962, the Sabin oral poliomyelitis vaccine was introduced. The public actively co-operated and the disease was eliminated from the city. Later, campaigns against measles and rubella were established. For various reasons parents resisted measles vaccine. In 1970, it was recommended that girls between the ages of 11 and 14 should be immunised with live attenuated rubella vaccine. Boys were to be allowed to obtain natural infection. To begin with, the response was again disappointing, but eventually reached 8,000. In more recent times a vaccine against one strain of meningococcus, measles and rubella has been used. Again, there is controversy, largely related to alleged complications of the procedure.

The great expansion of foreign travel has exposed more and more people to diseases of tropical or sub-tropical origin. The infectious diseases' hospitals of the past have been abolished and smaller units with a new breed of infectious disease experts have been founded.

The Local Government Act 1929

The Local Government Act 1929 brought together under the new local authorities (that is, the cities, county councils and larger burghs) the duties of the existing local authorities and the parish councils. The general administration of services became more integrated and better managed. Universities were brought into the system as advisors.

The functions of locally elected boards dealing with the poor law, with lunacy and with mental deficiency were transferred to the county councils and burgh councils. These became the new units of administration with the qualification that burghs with a population of less than 20,000 had to forfeit their autonomy and merge with the county councils they were situated in.

The effect of these changes on health service administration were that local health departments were to consist of general public health administration; education, health, maternity and child health services; mental services; and general hospital and outdoor medical services. This meant the transfer of poor law general hospitals, mental hospitals and institutions for mental defectives to public health departments. Staff of the education health services were also transferred to the public health departments.

During the period 1930 to 1948, the Corporation of Glasgow and the University of Glasgow co-operated in the upgrading of the old Parish Hospitals. Great improvements in the services available at Stobhill, the Southern General, and other hospitals occurred. Professor Noah Morris of the chair of Materia Medica took a leading part in the transformation achieved.

The Outdoor Medical Service looked after the poorer members of the community until 1948.

The National Health (Scotland) Act 1947

The National Health Service (Scotland) Act 1947 transferred all local authority hospitals and services such as bacteriology to Regional Health Boards. These boards also assumed responsibility for all voluntary hospitals in Scotland.

The Corporation of Glasgow and other local authorities were left with sanitary supervision, prevention of infectious diseases, local maternity and child health services and the school health services. The Medical Officer of Health and the Sanitary Inspector still retained their statutory offices.

From 1949, the Glasgow Public Health Department investigated the high accident and absentee rates amongst workers employed at an east end weaving mill and found that poor air quality, bad lighting and lack of seats were to blame. When these defects were remedied, the accident and sickness rates were reduced dramatically. Similar investigations took place amongst the 2,400 cleansing workers. An investigation into sewermen was reported to the Health and Welfare Committee. James H. Bell received a high commendation Doctorate of Medicine for his thesis on this matter. These and other works of Glasgow occupational health ventures were given in evidence to the Dale Committee in 1951. This committee recommended that large local authorities should conduct occupational health experiments, as in Glasgow. Glasgow remained the only one to take up the challenge.

Dr Andrew Meiklejohn was a leading force nationally and internationally in industrial medicine in the west of Scotland. When he retired, the leadership in this field passed to Alexander Mair, Professor of Public Health and Social Medicine at Dundee.

One problem practically unknown 40 years ago was mesothelioma, caused by exposure to asbestos. Great quantities of asbestos were used in ship building and other heavy engineering industries for lagging and other purposes. Within the last 20 years, this disease has become a major problem, largely amongst ex-shipyard workers and their families. Asbestos is no longer used but the medical problems due to it will exist for years to come.

Health Education

Health education at child health- and school health clinics has been greatly developed. Specialist services are now available. These people supplement the activities of health visitors, nurses and medical officers. The scope of activity has been greatly expanded.

Public Health Medicine

Under the 1974 health service reorganisation, the post of MOH was abolished. Health boards were established and the tripartite system of medical administration was abolished. The community health specialist (now public health medicine specialist) has been given the job of investigating and assessing the health needs of the population and establishing priorities. In the rapidly changing health service they have a challenging and important role.

The term 'public health' has evolved over the past 40 years to 'social medicine' and later to 'community medicine' but is now coming full circle: the chief administrative medical officer of a health board has been given the additional title of Director of Public Health Medicine.

In the 1970s, many people were beginning to think that infectious diseases were becoming things of the past. However, wild nature has other ideas as the number of new diseases such as Legionnaire's disease, hepatitis A, B and C and acquired immune deficiency syndrome (AIDS) have come forward while some old diseases such as TB are beginning to return.

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William Thomson, Lord Kelvin

1802 2002

George Wyllie

William Thomson, Lord Kelvin was rightly revered in his own time for his work across a range of scientific disciplines. Mathematician, theorist and experimenter, inventor and engineer, he was one of the founders of thermodynamics, the follower of Faraday in unifying the theory of electricity and magnetism, and the leading theorist, inventor and engineer in the development of electrical communication.

Thomson was born in Belfast in 1824, the son of Margaret Gardner and James Thomson who was the professor of mathematics in the city's Academical Institution. After his wife's death, James Thomson moved to the University of Glasgow in 1832, and his family were educated almost wholly by himself until his sons, James and William, were old enough (at twelve and ten respectively) to start attending university classes. James senior took an active interest in the Glasgow Philosophical Society (GPS) and became a member in 1839. The Society also had a junior section and in 1841 John Thomson, son of William Thomson, Professor of Medicine (one begins to see why the Glasgow College was called the Thomsonian University), gave a talk on the steam engine with the demonstration of a working model built by James junior, who had in the previous year been secretary of the Models and Manufactures Committee for the 1840 meeting of the British

Association in Glasgow. James had joined the junior section of the GPS in 1840 although it was not until William returned to Glasgow from Cambridge and Paris that he took up his membership.

Cambridge and Paris

William began his studies in Cambridge in 1841 but even before his move south, he had shown his mathematical powers in his understanding and enthusiasm for the work of Fourier. While at Cambridge, apart from the grinding labour of the Mathematical Tripos, he worked mainly on electricity, but also developed a keen and lasting interest in geophysical problems; this interest had been stimulated by his mathematical coach, William Hopkins, who is remembered as a founding father of geophysical studies in Britain. In 1845 William graduated as second wrangler in the Tripos examination and took first place in the subsequent Smith's Prize exam.

After his election to a Cambridge fellowship, Thomson, on the advice of his friends, went to practise experimental methods in the Paris laboratory of Victor Regnault, the most distinguished worker in thermal physics of the time. At the same time he became acquainted with members of the Paris group of mathematical theorists, to whom he in turn introduced the earlier fundamental work of George Green.

The Natural Philosophy chair at Glasgow had been an objective for William for several years, since the occupant, William Meikleham, a founder member of the GPS and a good friend of the Thomson family, was elderly and in poor health. William duly returned to Glasgow in 1846 to take up the professorship.

Glasgow and the Principles of Heat

During William's study absence, James junior had transferred to the senior section of the GPS and gave talks, in 1841 on power losses in hydraulic engineering and in 1842 on a new design of river boat. In this period also he had begun to consider the effect of tidal drag on the movement of the earth and moon. In 1842, the newly appointed Professor of Engineering, Lewis Gordon, spoke to the GPS on the design of dynamometers. Loss of power in all its forms was to be a permanent strand in the thinking of the Thomson brothers. In 1842, for example, they were recorded watching the filling of a canal lock near Manchester and discussing the loss of mechanical energy as the water came to rest. Through the conduit of James and the GPS, William became involved with a group of academically interested civil and power engineers including Lewis Gordon, J. R. Napier and William Macquorn Rankine soon after his return to Glasgow. This group were keenly interested in heat engines, losses and efficiency. In 1846-7, James was working on his design of a vortex water turbine with inward flow, and in 1847 William presented to the GPS *A Notice of Stirling's Air Engine*, a subject already well known but not well understood.

At this time the only lucid, though incomplete, account of the principles of heat engines was that produced by the French engineer, Sadi Carnot, in 1824 which Thomson probably knew through an even less complete account by Emile Clapeyron. Carnot's theory was based on an analogy with hydraulic engines in which he supposed the work done by a heat engine was to be drawn from the fall of heat from higher to lower temperature without loss of heat, just as work done by a water wheel is drawn from the fall of water from an upper to a lower level without loss of matter. In spite of the falsity of this supposed conservation of heat, Carnot and his successors contrived to give a correct account of a number of phenomena, and these successes made it hard to accept the contrary rule, that in an ideal heat engine the work done is in an invariable proportion to the heat which disappears.

Already in 1847, James Prescot Joule had presented to the British Association meeting at Oxford the results of his careful experiments which showed that, in dissipative fluid flow, the energy lost reappeared as an equivalent amount of heat. Thomson was present during Joule's talk and was deeply impressed by the potential importance of the result; however, it seems that his reservations about its accuracy were only finally dispelled by the repetition of some of Joule's results in his own laboratory.

In 1848 Thomson obtained a copy of Carnot's original memoir from Lewis Gordon, professor of engineering at Glasgow. One consequent suggestion was that it should be possible using a reversible engine as a heat pump to freeze large amounts of water at freezing point without expenditure of energy. In late 1847 or early 1848, James had remarked that since water expands on freezing, work would be done by that expansion against the ambient pressure, and deduced that the freezing point of water should be lowered by applied pressure. William subsequently designed an ether thermometer to measure the small temperature shift and succeeded in verifying the effect. In 1849 he also presented a full and clear account of Carnot's theory to the Royal Society of Edinburgh.

The Laws of Thermodynamics

Joule's continuing careful work had by now convinced the Thomson brothers that dissipated mechanical or electrical energy was transformed to heat in unvarying proportion but they remained unconvinced of the reverse. On the other hand, a general law of conservation of energy, now formalised as the First Law of Thermodynamics, was a speculative commonplace with European thinkers and it was Rudolf Clausius in 1850 who combined that with the statement that 'heat cannot of itself pass from a cooler to a hotter body' (or, colloquially, 'all refrigerators need power to drive them') to formulate a correct theory of thermodynamics. Thomson was happy then and later to admit Clausius' priority in publication, but insisted, probably correctly, that he had independently reached equivalent conclusions before reading Clausius' paper. What record remains of his discussions at this time with Macquorn Rankine and his brother James makes this highly likely. It is also true that William was as bad at reading other people's work as he was at listening to other people talk. The German physicist, von Helmholtz, has an anecdote of an evening in their company in which both brothers held forth fluently on different topics, neither listening for a moment to the other. He adds that James, having the more concentrated mind, usually won through in the end. William, after someone had uttered a couple of sentences, was commonly inspired to some thought of his own which he developed in entire disregard of its continuing relevance. Since this also happened when he was 'listening' to himself, and particularly in his lectures, students needed a good deal of mental agility to profit from him. The most able, on the other hand, found him difficult but inspiring.

Thomson adopted a more elaborate expression of the Second Law: 'It is impossible, by means of inanimate material agency, to derive mechanical effect from any portion of matter by cooling it below the temperature of the coldest of the surrounding objects'.

Both Thomson and Clausius re-established the theorem of Carnot, that, working between given source and sink of heat, no engine can be more efficient than a reversible engine, and showed what this efficiency must be. Thomson had earlier observed that this led to a possible absolute scale of temperature, and somewhat later showed with Joule how, by measuring the dissipative flow of a gas, the gas thermometer could be corrected to the absolute scale. His great paper on *The Dynamical Theory of Heat*, published in the *Transactions of the Royal Society of Edinburgh* in 1851, fully established the bases of thermodynamics with a clarity only perhaps surpassed when Clausius reissued his own 1850 paper in a much improved version in 1864. A stream of further papers by an increasing number of workers including James Clerk Maxwell and capped, much later, by Caratheodory set classical thermodynamics in essentially its permanent form.

During this period, Thomson's personal life proved no less challenging than his professional life. His father died in the

Glasgow cholera epidemic of 1849, and his brother James migrated to Belfast where he became a professor of civil engineering. In 1852 William had married Margaret Crum, a lively and attractive young woman of some literary skill and chemical knowledge. However, not long after the marriage, Margaret fell ill and suffered chronic pain and weakness with few remissions until her death in 1869. Thomson's destruction of all his personal papers leaves almost no record of their life together, but one surviving letter shows her as an affectionate wife and an acute supporter, as she rebukes him for letting a colleague (C. F. Varley) take rather too much credit for their work together.

What Thomson had done by the age of thirty would have been a remarkable life's work for a distinguished scientist yet he continued an almost frenetic output of work in theorectical science and practical application for more than forty years, his dominant interest moving from the science of energy to the science of communication.

William Thomson in 1876 (from an engraving in Nature*).*

Cables and Navigation

While continuing work on the thermodynamics of elastic and electrical phenomena, especially the thermoelectric circuit, he took up a suggestion made by Helmholtz in 1847 and developed six years later the theory of the electric oscillations which are universal in modern communication. A paper presented to the Philosophical Society of Glasgow (as the GPS had become) by John Thomson and Macquorn Rankine in 1852 on telegraphic communication between Great Britain and Ireland shows the attention now being given in Glasgow and other commercial centres to such possibilities.

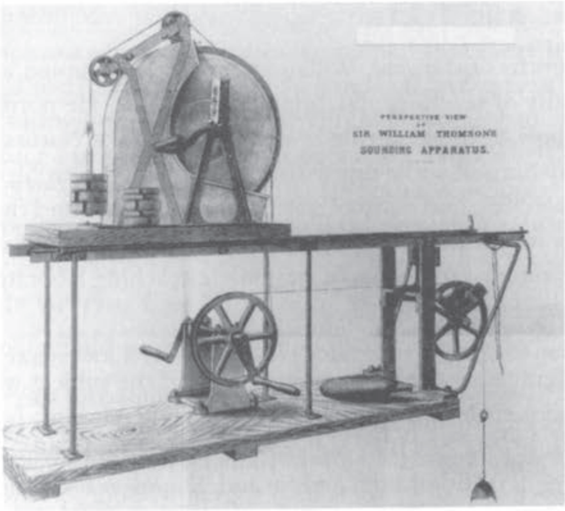
During the 1840s electric telegraphy using overhead land lines was widely developed, and by about 1848, the use of guttapercha as an insulator made underground and undersea cables equally possible. A serious limitation on these new cables was delayed transmission. For example, a later test on the multiple underground cable from London to Manchester found that with a total of 1500 miles of cable a pulse applied at one end was not perceptible at the other end until two seconds later. In 1854, Michael Faraday showed that this arose from the large electric charge immobilised in polarising the dielectric, and, with some prodding from G. G. Stokes, Thomson supplied a complete analysis of (noninductive) cable transmission by the end of the year. Working with given materials, he showed that reduced delay required both a larger conductor and a larger relative thickness of the insulator. Thomson also gave an analysis of the resulting economic problem of relating capital expense to subsequent income.

The unwelcome expense arising from recognition of this analysis made cable entrepreneurs easy victims of 'practical' charlatans promising easy and cheap results. Common sense and Willy Thomson prevailed only after a good deal of wasted effort.

The final success of the transatlantic cable depended not only on the devotion of seamen and engineers but on Thomson's systems of standardisation, measurement and detection, and he received the public recognition of a knighthood in 1866. Moreover, his experience at sea during the cable-laying turned his attention further to marine engineering and navigation.

The substitution of iron for wood in shipbuilding had raised interest in the dependence of compass readings on the attitude of a ship, arising firstly from the permanent magnetisation of the hull during building (and varying as a result of wave- and weather stresses in successive voyages) and secondly, from the induced magnetisation due to the Earth's local field. S. D. Poisson had addressed the problem in 1824, as had G. B. Airy again in 1838, but neither in a form suitable for application. Archibald Smith of Jordanhill, who might have been a serious competitor for Thomson's chair, gave a complete account of the matter using Fourier's harmonic analysis after considerable discussion with the Thomson brothers and J. R. Napier, and his results were incorporated in the Admiralty Manual of Deviations of the Compass, in the form of correction tables to deduce the true course from the reading of a deviated compass, as well as methods to reduce the deviations. Unluckily, Smith's health failed under the strain of his legal work and he died in 1872 when Thomson was starting to develop his new compass.

Thomson's experience on the cable-laying ships had impressed him with the need for both improved compasses and improved corrections. His enthusiasm for the sea along with a substantial income from his consulting work let him buy the *Lalla Rookh* in 1870, a schooner yacht which served also as a floating laboratory. In 1876 he applied for a patent for a much improved compass with compact correcting irons, which soon became the standard equipment on merchant vessels. The Admiralty, as usual, took another decade or so to catch up. His other important contribution to navigation was his lightweight sounding machine, which enabled quick depth soundings to be taken without taking way off the ship. Traditional sounding lines, drawn back by the drag of the water, gave exaggerated depths when used from a moving vessel. Amusingly, his first full-scale model nearly failed because



A perspective view of Thomson's lightweight sounding apparatus.

he had forgotten the enormous crushing force which the turns of the sounding wire exerted on the winding drum when drawn back up from depth. The problem was solved by using a raising wheel carrying several turns of the wire, while the storage drum wound on at a tension of only a few pounds.

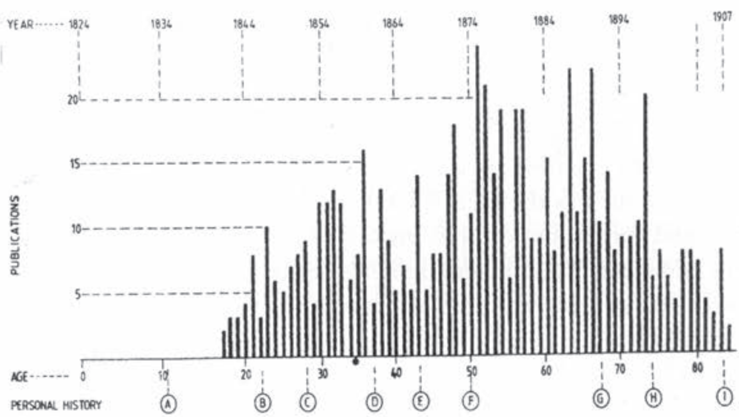
In the long cruising season, the *Lalla Rookh* became Thomson's retreat from business pressures, as well as a place to welcome colleagues such as the great Helmholtz who shared his interest in wave and vortex motion. His pursuit of analogies in heat and fluid flow and electric and magnetic fields led to a brilliant theory of vortex atoms. This was not a success at the time but the pictorial notion keeps reappearing in various disguises in 20th-century physics.

James Thomson had returned to Glasgow, succeeding Macquorn Rankine as professor of engineering in 1873. He and William applied themselves to the harmonic analysis of the tides, and in 1876 showed mechanisms for doing the analysis and for reconstituting the tidal levels for past or future times.

Teaching and Texts

For six months of the year, William was mainly occupied with his primary duty of teaching undergraduate students. He normally did the whole of the lecturing to the two classes of Natural Philosophy himself while one assistant conducted a problem class, marked exercises, and assisted with demonstrations and the laboratory, which for many years served as a research and standardising laboratory rather than a systematic teaching laboratory in the modern sense.

The lack of a modern textbook was a serious hindrance, though Thomson's way of inventing much of the subject while he taught meant that no text could be completely relevant. In 1860 Peter Guthrie Tait had become professor of natural philosophy at the University of Edinburgh and he and Thomson had much in common. They embarked on a *Treatise on Natural Philosophy* whose first (and last) volume appeared in 1867. This became the standard text of advanced dynamics in English for the rest of the century.



A diagrammatic representation of Thomson's remarkable published output. A: Matriculation; B: Chair; C:First Marriage; D: Serious Injury; E: Knighthood; F:Second Marriage; G: Peerage; H: Retiral from Chair; I: Death (produced by J. T. Lloyd in The Physics Teacher, *January 1980).*

An *Elements of Natural Philosophy*, constructed mainly by omitting the mathematics from the *Treatise* contained some very ingenious proofs but had deficiencies as a student text, and in later years when lecturing began to be deputised, the deputies had effectively to construct a lecturing text from notes of Thomson's previous lectures. The general introductory course that developed as a result survived with little change well into the 20th century.

The Age of the Earth

Another main strain in Thomson's work was his permanent interest in geology and geophysics. At Cambridge he had written a prize essay on the figure of the Earth, whose main conclusion was that the Earth must have solidified at a date when the length of the day was not much different from its present value, and his inaugural dissertation at Glasgow was on *De caloris distributione per terrae corpus*. The supposition that the Earth was already solid now appears unsound, but accepting that, it was hard to reconcile the known outflow of heat through the Earth's solid surface, with any reasonable initial temperature, with an age greater than about 200 million years – very much less than the geological record of rock deposition seemed to require.

Equally, he proposed that the evolution of living forms must require a similar extent of time. Thomson was deeply religious, though latitudinarian in his practice, and, accepting the argument from design as basic to belief, took Darwinian arguments less seriously than they perhaps deserved. He returned repeatedly to this topic over the years, both at the Geological Society of Glasgow, of which he was president from 1872 to 1893, and at meetings of the British Association. Only at the end of his life did the contradiction between physical reasoning and geological evidence as to the age of the Earth start to be resolved with the realisation that radioactive minerals constituted a considerable heat source inside the Earth.

Thomson did much less work on the optical than on the electrical properties of materials, but tried obsessively to find a mechanical model for the supposed medium which supported the propagation of light. It was clear that light should be an electric wave of some sort, but a self-consistent mechanical theory was unattainable. Thomson came nearer than anyone else with a beautiful but complex model of connected vortices, but by 1884 when Thomson, now Lord Kelvin, gave his marvellous Baltimore Lectures to 'professorial fellow-students in physical science' acknowledged leadership in electromagnetic theory was passing to his younger friend and colleague, James Clerk Maxwell.

William Thomson, Lord Kelvin, was a leading figure in science and engineering for the world and for his city. He was modest and generous, not only respected but loved by almost all his associates, and by far the greatest figure among the members and Presidents of the Royal Philosophical Society of Glasgow.

Glasgow: the Architecture of the City

Peter A. Reed

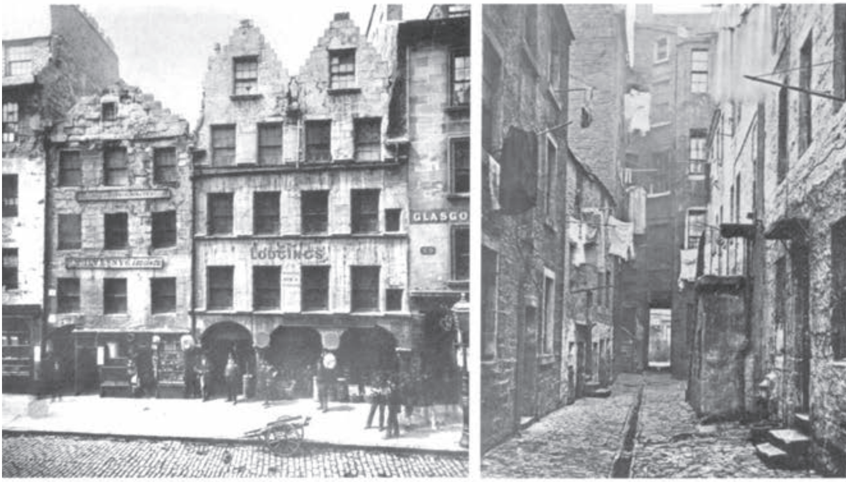
The architecture of a city is not just a matter of its individual buildings. It is as much to do with the way in which the buildings are related to each other and to the spaces between them and around them. Buildings and spaces come together in distinctive patterns characteristic of their times and the architecture of a city is the aggregation, juxtaposed or superimposed, of these various patterns.

A plan of Glasgow (see overleaf) published in 1841 reveals the patterns of the city on the eve of its great period of industrial prosperity. In an irregular line, the ancient streets – Castle Street, High Street, Saltmarket and Bridgegate – trace their way southwards from the cathedral to the historic river crossing. This route is continuously edged with buildings and the deep furrows of its backlands are densely built upon (see page 100). At Glasgow Cross, the pivot of the pre-industrial burgh, the route is intersected by Gallowgate and Trongate, opening up the lands to east and west. Here was sited the focal civic building, the Tolbooth, the centre of administration and of law (see page 101). The estates south of the river – Trades Town, Laurieston and Hutcheson Town – are by this date connected by four bridges and they flank what was the main street of Gorbals village in variously proportioned rectilinear grids. Hand-some frontages overlook the river

An 1841 plan of Glasgow as featured in Glasgow Illustrated in 21 Views … .

(see page 101) but behind them these lands have already begun their decline into what were to become among Europe's most notorious slums. To the east are the weaving villages of Calton

and Bridgeton – not yet within the Glasgow burgh boundary – the first expanding eastwards from its own crossroads, the second on an orthogonally gridded plan set off from the straight road to



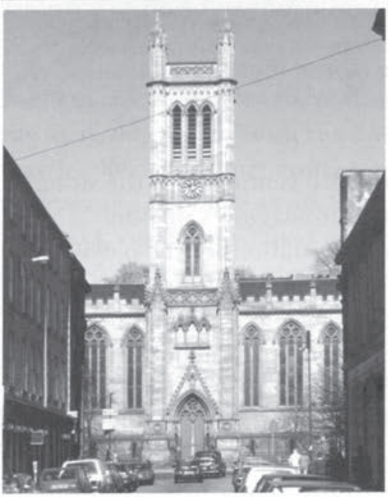
Tenements on High Street before city improvement development, as photographed by Annan.

Rutherglen Bridge. But the thrust of the city is emphatically to the west, downriver. With the opening of the Clyde to deep-sea vessels, the development of the inland port is well advanced, with wharves and dockside sheds lining both banks below Glasgow Bridge. A vignette included with the plan showed the harbour crammed with sailing ships and the plan already intimates the next and necessary stage in the development of Glasgow's port. Proposed off-river basins are lightly shown in locations where Kingston Dock and Queen's Dock were to be opened up later in the century. The northern hinterland to this business of the river shows gridded development as far as Anderston, in blocks ever longer and narrower to the west. By this time, the development here had already become an unregulated mixture of warehouses, wood yards, glass- and bottle works, foundries, machine workshops and factories, all enmeshed with housing and occasional public buildings.

The Trongate–Argyle Street axis, extended westwards, divides this industrial and dockside zone from the planned expansions of


Left: Trongate and Argyle Street, with the Tolbooth steeple, Tolbooth and beyond them the Tontine Hotel. Of the three, only the steeple survives. Painting by John Knox, c. 1820. Right: Carlton Place (Peter Nicholson, 1813-18), with Gorbals Parish Church (David Hamilton, 1806-10, demolished 1973).

the city that had begun in the early 18th century with the siting of what were then suburban mansions for Glasgow's wealthy merchant class; these were early manifestations of the persistent impulse for the better-off to remove themselves from the less salubrious aspects of the city. The Shawfield mansion (*c.* 1712) established the precedent, both in its choice of architectural style (the classical) and in its axial closure of the view along a newly opened or regularised street (in this case Stockwell Street). By the time of our 1841 map, what had survived of these townhouses had become absorbed into the tight urban structure of what we now call the Merchant City. The most monumental of these was the Cunningham Mansion, built in the 1780s, which had been transformed in 1827-32 into the Royal Exchange and set centre-stage in a formal square. But although the merchant's mansions have all but disappeared, the point-de-vue principle of planning they established was later adopted in the siting of public buildings



Top Left: Trades' House (Robert Adam, 1791-4).
Top Right: Hutcheson's Hall (David Hamilton, 1802-5).
Bottom: Ramshorn Kirk (Thomas Rickman, 1824-6).

such as the Trades House, Hutcheson's Hall and the Ramshorn Kirk (all above), which remain among the Merchant City's most distinctive civic features.

The opening up of the Merchant City lands was initially by projections northward from Trongate and Argyle Street toward

Top: Wilson Street with the pedimented portico of the City and County Buildings (Clarke & Bell, 1842-4). Bottom: Merchants' House (Clarke & Bell, 1842-4).

Ingram Street (then not the undeviating thoroughfare it is now). In the 1790s, an east-west axis, Wilson Street, was constructed midway across these routes. Broader than other streets in the Merchant City, it gave the area its own focus and its status was affirmed when the civic functions of the Tolbooth were moved here in the 1840s, so signifying a westward shift in the centre of gravity of the city. The City and County Buildings, occupying a full urban block, incorporated initially the county offices and sheriff court on Wilson Street (left, top) and the Merchants' House (moved from Bridgegate) on Hutcheson Street, where it was elevated in axial relationship with the Trades House on Glassford Street (left, bottom). Thus were the administrative, juridical, mercantile and manufacturing interests of the city brought into a classically structured relationship at the new core of the extended city.

But, as our 1841 plan shows, further westward expansions of the burgeoning city were already securely under way. In the 1780s, the burgh surveyor, James Barry, had laid out land to the north-west of the Merchant City on a gridded plan with George Square near its centre and with Buchanan Street, edging the Merchant City to its west, connecting the scheme directly to Argyle Street. The plan was principally for housing in terraces and tenements. George Square introduced a rare neo-classical tone for Glasgow at this time in that each its blocks was integrated elevationally. Only one of them survives, much modified, as a hotel. Other streets in Barry's plan openly invited their extension into the neighbouring countryside but for legal reasons, it was not until the turn of the century that this invitation could be taken up by the Campbells of Blythswood, the owners of the estate adjacent to the west. The undulating Blythswood lands were feued out on a plan that imprinted the grid untrammelled across the terrain. South of Sauchiehall Street, the development was mostly for individual terraced housing, two- or three storeys high and not architecturally co-ordinated (below, left), though in Blythswood Square, the western counterpart to George Square, each of the four defining terraces is elevated to a single neo-classical design. Our map shows that north of Sauchiehall Street, detached villas, rather than terraces, were the norm (the façade of one has recently been revealed within the newly furbished Centre for Contemporary

Above: 204-226 West George Street. Right: West George Street successive developments; the modernist building to the right has recently been rebuilt.

Buchanan Street, west side. From left to right (using the original building names): Royal Bank of Scotland (extension, A. Sydney Mitchell, 1886-8); not known; Carron Building, on the corner of St Vincent Street (James Boucher, 1884); Western Club (D & J Hamilton, 1839-42); Stock Exchange (John Burnet, 1875-7); the tower of St. George's Tron church (William Stark, 1807-9); Liberal Club (J. J. Burnet, 1886) and the Athenaeum Theatre (J.J. Burnet and J.A. Campbell, 1891-93).

Arts). Most of Blythswood's early buildings have disappeared, for as Glasgow prospered and came to its industrial and manufacturing prominence, much of the estate was progressively taken over to become the main part of the central business district. It is one of the attributes of the grid that it imposes no strict architectural discipline and so, for good or ill, is openly susceptible to commercial pressures. Terraces, tenements and villas were replaced piecemeal by offices, hotels, banks, shops and warehouses, often raised many storeys above the original constricted sites (opposite, right). The transformation of the Blythswood area continues to this day.

If Glasgow in modern times has been recognised as 'the finest surviving example of a great Victorian city'[1], this is due in great part to the high quality and originality of the buildings put up in the central business district during its Victorian and Edwardian heyday. Buchanan Street, for example, demarcating the Merchant

The Grosvenor Building, Gordon Street (Alexander Thomson, 1859-61, rebuilt 1866 – the addition, above Thomson's topmost cornice, by J.H. Craigie, 1907).

Offices on St. Vincent Street: on the left, the 'Hatrack' (James Salmon junior, 1899-1902) so-called because of its skyline projections; on the right the cornerpiece by Burnet, Boston and Carruthers, 1899-1900).

Glasgow School of Art, from Sauchiehall Street (C. R. Mackintosh, first phase begun in 1897, the second in 1907).

City from Blythswood lands, was transformed from a procession of unremarkable terraced houses into Glasgow's most fashionable shopping street with 'the best mixed 19th- and early 20th-century group in the whole country'[2] (see above). The style of Victorian Glasgow was generally classical, often personally interpreted and seen at its most idiosyncratically original in the work of Alexander 'Greek' Thomson (left). In the later years of the Victorian age, some leading Glasgow architects turned from the regularising discipline of classical design to the expressive freedom offered by Art Nouveau. The 'Glasgow Style' of Art Nouveau is more easily recognised – that is to say more homogeneous – in the decorative arts than it is in contemporary architecture, which encompassed both the bristling elegance of the Hatrack building (by James Salmon junior) (left, bottom) and the austere eclecticism of Charles Rennie Mackintosh. Thomson and Mackintosh are deservedly the most famous of Glasgow's architects but Mackintosh, unlike Thomson, had little opportunity to contribute to the architectural heritage of the city – apart, that is, from his masterpiece, the Glasgow School of Art, one of the great buildings of its time (above).

The City Chambers, George Square (William Young, 1882-90).

Glasgow in the second half of the 19th century found its apposite expression in new and grandiose municipal buildings erected during the 1880s on the east side of George Square, where they replaced a row of modest 18th-century terraced houses. The City Chambers (above) make an appropriate symbol for the Glasgow of its time in several ways. Their exterior lavishness and interior opulence have been seen to represent, somewhat ostentatiously, a prosperous city proudly aware of its place as the 'Second City' of the British Empire; in their scale and monumentality they also demonstrate the power of the municipal authorities over the well-being of the local citizenry. Significantly, the location of the City Chambers meant a further distancing of the focus of the city from its origins, this just forty years after the move to the City and County Buildings on Wilson Street. By the 1860s the back-lands off the High Street had become a deep sink of destitution with a population living at densities at least as high as anywhere

City Improvement housing: High Street (Burnet, Boston & Carruthers, 1899-1902)(left) and Saltmarket (John Carrick, 1880-1887)(right).

else in Europe and in conditions – graphically preserved for us in the invaluable photographs of Annan seen on page 100 – that could scarcely have been worse. Here and in other neighbourhoods to the north, east and south of the city centre were concentrated the many thousands of immigrants who had arrived in the city looking for work in Glasgow's burgeoning heavy industries. The Merchant City, too, had begun a decline that was not to be reversed until the later decades of the 20th century.

In this age of high capitalism, the response to such problems was what has been called 'municipal socialism'. A number of improvements in public services were initiated throughout the city, beginning with the provision of uncontaminated water and the removal of sewage. During the second half of the 19th century, other public services were brought under municipal control and steps were taken to reduce overcrowding, culminating in an almost complete reshaping of the city's historic core. A Glasgow Improve-ment Act was passed by Parliament in 1866. Over a period of 36 years, the City Improvement Trust progressively cleared High Street, Saltmarket, Bridgegate, Gallowgate and the adjacent backlands of their old structures and redeveloped the area with new tenement housing. The architecture was mostly in a classical manner with direct Parisian influences, but there was also an inventive use of Scottish baronial (page 109). In other settlements around the city – such as Calton and Bridgeton and the Gorbals – where conditions were hardly more salubrious than in Glasgow's historic core, redevelopments were also undertaken by the Trust. These were real achievements of the Trust, but they were made much more for the sake of urban improvement than for the relief of the overcrowding of the masses. This problem was largely shifted to the surrounding neighbourhoods.

The City Chambers turned their back on these problem areas and faced westward, to the expanding commercial district – they still effectively mark its eastern limit – and, beyond that, to new fauborgs for the more affluent classes. Our map of 1841 shows that on the Blythswood Estate construction had proceeded on street block lines as far as Blythswood Square, but then it appears to have run out of steam, leaving much of the grid unoccupied. For by this time those who could afford it had begun to look even further afield for a different style of living, one that was both healthier and more securely distanced from the older and declining parts of the city. There were, of course, others who sought to increase their own wealth by meeting this demand. Landowners all around the city began to look to the development potential of their estates. Over twenty estates of greatly different size were involved in the suburban development of what is now known as the West End of Glasgow. These estates enjoyed great advantages over those lying in other directions from the city. Given improved roads (which came with the regularisation of Great Western Road and the opening of a New City Road – now Maryhill Road – leading to Garscube, both in place by 1840) they were directly accessible to the business centre and, moreover, without the need to travel through areas of destitution. Then there was the natural advantage of the undulating territory which, properly exploited, offered the benefits of fresh prevailing breezes and southerly prospects across the Clyde.

Our map shows the first stages in the development of the West End with the emergence of new residential forms upon the Glasgow scene, forms that were released from the discipline of the orthogonal grid. Around the lower slopes of Woodlands Hill are terraces, some straight, some curvilinear, off-set from the street and with gardens laid out for communal recreation. Architecturally, these south-facing terraces and crescents are organised in palatial symmetry like the grandest of country mansions. These early picturesque developments, accessed directly from the extension of Sauchiehall Street, were soon followed nearby by neo-classical developments generated around St George's Cross, the main junction of the new road layout: Southpark (below) celebrating the entry to New City Road with a grand pair of porticoes (though only one was built) and Queen's Crescent, part of a more introverted scheme related to Great Western Road.

Clarendon Place as illustrated on the feuing plan (by Alexander Taylor, 1839) of the lands of Southpark belonging to W. S. Nisbet Esq.

Top Left: Kirklee Terrace (Charles Wilson, begun 1845).
Top Right: Grosvenor Terrace (J. T. Rochead, 1855).
Bottom: Crown Circus (James Thomson, 1858).

Soon after the opening of Great Western Road, the owners of Kelvinside, by far the largest of the West End estates, commissioned a feuing plan (*c.* 1841) for their estate. The scheme, although it proposed a number of palatial terraces overlooking the thoroughfare, was mostly given to commodious villas, each detached in its own landscaped garden. In fact, this vision of an arcadian suburbia came to naught – only the terraces were built (above). It was not until the 1870s, when the tide of building reached out this far from the city, that the development of Kelvinside gathered pace, this time not to one grand design but in separate parcels under a number of owners and to a variety of plans.

Top: The Park development: Park Terrace, Park Quadrant and Park Circus (Charles Wilson, begun 1855). Bottom: The University of Glasgow (George Gilbert Scott, begun 1866; the tower and spire completed by J. Oldrid Scot, 1887-91).

Changes of plan were the norm in the development of the suburban estates, mostly because the landowners were initially too ambitious, aiming at the higher end of the market. Kelvinside apart, plans were soon revised to accommodate all levels of the bourgeoisie. There was only one West End estate where the need for different kinds of housing for a wide spectrum of society was recognised from the outset. Dowanhill, contiguously south of Kelvinside and stretching down to Partick, was first prepared for feuing in 1853. Over the undulating uplands of the estate were disposed villas and terraces for the well-to-do. The summit of Dowanhill itself was crowned with a circuit of grandly designed outward-looking terraces, providing a prominent advertisement for the new development. Below, on the plain stretching towards the emerging manufacturing base of Partick, a grid was laid down for the building of tenements, appropriate to the growing class of artisans. These features were carried into the construction of the estate, which proceeded slowly over the next 60 years or so.

These private developments lay outside the boundaries of the Municipality. It was east of the Kelvin and within the city limits that, in the 1850s, the Corporation made its own direct intervention in the development of the West End. The Corporation acquired the lands of Woodlands (which encompassed the brow of the hill), Kelvingrove and Kelvinbank together with small contiguous parts of other estates. A feuing plan was prepared

The West End of Glasgow in 1860 (Ordnance Survey).

which incorporated a large public park on the east bank of the Kelvin and, to help pay for it, housing of the most superior kind high up on the plateau of Woodlands Hill. The result is a relationship between terrace and landscape rivalled elsewhere in Britain only in Bath and Marylebone (page 113, top).

By the time of the first Ordnance Survey in the 1860s, most of the estates of the West End had made their initial moves into the competitive housing market. The survey (opposite) shows their fragmentary nature, holding little promise of a coherent urban structure for the expanding Glasgow. But in the later decades of the 19th century and the years leading to the First World War, two developments transformed this suburban scatter into a cohesive, well-serviced and densely populated adjunct to the city (below).

The West End of Glasgow, c. *1930 (Ordnance Survey).*

The first was the establishment of cultural and social institutions in these western parts. Even before its residential development, Kelvinside had attracted a re-location to its pollution-free territory of what were two University-based concerns: the Botanic Gardens and the Observatory. It was, however, the move of the University itself from the High Street (where it gave way to a railway goods yard) to Gilmorehill, the prominent site overlooking Kelvingrove, that proved a decisive moment in the promotion of the West End to being something more than a collection of semi-rural off-shoots from the city (page 113, bottom). Work began on the buildings in 1867 and they were occupied in1870. In a short time, the park and the buildings around the new University site were to constitute a centre for the leisure, education and culture of the region as a whole.

But even more significant in the transformation of the western estates was the second development. As the metropolis encroached upon these lands and as they became more accessible to a wider social range, the building of individual houses – as villas or in terraces – ceased on the estates nearer to the city. Then began that extensive construction of tenement buildings that was to gather together the separated settlements of the West End into a coherent urban complex.

Glasgow's population was rising almost exponentially throughout the 19th century. Through the 1830s, '40s and '50s there was a two-fold increase bringing the total population to around 400,000 by 1861. Between 1861 and the outbreak of the First World War, this figure doubled again. This pre-dominantly working-class population growth offered attractive opportunities for capital investment in the construction of new housing (for the skilled rather than the casual worker) on a modest scale and for rent. In spite of some extreme fluctuations in the construction industry, there was a massive investment in this market and the consequence was a dramatic transformation in the shape and culture of the city of Glasgow.

The bulk of this new housing was in the form of tenements

Great Western Road with (left) Lansdowne Church (J. Honeyman, 1862) and (right) St Mary's Episcopal Cathedral (George Gilbert Scott, 1871-74; spire by J. Oldrid Scott, 1893).

with, on each floor, three flats (or 'houses') of only one or two rooms (or 'apartments') accessed from a common street entrance and stair (or 'close'). The tenements could be of three-, four- or five storeys, though four was the norm. Tenement units were aggregated into rows, rows into blocks and blocks into districts. Since economics dictated an orthogonal subdivision of the available land, in the tenemental quarter, the grid re-appeared, but now on a new urban scale. Such tenemental quarters appeared all around the expanding city. They followed the outward movement of heavy industry to the peripheries and the opening of new docks and shipyards westwards along the Clyde. Tenement rows filled the interstices left in the suburban speculations of the West End and other similar ventures to the south and east of the city. Cliffs of tenements lined the major thoroughfares, their

Parkhead Cross (left, Burnet Boston & Carruthers, 1902; centre, Crawford & Veitch, 1905).

commanding monotony punctuated by the occasional public building (opposite, top) and, perhaps, at intersections by a distinctive Glasgow 'cross', where the tenements would be architecturally elaborated and raised up a further storey or two with skyline features like turrets, domes or spires (left).

By no means were all tenements of the meanest kind. Indeed the grander tenement was adopted in the later development of many of the middle-class suburbs. Thus in the Woodlands area beyond Queen's Crescent, where most of the estate had remained vacant for two decades or so, building activity was renewed in the late 1860s. Over the next 30 years, the district was built-up with tenements on a plan of angled street-blocks generated about the axis of West Princes Street (opposite, top). In Dowanhill, even more up-market flatted housing on the slopes above Highburgh Road brought to conclusion the development which had been initiated in the1850s, while in nearby Hyndland, a new middle-class tenemental settlement of similar quality was established after this area was connected (in 1886) to the city centre by suburban railway (opposite, bottom).

It was the tenement therefore, with its concentration of

Top: Barrington Drive, Woodlands.
Bottom: Hyndland Road.

dwelling, its linear continuity, its intimate relation with the street and its adaptability to different norms and uses, that provided the connective tissue of the expanding city. Through the ubiquity of the tenement and with a population close to a million, Glasgow had become one of the most coherent and densely occupied of cities by the time of the First World War. It was *the* tenement city.

Tenement-building construction was, perhaps, too good or, rather, it was good enough to last well beyond the time when the accommodation and services it provided for the poorer classes could any longer be deemed acceptable (even as late as 1951, half

Public housing, Cranhill, built 1963-6; tower blocks refurbished and refaced 1990-91.

of Glasgow's housing stock was made up of one- or two-room flats, many without their own sanitation). Glasgow became closely identified with its congested, insanitary and decayed tenement housing, blackened by decades of pollution. Post-Second World War reconstruction was therefore targeted on the demolition of its poorer tenement areas and their rebuilding on wholly new, comprehensive lines, following ideas that had first been explored in continental Europe in the 1920s.

During the 1960s and 1970s the Corporation saw the solution to its housing problem generally in terms of high density developments of multi-storey, pre-fabricated building in theory (but rarely in practice) set in landscape and requiring the abolition of traditional urban structures based upon the street. Slabs and towers, ranging from eight to thirty-one storeys, appeared all around the city (above). But the reality did not often match the vision, not least because of inadequacies in construction. By the early 1970s the ill-effects (and high cost) of comprehensive redevelopment were recognised and a halt was called to the programme. However, since demolition of tenement areas necessarily preceded redevelopment, this left the city with large areas of vacant land which, in the straightened economic circumstances of the later 20th century, were to remain derelict for decades.

In the regeneration of the city that began in the mid-1980s with the brilliantly successful 'Glasgow's Miles Better' campaign, nothing has been more significant than the revaluation of its architectural heritage and the rehabilitation of the tenement as an urban form and a way of life. In this change of direction, tenements have been repaired, modified and refurbished, enclosed backcourts landscaped and the street facades stone-cleaned as part of a city-wide campaign that progressively lifted the veil of industrial grime from the rich facades of Glasgow's great ensemble of Victorian buildings. The virtues of tenement housing have, moreover, been recognised in the ongoing rebuilding of the inner-city. In Gorbals-Hutchesontown, the first of Glasgow's post-war comprehensive development areas, the 1987 demolition of notorious deck-access blocks made way for the Crown Street

Crown Street Regeneration Project: Errol Gardens.

Top: Crown Street Regeneration Project: Ballater Gardens. Bottom: the Glasgow Science Centre.

Regeneration Project, launched in 1990. Here has taken shape a restatement, albeit with a difference, of Glasgow's traditional urban character of street-bound housing in three- or four storeys; but in place of the old-style partitioned back-court the inner space of a block has a perimeter of small private gardens with a secure communal play area at the centre (above).

The Clyde, the conduit through which flowed much of the industrial wealth of

Glasgow, has scarcely figured in this brief account of the architecture of the city. For most of the last 200 years it has been a working river – a port, a shipyard, a highway, a supplier of water, a sewer – and rarely has it been dignified architecturally. The closing of the port and most of the shipyards during the second half of the 20th century created the most visible of Glasgow's stretches of dereliction but also, of course, the city's most magnificent opportunity to establish its image as a city with a dynamic future. Sadly, little of what was achieved before the turn of the century fulfilled this expectation. It has taken a Millennium Commission award for the creation of a National Science Centre (opposite, bottom) on the site formed from the part-infilling of Prince's Dock (where the Garden Festival was held in 1988) to raise hope that a regenerated Clyde may have a leading part in the continuing story of the architecture of the city.

NOTES

1 Lord Esher *Conservation in Glasgow: A Preliminary Report* The Corporation of Glasgow 1971.

2 Gomme A. & Walker D. *The Architecture of Glasgow* Lund Humphries, London 1968.

Photographs are by the author except for those on page 100 (Annan); page 113 (bottom), courtesy of Glasgow University Archives); and page 122 (courtesy of Glasgow Development Agency)

From Dalton's Atom to the Atom Bomb

Leslie Barr

During the 19th century the Philosophical Society of Glasgow had as members, or very close associates, a remarkable group of scientists whose work laid the foundation for much of modern science, technology and industry. Many reasons can be advanced for the existence of this group in Glasgow, including the educational system, increasing wealth, the rapid growth of industry and technological innovation in the West of Scotland, but the importance of the idea of matter being composed of atoms, whose relative weights can be found and whose properties have regularities which vary with the weights, cannot be underestimated. It was the good fortune of chemists in Glasgow to be the first in the world to be exposed to this key idea and to have the practical training to play a vital role in working out the consequences.

The Founders: Thomson and Graham

Thomas Thomson was already a distinguished teacher, textbook writer, journal editor and historian when in 1817 he became first lecturer then Regius Professor of Chemistry in the University of Glasgow. More importantly, he had visited Manchester in 1804 where Dalton explained to him his ideas on the atomic composition of matter. Thomson later wrote 'I was enchanted with the new light which immediately burst upon my mind and I saw at a glance the immense importance of such a theory'. He published the first ever account of Dalton's theory in his *System of Chemistry* in 1807. In addition to his advocacy of Dalton's atomic theory Thomson founded in Glasgow the first university school of practical chemistry and after his election as President of the Philosophical Society in 1834 'was largely responsible for changing the moribund Society dominated by artisans into an intellectually competent one'. His work culminated in the start of publication of the *Proceedings* in 1841.

When Thomson was elected President his distinguished pupil Thomas Graham, then Professor of Chemistry at Anderson's University, was elected Vice President. Graham, thoroughly instructed in Dalton's atomic theory and an ingenious and skilled experimenter, took as his main research interest the mobility of atoms in gases and liquids. His interest in this field seems to have been stimulated by Dalton's observation that 'gases of a different nature, when brought into contact, do not arrange themselves according to their density, but spontaneously diffuse mutually and equably through each other, so as to remain in an intimate mixture'.

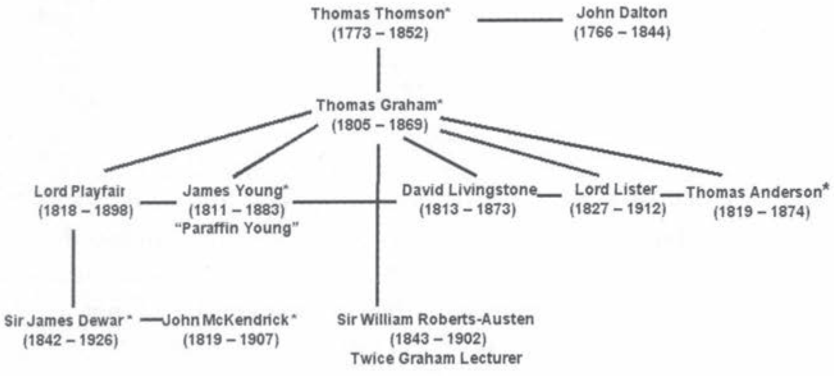
In the course of his researches, Graham invented his diffusion tube – made of glass and closed at one end by a porous plug – which led to Graham's Law: that the rate of diffusion, of a gas varies inversely as the square root of its molecular weight. Graham developed this into the process of atmolysis whereby gases of different molecular weights can be separated by diffusion through porous pipes. This became widely used, and culminated in the huge diffusion plants built to separate uranium isotopes during and after the Second World War.

When Graham extended his studies to diffusion in liquids, the result was Fick's mathematical laws of diffusion, fundamental to all subsequent research in the field, and also to the invention of the process of dialysis (a word coined by Graham) by which solutes can be separated by diffusion through a membrane. This process is, of course, the basis for artificial kidneys.

In 1837 Graham became Professor of Chemistry in University College, London, and in 1855 Master of the Mint. His assistant there, who later succeeded him as Chemist to the Mint, Sir William Roberts-Austen, was twice Graham Lecturer to the Society. In 1879 he gave the first Graham Lecture and in 1900 summarised his own life's work on diffusion in metals and the influence Graham had on him, ending 'I doubt whether he would have wished any other recognition than that universally accorded to him of being the leading atomist of his age'.

Graham's Followers

The figure below shows some of Graham's students and research assistants. The first group (Playfair, Young and Livingstone) attended Graham's lectures on medical chemistry at Anderson's University. They formed a very disparate group but remained close friends and in contact all their lives. Lyon Playfair came from a wealthy and politically powerful background. His grandfa-



Thomas Graham, his predecessors and pupils. Vertical/sloping linkage indicates pupils and research assistants. Horizontal linkage indicates collaboration or close relationships. An asterisk indicates membership of the Society.

ther was Principal of St Andrews University and his father, Inspector General of Hospitals in India. Young, on the other hand, was poor – his father a carpenter – but of great ability: he was Graham's personal assistant. Livingstone was, of course, a weaver studying medicine to become a missionary. All were attracted to Anderson's University because of Graham's high reputation; in Playfair's case instead of some more socially prestigious establishment. One point which turned out to be crucial was that Playfair lodged with a family by the name of Ramsay whose mother had been recently widowed.

Playfair, well launched on a career in chemistry due to Graham, became Professor at Edinburgh and acquired such great scientific and political influence that he could facilitate Graham's appointment to the Mint. However, he was essentially a political animal, becoming MP for the Scottish Universities before being raised to the peerage by the patronage of Gladstone.

It is often said that Playfair's greatest scientific discovery was James Dewar, who became his research assistant at Edinburgh. Dewar, who came from Kincardine, was one of the most skilled experimenters of his age. He became a member of the Society in 1883, while Jacksonian Professor at Cambridge, as a result of his collaboration with John McKendrick, Professor of Physiology at Glasgow and Secretary to the Society. They worked together on the physiology of vision. Dewar, however, is even better known for his work in low temperature physics, a subject he founded; he was the first to make and store liquid oxygen in bulk and also the first to liquefy hydrogen, making use of his invention of the dewar (thermos) flask. He also developed the use of charcoal to absorb gases at low temperatures, a device widely used to improve vacua in many fields of research. With these innovations Dewar not only laid the foundations of the liquid gas industry but even those of space travel.

In 1847 Playfair drew his friend Young's attention to a natural oil well on an estate in Derbyshire. Young followed up this hint, profitably exploited the well, making many important innovations in processing the oil. These included 'cracking' it (a word he coined) to obtain more useful by-products. He later moved back to Scotland seeking new sources of oil and founded a shale oil industry which became the world's largest. He used his wealth to support Livingstone's later expeditions and subscribed largely for the erection of statues of Graham, in Glasgow's George Square, and of Livingstone, near the city's Royal Infirmary. As a distinguished member of the Society he financed the collection and publication of Graham's collected papers.

While he was at University College, Graham had Joseph Lister as one of his students, and there is a story, probably apocryphal, that it was on his advice that the latter undertook further study at Edinburgh, which led eventually to his appointment as Professor of Surgery at Glasgow in 1860. Lister was studying the inflammatory process in wounds – a cause of great mortality – which he believed was due to exposure to air, when Thomas Anderson, President of the Society in 1865, drew his attention to work by Pasteur which showed that putrefaction was due to the presence of minute living particles in the air. Antiseptic and eventually aseptic surgery was the result.

Sir William Roberts-Austen, Graham's last research assistant has already been mentioned. In addition to making the first diffusion measurements in metals – 'My long connection with Graham's researches made it almost a duty to attempt to extend his work on liquid diffusion to metals' – his duties at the Mint led him to study the steels used in making dies, and hence to the properties of steels in general. This in turn led to the chairmanship of a series of influential committees on the properties of alloys, with particular focus on naval armour and shells. The increasing threat of German militarism in the late 19th century had caused a great increase of government concern in this field. By this work Roberts-Austen became a founding father of modern metallurgy. His pioneering work on solid state diffusion led directly to the diffusion technology which is basic to the modern microelectronic industry.

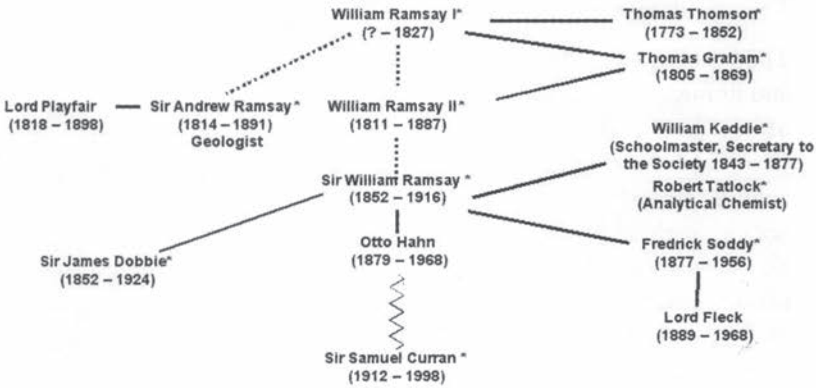
The Ramsay Family

The years around the 1800s were a time of intellectual ferment and numerous societies were founded to promote the spreading of new ideas and useful arts. Typical was the Chemical Society of Glasgow, founded in 1798 by William Ramsay I, an industrial chemist from Haddington. In 1802, when the Philosophical Society with its broader interests was founded, the Chemical Society was dissolved, and William Ramsay joined the new organisation becoming a friend of Thomas Thomson. His grandson, Sir William Ramsay, gave a record book of the Chemical Society to its Philosophical successor.

When William Ramsay I died, his widow took in boarders to assist finances and Lyon Playfair became part of the family circle. He became particularly friendly with Andrew (later Sir Andrew) Ramsay, an amateur geologist, who with Playfair's advice and help became a professional, and eventually Director-General of the Geological Survey.

Sir Andrew's brother William Ramsay II studied briefly under Graham, who was a family friend; he was then apprenticed to Robert Napier, the celebrated shipbuilder, and qualified as an engineer specialising in insurance. He had a great interest in scientific matters and was an early subscriber to *Nature*, which was founded in 1869 by Lochyer.

The figure opposite shows details of these relationships. William Ramsay III (later Sir William) was born at 2 Queens Crescent and later lived at 11 Ashton Terrace. He attended Glasgow Academy, where he was taught science by William Keddie, Secretary to the Society from 1843 until 1877. Later, as a student at Glasgow University, he became a pupil of Sir William Thomson. Because of his interest in chemistry he was apprenticed to Robert Tatlock, the City Analyst and later founder of the famous firm of chemical suppliers; here he started to acquire the manipulative skills which gave his career such distinction. He obtained his PhD at Tubingen where he became fluent in German, and though impressed by the national university and



Sir William Ramsay, his family and research assistants Vertical / sloping linkage indicates pupils and research assistants. Horizontal linkage indicates collaboration or close relationships. An asterisk indicates membership of the Society.

research system, he developed strongly anti-militaristic views, having seen at first hand the triumphalism that followed the Franco-Prussian war. On his return to Glasgow he became an active member of the Society, Secretary of the Chemical Section, and lectured at Glasgow and Anderson's Universities where one of his pupils was James (later Sir James) Dobbie, with whom he later collaborated on chemical research. Indeed Dobbie succeeded him as Chemical Section Secretary, before later becoming Director of the Royal Scottish Museum.

In 1880 Ramsay became Professor of Chemistry at University College, Bristol, and later its Principal, and in 1887 moved on to be Professor of Chemistry at University College, London, where both Graham and his uncle, Sir Andrew, had held chairs. He became deeply interested in teaching and, assisted by Playfair, succeeded in securing funding to match German levels of research and university provision. He maintained his close contacts with Glasgow and the Society through his father and because he inherited a Clyde coast house, Belmont, where he spent his summers sailing and swimming.

Sir William Ramsay

In 1894 Ramsay's career was radically altered by Lord Rayleigh's announcement that there was a small density difference between nitrogen prepared from air and nitrogen produced from ammonia. An example of looking for the next decimal place! Ramsay believed that nitrogen from air might contain a heavier gas and pointed out that in 1783 Cavendish had done experiments that supported this view. With Rayleigh's permission, Ramsay attempted to produce a large volume of this gas chemically. He succeeded, and they jointly announced the discovery at the 1894 British Association meeting. The meeting adopted a suggestion that the gas be called argon, after the Greek for 'idle'.

Ramsay investigated the properties of the new gas and showed it to be completely inert and, from its specific heats, monatomic. This suggested a radical extension of the periodic table which included spaces for a number of inert gases, so far unknown. Ramsay promptly verified this conjecture by obtaining a new inert gas from the mineral cleavite. Spectroscopic studies by Sir William Crookes promptly showed that this gas was the helium which had been suggested as an element by Lockyer on the basis solar spectra observations.

He now started a systematic search for other inert gases which he had provisionally called anglium, scotium and hibernium following the contemporary nationalistic fashion for naming new elements (for example, germanium). He duly found the elements using fractional distillation of liquid air but sensibly turned to Greek for their names: neon, krypton and xenon ('new', 'hidden' and 'strange' respectively).

It is impossible to overestimate the significance of Ramsay's discoveries. They added a new column to the periodic table, created a completely new field within chemistry, and even a new industry, while a detailed study of the helium spectrum now made it possible to obtain clinching evidence for Bohr's atomic theory. Ramsay was awarded the Nobel Prize for Chemistry in 1904, the first Briton to be so honoured.

Thereafter, Ramsay pioneered the subject of radiochemistry, a natural step since he had discovered helium in a radioactive mineral. In 1903 he was joined in this work by Frederick Soddy whom he had examined for his Oxford degree. Together they verified that radium continuously produces helium, strongly suggesting that alpha particles were in fact ions of that gas. Influenced by Ramsay, Soddy joined the chemistry department at Glasgow University where for the next decade he clarified the role of the radioelements in the periodic table and (at a dinner party) coined the word 'isotope' for atoms having identical chemical properties but differing atomic weights. In his experimental work, Soddy was assisted by a technician, Alexander Fleck, whose interest in chemistry he encouraged. Fleck graduated from the University and pursued a career in industrial chemistry, becoming Chairman of ICI and later Lord Fleck. Soddy joined the Society and gave the Graham lecture in 1909. For his work in showing the existence of isotopes and so completing the periodic table as we know it, Soddy was awarded the Nobel Prize in 1921.

Another of Ramsay's research assistants was Otto Hahn who was attracted to work with him by his reputation and German contacts. Ramsay taught him the basics of radiochemistry and gave him an sample of a thorium-bearing mineral from Ceylon, a study of which had suggested that it might contain a new radioactive element. Hahn separated out the element – radiothorium – and Ramsay unselfishly encouraged him to publish the discovery under his name only, allowing him to establish his independent reputation in radiochemical research. Hahn, unfortunately, was less generous in later years. When he published his discovery of nuclear fission in 1938, he excluded Lise Meitner from co-authorship, in spite of their 30 years' collaboration. Indeed Meitner was given no share when Hahn was awarded the Nobel Prize in 1944, an oversight which launched a controversy which is still alive today, almost 50 years later.

The discovery of uranium fission led directly to the atom bomb, in whose development a long-time active member and President of the Society played an active part. Samuel Curran (later Sir Samuel) worked on isotope separation in the USA between 1943 and 1945, during which he invented the scintillation counter, which has become a vital tool in modern science. After that he headed the British fusion bomb project before becoming the first Principal of the University of Strathclyde, the very institution in which, under its earlier name of Anderson's University, Graham himself had taught and researched one hundred and fifty years earlier.

Appendices

1802 2002

Appendix 1: Presidents of the RPSG 1802-2002

1802–04	Dr William Meikleham
1804–06	John Geddes
1806–07	George McIntosh
1807–08	Dr James Monteath
1808–09	Dr James Watt
1809–11	Richard Gillespie
1811–15	James Denholm
1815–16	James Fleming
1816–17	Dr Robert Watt
1817–20	John Geddes
1820–27	Robert Hastie
	Alex Watt
1827–34	Andrew Liddell
1834–52	Dr Thomas Thomson
1852–54	Walter Crum
1854–56	Dr Allen Thomson
1856–58	Prof. William Thomson
1858–60	Prof. Thomas Anderson
1860–62	Prof. W. J. Macquorn Rankine
1862–65	Prof. Henry D. Rodgers
1865–68	Dr Francis Hay Thomson
1868–71	Dr James Bryce
1871–74	Prof. Robert Grant
1874–77	Prof. William Thomson
1877–80	Dr Andrew Fergus
1880–83	Dr William Wallace
1883–86	Dr Henry Muirhead
1886–89	Dr James B. Russell
1889–92	Prof. J. G. McKendrick
1892–95	Prof. John Ferguson
1895–98	Dr Ebenezer Duncan
1898–1901	Lord Blytheswood
1901–04	Prof. Archibald Barr
1904–07	David Murray
1907–10	Freeland Fergus
1910–13	Prof. John Glasister

1913–16	George Neilson
1916–19	John Edwards
1919–22	William Gillies
1922–25	Charles R. Gibson
1925–28	Prof. J. Graham Kerr
1928–31	George A. Mitchell
1931–34	Prof. W. S. Scott
1934–37	Dr James Weir French
1937–40	Prof. Edward Taylor Jones
1940–43	George Henry Edington
1943–44	Prof. Edward Hindle
1944–47	Sir Robert Bruce
1947–49	Prof. Thomas Alty
1949–51	Prof. James W. Cook
1951–52	Sir Archibald Campbell Black
1952–56	Dr John Norman Cruickshank
1956–59	Prof. James Small
1959–62	Prof. Esmond Wright
1962–63	Sir David Stirling Anderson
1963–65	Angus MacDougall
1965–67	C. B. Esslemont
1967–69	John C. Neill
1969–71	Prof. William Fletcher
1971–73	Dr I. W. Pinkerton
1973–76	James McL. Fraser
1976–79	Muriel K. A. Smith
1979–81	Dr Paul Bacsich
1981–83	Dorothy Dick
1983–85	Dr Neil D. S. Bell
1985–87	Dr George A. P. Wyllie
1987–89	Dr T. Scott Wilson
1989–91	John Little
1991–93	Jenny Johnston
1993–96	Prof. L. W. Barr
1996–98	Dr Arthur M. Shenkin
1998–2000	George Gorman
2000–2003	Ephraim Borowski

Appendix 2: Honorary Memberships from 1860

1860	Prof. Loomis	New York
	Prof. Jos. Henry	The Smithsonian
	Prof. J. Dana	Yale
	M. Chevreal	Paris
	M. le Verier	Paris
	M. Dumas	Paris
	Prof. Helmholtz	Heidelberg
	Prof. Kolliker	Wurtzburg
	Baron Leibeg	Bavaria
	Prof. W. Weber	Liepzig
	Prof. Faraday	London
	Principal J. D. Forbes	St Andrews
	W. Hopkins	Cambridge
	Dr J. P. Joule	Manchester
	John Mercer	Oakenshaw
	General Sabine	London
1874	Prof. A. C. Ramsay	London
	Prof. Ellery	Victoria, Australia.
	Robert Lewis	Victoria
	Prof. J. D. Hooker	London
	Dr R. A. Smith	Manchester
1875	W. Froude	Torquay
1876	T. H. Huxley	
1878	Prof. Allan Thomson	London
1879	Herbert Spencer	
1880	Ernst Haeckel	Jena
	John Tyndal	London
	Dr Andrew Buchan	Glasgow
1883	Sir J. W. Dawson	McGill University
1885	Louis Pasteur	Paris
	The Rev. John Kerr	Glasgow
	Sir Gabriel Stokes	Cambridge
1889	Sir Max Muller	Oxford

1890	George Quinke	Heidelberg
	Lord Rayleigh	London
1892	Thomas Muir	Cape Colony
1895	Sir Archibald Geikie	Surrey
	Prof. S. P. Langley	The Smithsonian
	Lord Lister	
1896	Lord Kelvin	Glasgow
1898	Dr J. B. Russell	Glasgow
1902	Prof. E. A. Schafer	Edinburgh
	Sir W. Ramsay	London
	Prof. D. Mendeléeff	St Petersburg
1908	Sir W. Crookes	London
	Sir David Gill	London
	Prof. A. B. Macallum	Toronto
1918	Sir Herbert Maxwell	Wigtownshire
1922	The Earl of Balfour	London
1923	Prof. I. Pavlov	Petrograd
	Ronald Ross	London
	Sir J. J. Thomson	
1925	Prof. H. E. Armstrong	London
	Sir J. G. Frazer	London
	Prof. Andrew Gray	Glasgow
1926	Sir Arthur Evans	Oxford
	Sir Ernest Rutherford	Cambridge
	Dr Albert Einstein	Berlin
1931	Sir C. Raman	Calcutta
	Sir Donald MacAlister	Glasgow
	Prof. F. O. Bower	Glasgow
1965	Sir Charles Wilson	Glasgow
	Prof. S. C. Curran	Glasgow

Appendix 3: Selected Acknowledgments from Honorary Members

From Professor Pavlov

I beg to present my most cordial thanks to your President, yourself, and all the members of The Royal Philosophical Society of Glasgow, for the great honour conferred upon me. It is my sincere wish that my future scientific work should justify such attention. I send my best wishes for increasing prosperity to your Society.

From Professor Rutherford

I have rcceived your letter announcing that I have been made an Honorary Member of The Royal Philosophical Society of Glasgow. I have much pleasure in accepting the proposal, and appreciate the high mark of distinction from your Society. As my ancestry is half Scottish, I value all the more this mark of recognition from the representatives of an all-Scottish Society.

From Professor Einstein

I thank you heartily for the great distinction which you have conferred upon me. I have always refrained from writing treatises on philosophy, and am thus compensated.

From Sir Arthur Evans

Your kind letter informing me that The Royal Philosophical Society of Glasgow has elected me an Honorary Member has been forwarded to me at Knossos where I am presently working. I need hardly say how greatly I value such an honour from a Society for which I have a very high respect. May I ask you to convey to the Society my sincere thanks for the honour that they have conferred on me, and which I feel to be a great encouragement to my work.

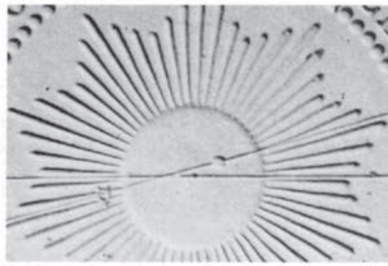
Appendix 4: Membership of the RPSG 1802-2003

1802-03	67 members
1812	129 members
1822	92 members
1832	47 members
1842	137 members
1852	270 members
1862	291 members
1872[1]	533 members
1882	676 members
1892	628 members
1902[2]	975 members
1912	976 members
1922	1133 members
1932	968 members
1942	862 members
1952	536 members
1962	311 members
1972	271 members
1982	230 members
1992	212 members
2002	340 members
2003	420 members

1 1876 BAAS Meeting

2 Centenary

Appendix 5: The Seal of the Society: the transit of Mercury 9th November 1802



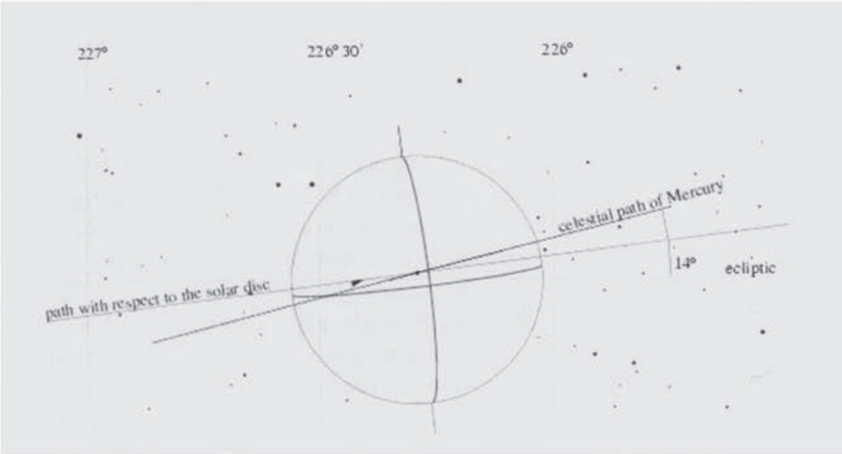
Seal detail: The position of Mercury corresponds to a time of about 1000 UT.

The seal of The Royal Philosophical Society of Glasgow is thought to depict the transit of Mercury (across the face of the Sun) that occurred on 9th November 1802 – the day of the first meeting of the Society. The centre of the design on the seal (right) appears to show two lines across a solar disc making an angle of approximately 15°. The slanted line is clearly labelled with the symbol for Mercury and has a smaller disc upon it, offset from the centre. The other line is not labelled. Around the solar disc are 60 radial rays, 6° apart. The unlabelled line across the solar disc does not quite align with any of these rays, being rotated anticlockwise by about 3° around the central axis.

Interpretation

The appearance of the 1802 transit was reconstructed using the commercial software package Starry Night Pro (v 3.0.2, Sienna Software). The task was well within the quoted accuracy of the software, and the predicted time of central transit (0859 UT) agrees with that from the JPL DE406 Ephemerides for this transit. For completeness, the viewing location was taken as Glasgow.

The transit began at 0616 UT on the morning of 9th November, well before sunrise (0742 UT). Local noon was at 1201 UT. The transit ended at 1141 UT that morning, and at the mid point of the transit, Mercury was very close to the centre of the solar disc. This central instant is depicted in the figure opposite, showing the position of Mercury and the Sun at 0859 UT with respect to (unobserved!) background stars in the constellation of Libra. The Sun at this point is at RA 15h 6m.34, dec 17° 30′.3 (J2000), and is shown with its rotation axis, equator and prime meridian



The solar disc at 0859 UT on 9th November 1802, as seen from Glasgow. The verticals show lines of constant ecliptic longitude.

for reference. The other lines crossing the solar disc are the ecliptic (taken as roughly the celestial path of the Sun), the celestial path of Mercury and the path of Mercury with respect to the solar disc. This last line needs some explanation. The Sun is moving right-to-left with respect to the background stars, and Mercury is moving left-to-right. The vector difference represents the apparent motion of Mercury across the solar disc, and therefore the view an observer would see if tracking the Sun with a polar-mounted telescope.

The diagram shows that the angle between the ecliptic and the celestial track of Mercury is approximately 14°. If an observer has written down the right ascension and declination of Mercury and of the Sun during the transit and plotted these, the two tracks would have made an angle of 14°, close to the 15° measured from the seal. However, the *apparent* path of Mercury with respect to the Sun subtends a much shallower angle with the ecliptic, so it is unlikely the seal accurately depicts the transit as it would appear to progress to a casual observer.

It is not obvious that the horizontal line across the solar disc represents the ecliptic; however, lines of constant altitude (as seen from Glasgow) and of constant declination both subtend too great an angle to either path of Mercury to work, so the ecliptic appears the best choice.

Conclusion

The angle between the lines on the seal corresponds well with that between the celestial tracks of the Sun and Mercury during the transit. It is therefore consistent with a retro-calculation of the transit from an ephemeris. It does not, however, accurately represent the track of Mercury across the *disc*.

The 3° deviation of the ecliptic with respect to the rays does not seem to have any significance, as the computed solar rotation axis appears tilted by 7° to a line of constant ecliptic longitude. The size of the planet is also greatly exaggerated. At 10 arcsec, it would appear as only 1/192 times the apparent diameter of the Sun.

Graham Woan