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CONTENTS

LIBRARY CIRCLE MEETING

Thursday, 31st January, 1966

THE ROYAL INSTITUTION'S MANUSCRIPTS – HUMPHRY DAVY AND W. R. GROVE

By K. D. C. VERNON, F.L.A.
Librarian of the Royal Institution

James Lawrie,
in the Chair

THE Library Circle Meetings were started thirteen years ago. Their objects were to provide Members and others with the opportunity of getting to know better the fascinating and varied contents of the Institution's fine Library and manuscript collection; to provide a forum for the discussion of subjects connected with books; and to consider aspects of the Institution's history. Sixty-three informal meetings have now been held, and the speakers have always been Members, staff, or friends of the Institution. We have been delighted, instructed, amused and fascinated by their talks, which have usually been illustrated either by lantern slides or by a display of books from the Library. We are grateful to the speakers who have given so freely of their time and we are glad that many of these talks have reached a wider audience by being printed in the *Proceedings*. In addition the studies which have been made in the Institution's history have contributed towards our understanding of the lives and achievements of the great men who have worked in this famous place during the past 167 years.

The full history of the Institution must one day be written. The story will be found in our manuscripts and archives and so it seems appropriate that before I leave the Institution's service I should tell you a little more about the manuscripts and leave you with some notes on their extent.

The collection spans the nineteenth century, and now, with the recent addition of Sir William Bragg's papers which Sir Lawrence and Mrs. Caroe presented to the Institution in 1964, extends well into the twentieth. It is a collection of great importance in the history of science and contains much of the immense contribution to knowledge which leading British scientists, working at the Royal Institution, made over a period of about 130 years. The collection is therefore of national importance, and it is incumbent on the Institution to preserve it in the best possible condition and to encourage scholars to make use of it.

Parts of the collection have been well studied, but many untapped resources remain, and for years to come historians of science will doubtless come here to work on these manuscripts and reveal new aspects in the rapid development of science since 1799.

By the publication of Faraday's *Diary* between 1932 and 1936 the Institution made a great contribution to scholarship. As a result of the facilities granted to scholars some important biographies and shorter historical papers have been written on Davy, Faraday, Tyndall and others. Faraday's selected correspondence is now being prepared for publication under the editorship of Professor L. Pearce Williams. Davy's letters will probably be published before very long by Professor J. Z. Fullmer. Thus the riches of our collection are gradually being revealed. But in order to facilitate further research the Institution has a big task ahead. Money must be provided for all the indexing, repair and binding which needs to be done in order to preserve the collection and exploit it for the benefit of the history of science.

The collection roughly comprehends the following groups of manuscripts and papers:—

1. *The Royal Institution's archives*: (*a*) Minute Books since 1799 of the Managers, Visitors, General Meetings and various committees, from 1799 onwards; (*b*) lists of Members; (*c*) guard books containing printed notices, balloting lists, syllabuses of lectures, etc.; (*d*) miscellaneous correspondence and papers about the Institution's work and affairs.

2. A very large collection of *Davy*'s manuscripts.

3. *Faraday*'s letters, laboratory notebooks, lecture notes and collections of printed and manuscript papers, including books bound by him and books which he bequeathed or presented to the Institution.

4. The great collection of *Tyndall*'s manuscripts, which pro-

vide much scope for further study and urgently require to be indexed.

5. *John Davy*'s manuscripts, which have never been properly listed or studied.

6. The *Dewar* collection of numerous notebooks, papers and letters, which also should be indexed.

7. Sixteen volumes of *Sir William Crookes*' laboratory notebooks covering the period 1881—1919. The remaining volumes are in the Science Museum.

8. The almost unknown collection of *W. R. Grove*'s letters and papers.

9. *Sir William Bragg*'s notebooks and papers. These surely should be indexed, studied and published by the Royal Institution, which is the very home of crystallography.

10. A small collection of *Rumford*'s letters and papers.

11. Letters, papers and miscellaneous writings of others connected with the Institution such as Earl Stanhope, John Barlow, J. P. Gassiot, and E. D. Clarke.

Some obvious gaps exist and it is highly desirable for the Institution to acquire, if possible, some of the manuscripts of Thomas Garnett,* Thomas Young, Thomas Bernard, William Spottiswoode and William Odling, for example. In addition, it seems a great pity that we possess so few of the manuscripts of our founder, Count Rumford.

That summarises the extent of our collection. Now let us turn to Davy and W. R. Grove and consider their manuscripts in rather more detail.

Davy's Manuscripts

This collection can be divided into four groups as follows:—

(*a*) Laboratory notebooks.
(*b*) Papers and lectures.
(*c*) Personal notebooks and sketchbooks.
(*d*) Letters.

Davy, you will remember, only lived for fifty-one years, from

*Since this talk was delivered two Garnett letters have been purchased by the Royal Institution.

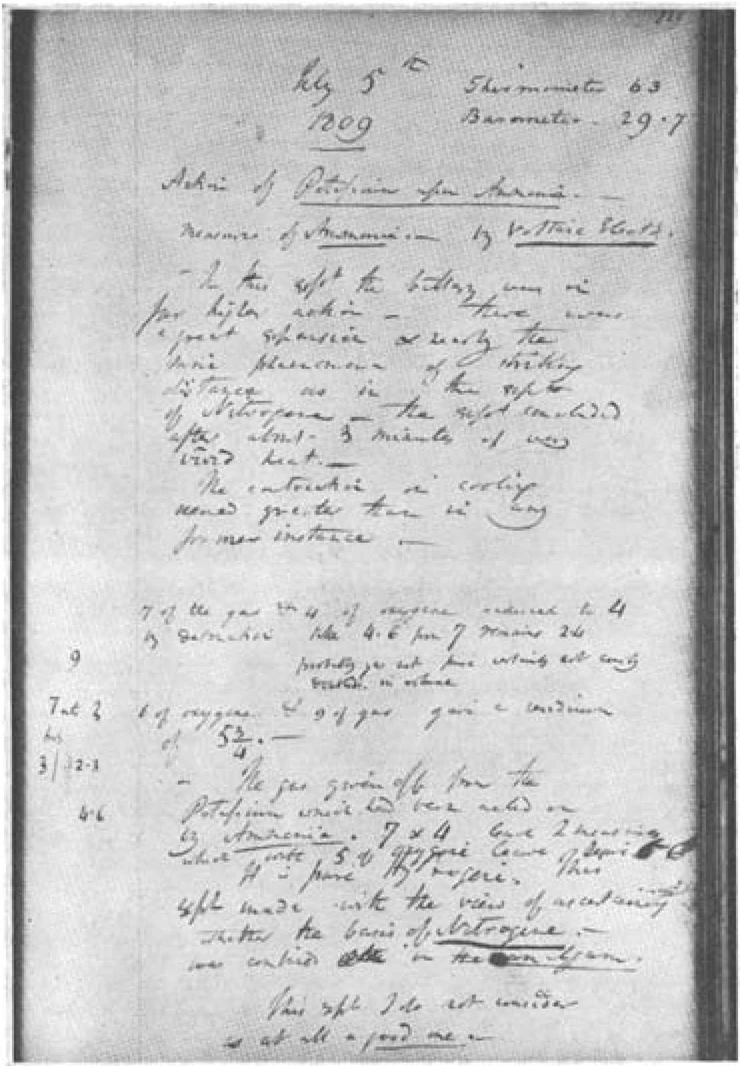
1778 to 1829. His most important research was crowded into about fifteen years, from 1801 to 1816, when he worked in the Laboratory at the Royal Institution. It is naturally that period which interests us most, and his manuscripts reveal, in fascinating snatches, something of his character, his thoughts and his method of working.

While he was working at the Pneumatic Institution in Bristol under Dr. Beddoes he discovered that nitrous oxide had anaesthetic properties. He lived at that time in a circle of brilliant young men—Coleridge, Southey, Gregory Watt—who allied science with literature. Count Rumford heard about him and brought him to the Royal Institution in February, 1801. Here Davy seized the opportunity which the Institution's laboratory and lecture theatre offered to him. Now he was on the way to great scientific achievement, fame and fortune—but not, unfortunately, to happiness.

After Rumford went to France in 1802, Thomas Bernard and others reorganised the Institution and based their policy largely on Davy's brilliance. Bernard "cultivated" the slightly uncouth young man and introduced him to a wealthy and influential society of scientists and noblemen. Davy enjoyed this new life to the full; but he asserted his independence as a scientist and determined his own line of research, even though he was required by the Managers of the Institution to spend part of his time investigating processes of dyeing and tanning leather, collecting mineral specimens and lecturing on geology and agricultural chemistry. Perhaps this rather trivial work wasted some of Davy's precious time and interrupted his vastly more important chemical researches. Nevertheless he achieved much; so let us look at the manuscripts which show him at work in his basement laboratory ,here at the Royal Institution.

(*a*) *Davy's Laboratory notebooks* show us his method of research. (See, for example, Plate I.) They consist of three folio volumes covering, intermittently, the years 1805-21. They were preserved for us by his assistant Faraday, and this is what Faraday wrote in 1829 in the front of the first volume:—

> These two volumes contain the Experimental notes made in the Laboratory of the Royal Institution from October 1805 to October 1812 during which time *Sir H. Davy* was Professor of Chemistry.



July 5th 1809 Thermometer 63
Barometer 29.7

Action of Potassium upon Ammonia. —

Measure of Ammonia by Voltaic Electy.

— In this expt the battery was in far higher action — there was a great expansion & nearly the same phenomena of striking distance as in the expts of Nitrogene — the expt concluded after about 5 minutes of very vivid heat. —

The contraction in cooling seemed greater than in any former instance —

7 of the gas & 4 of oxygene reduced to 4 by detonation like 4.6 from 7 [illegible] 2.6

[illegible]

9

7 at 2 [illegible]

3 | 32.1

4.6

1 of oxygene & 9 of gas gave a residuum of $5\frac{3}{4}$. —

— The gas given off from the Potassium which had been acted on by Ammonia. 7 & 4 [illegible] which [illegible] 5.0 [illegible] It is pure Hydrogene. This expt made with the view of ascertaining whether the basis of Nitrogene was contained [illegible] in the [illegible].

This expt I do not consider as at all a good one. —

A typical page from one of Davy's Laboratory Notebooks.

PLATE I

> After I knew Sir H. Davy he occasionally tore away leaves upon which notes had been written that he might carry the data home for consideration but I presume that during the time he resided in the house of the Institution there would be no inducement to do so and that these two volumes have been but little injured in that way.
>
> For their future security I have this day paged the leaves regularly. There are 265 pages in this volume and 691 in the other not one of which is wanting.

Davy was always very good to his family, and so when he needed assistants to help him in the Laboratory he appointed first Edmund Davy, his cousin, who later went on to make his mark as Professor of Chemistry at the Royal Dublin Society, and then his younger brother John Davy. Humphry took a great interest in training John and in helping him in his early career as a doctor. John greatly admired his elder brother and in 1836 he published his *Memoirs of the Life of Sir Humphry Davy, Bart.*, in two volumes.

When Faraday came to the Institution in 1813 as Davy's assistant he was given a long and thorough training in chemistry by the great man. They worked very closely together, first as master and pupil and later as colleagues. Davy's assistants, including Faraday, wrote up much of the research in the Laboratory Notebooks and consequently they contain a mixture of handwritings—Humphry and Edmund Davy's and Faraday's.

A fourth volume in the same series spans the years 1821 to 1859, but this volume of course contains little of Davy's work. It deals mainly with the researches of Faraday and W. T. Brande.

It would be a great undertaking to edit and publish these Laboratory Notebooks, but the Institution should consider this matter. Perhaps these volumes should be reproduced on microfilm or microcards or made available in book form by the xerox process so that scholars could study them.

(*b*) *Davy's personal notebooks and sketchbooks* are the next group of manuscripts. They were written between 1795 and the end of his life, and in these small volumes we can glimpse the real Davy and the many facets of his character—his poetry, his philosophising, his geological sketches, accounts of his travels, scientific notes and parts of lectures. They were written in ink and pencil, sometimes beginning at one end, sometimes at the other, and they contain numerous little sketches of faces or other doodles

One of the faces which were suggested to Davy by geological features.

PLATE II

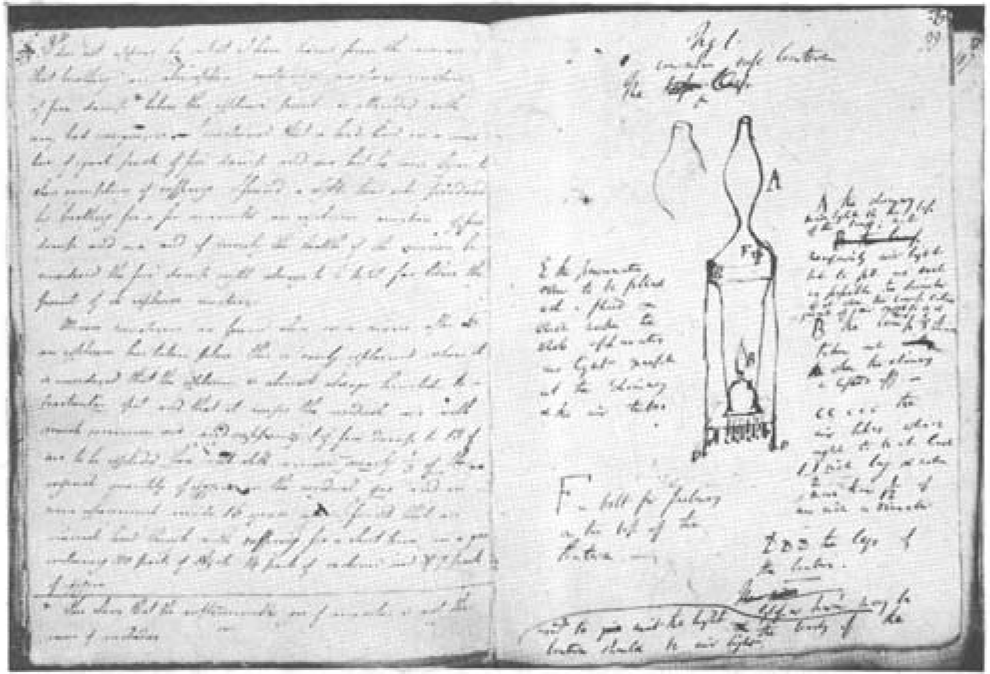
(Plate II). Some of the pages have been torn out, and one wonders whether the faithful brother John did this in order to hide his brother's hints at amours and other private affairs. Professor Fullmer has been studying these notebooks, and will probably describe their contents in detail.

The geological sketchbooks show Davy's sketches of rocks and scenery, and it is interesting to see his free style with the pencil. He kept these notebooks during his frequent travels in the British Isles while he was collecting specimens for the Mineralogical Collection at the Royal Institution, and probably he also used these notes in the preparation of his geological lectures.

(*c*) *Papers and lectures.* This group of manuscripts includes two volumes of papers which Faraday collected while he was assisting Davy in his work on the safety lamp and other research about the same time. They are of particular interest because they show how Faraday wrote up the work in his clear handwriting with neat diagrams from Davy's rough notes (Plate III), and it is probable that the volumes were also bound by Faraday.

Then we have Davy's notes for his lectures on agriculture and geology. Many of them appear to be the texts of the lectures, and it is interesting to speculate that perhaps Davy used to write out his lectures in advance; but it would seem improbable that such a fine lecturer would speak from anything more than notes. Perhaps somebody should investigate more closely Davy's lecturing methods, as I feel sure that much could be learnt from a close study of how he achieved his remarkable success as a lecturer. Incidentally, the lectures on geology are incomplete; but the remaining manuscript lectures are in the Library of the Royal Geological Society of Cornwall at Penzance. It would surely be beneficial to scholarship if the two collections could be amalgamated for study, and the manuscripts suitably restored and bound. These manuscripts have probably not been checked against Davy's published works to ascertain whether the lectures have indeed all been published.

(*d*) *Letters.* There are numerous other miscellaneous Davy manuscripts in the Royal Institution collection, but only the letters need be mentioned here. The Institution has some 330 of these and most of them were presented in 1925 by Sir Humphry Davy Rolleston. About half of the letters are to or from Lady

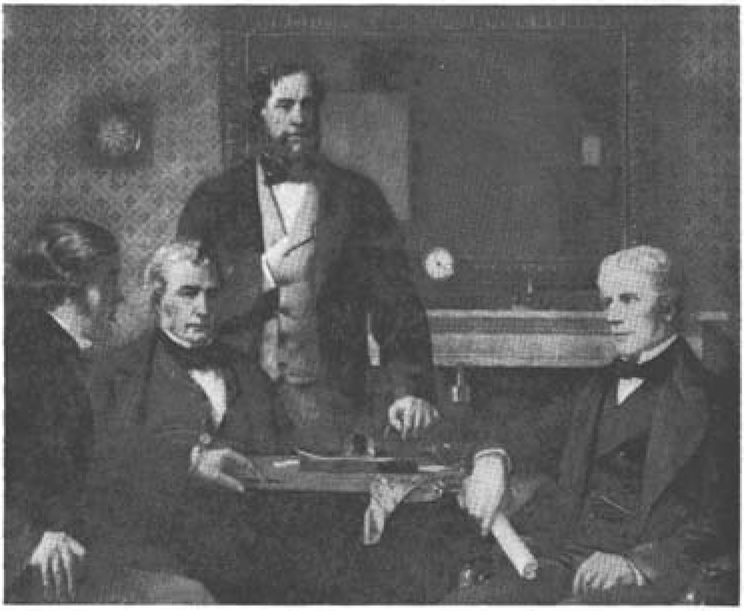


Work on the miner's safety lamp: notes by Davy (right) and Faraday (left) on facing pages.

PLATE III

Davy and members of the Davy family and it is evident that Davy's strong affection for his family continued all his life. The other half of the collection are letters to and from numerous friends and scientific colleagues, but few are of real scientific interest. These letters will mostly be published by Professor Fullmer.

During recent years we have indexed these letters, but a big



Grove (standing) on "a deputation to Faraday".

PLATE IV

and expensive preservation task remains. The letters are in urgent need of repair, mounting and binding—perhaps transcripts should also be bound with the letters as they are sometimes very difficult to read. This is a task which should certainly be started quickly.

I have said enough to indicate the resources of our Davy Collection and I hope it will be agreed that these manuscripts, which are a national treasure, must be afforded the care and attention which they so urgently require.

You can have no idea, my dear Sir, of the sorrow with which I have been viewing the diaphanous atmosphere of this evening, nor how bitterly I have been reproaching myself that we are not now performing our duty at Hartwell, for such nights as this are truly rare. I sought you in the sylvan retreat of Hare Court to plot a move, but not finding you there, I allowed my time to be devoured by very secondary concerns. [illegible]

A letter from the Grove collection.

PLATE V

K. D. C. VERNON

The manuscripts of W. R. Grove

While preparing a general handlist of the Institution's manuscripts in 1964 I discovered a cardboard box, which originally came from Harrods, addressed to Sir William Bragg. It contained nearly 500 manuscript letters, mostly written to W. R. Grove, and a collection of his papers. Here indeed was an exciting find. The collection was presented to the Institution in 1940 by Mrs. Grove-Hills, who is now ninety-nine and still a Member. It was officially recorded as a gift in the Managers' Minute Books, but evidently, because of the War, had never been examined. So now for the first time we can take a somewhat superficial glance at this very significant collection; and I am glad that we are able to do this appropriately at a Library Circle Meeting. Others, however, must soon study these manuscripts more critically to find what they have to add to our knowledge of nineteenth-century science.

William Robert Grove (Plate IV) had a long life. He lived from 1811 till 1896 and witnessed most of the great scientific advances made during the nineteenth century. He played an active part in many of them and, like Davy, he was a man of two cultures—science and the law.

Grove was the son of a magistrate and was born in Swansea. He was educated first by private tutors and then at Oxford. He was called to the Bar in 1835, but his indifferent health prevented him for a long time from becoming fully active in the law. This, however, left him free to spend time on his real natural bent—scientific research. Again, like Davy, he carried out most of his really important research in a comparatively short time and published the results during the ten years from 1839 to 1849.

As a scientist he is remembered mainly in three capacities: (1) as the originator of the Grove Cell in 1839; (2) as the inventor of the fuel cell— he called it his gas voltaic battery, but he probably did not envisage this as a practical producer of electrical energy, and it is only now of course being developed for this purpose; (3) as the author of that very important book *On the Correlation of Physical Forces* which was first published in 1846 and anticipated the work of Helmholtz and Joule on the conservation of energy.

Grove then became a leading figure in scientific affairs in this

18th Nov. 1867—

My dear Grove—

Here's a pretty "fix". I will state the matter, & leave you to rule it down. Mr Horner writes to express his regret that he forgot — aye forgot — he was on the Committee, when he signed Galloway's testimonial for the T.C. So pray arrange the case righteously, and thereby oblige

Your's very truly,

W. H. Smyth.

The opening page of another letter from Admiral W. H. Smyth to W. R. Grove.

PLATE VI

country, besides carrying on his legal work. For a time he was Professor of Experimental Philosophy at the old London Institution in Finsbury Circus, an organisation very like the Royal Institution. He worked immensely hard for the Royal Society and for many years was one of the most active Fellows in the Society's affairs, being largely responsible for revising its statutes in 1846. This revision opened the way for the Royal Society to restrict its elections of Fellows to scientists—a much needed reform which lifted the Society out of the decline into which it had sunk. In 1847 he formed the Philosophical Club of the Royal Society which was a dining club for the Society's reformers, who were dedicated to the purpose of checking any retrograde tendencies on the Council!

Grove was also a great worker for the Royal Institution, being a life member from 1835 onwards. He gave seven Friday Evening Discourses, the first in 1852 *On the Heating Effects of Electricity and Magnetism*, the last and perhaps the most famous on *Antagonism* in 1888. He served as a Manager for many years and as a Vice-President. In addition Grove was a founder member of the Chemical Society in 1841.

As a lawyer also he became famous, and his reputation as a scientist brought him many briefs in patent cases. He took silk in 1853, becoming a Q.C. In 1856 he was counsel for the defence of the notorious poisoner William Palmer in the great Rugeley murder case, and in 1871 he was appointed a Judge in the Court of Common Pleas. He retired from the Bench in 1887, when he returned joyfully to his scientific studies at the age of 76.

Letters to Grove

The collection of letters is so voluminous that it would be impossible to give more than a brief introduction to them in this talk; so let us merely dip into this treasure trove and look at a few letters at random.

Two delightful letters from Admiral W. H. Smyth are reproduced in Plates V and VI.

Here is one from that well-known scientist-statesman Lyon Playfair, asking for Grove's support in his application for the post of Professor of Chemistry at Edinburgh:—

34 Cleveland Square,
Hyde Park St.
22 May/58

My dear Grove,

Anxious, now that I am able, to devote myself to science, without the distractions of public office, I have consented to my Edinburgh friends placing me in the list of candidates for the Chair of Chemistry. But now I find to my great disgust that I must either consent to be beaten or I must bother my friends for testimonials. The Edinburgh Town Council, the electors, in this instance, support in all its viciousness this testimonial system & consider it the only Evidence within their reach.

I am very unwilling to ask for it, but you would do me a great favour if you would write me a letter alluding to my taking active interest in scientific pursuits in London & especially to my qualifications as a lecturer, of which at some of the Friday Evening Meetings you have lately heard some of my discourses—I am very sorry to bother you, but having been plunged into this caucus, I must get some planks to enable me to swim ashore.

Yours truly
Lyon Playfair

Playfair was successful in his application, and famous though he was he evidently thought that Grove's support was necessary.

This undated letter from the botanist Sir Joseph Hooker, who was a friend of Darwin and a champion of his theories, discusses the origin of species with Grove:—

My dear Grove,

I hear you are about to do battle in Nat Hist: or at least to touch the question of the origin of species. You have most likely not had time to go into the literature of the subject—which is very voluminous & I therefore take the liberty of sending you a little paper of my own on one branch of the subject. I wish that Mr. Powell could have seen it before he wrote, not that it wd. have modified his views at all, but it would have shewn him that there are a large class of facts upon which the opposite party have laid more or less stress, but of whose existence and nature he does not seem aware—unfortunately they are those which it requires some experience of to appreciate—for after all Nat Hist: is like medicine—easily theorized upon in the absence of facts.

C. Darwin can give you better help than any man in Europe & he is on Powells [*sic*] side—I withold [*sic*] any opinion of my own until I am 10 years older.

Ever yrs [?]
Joseph Hooker

Kew Tuesday Mg.

The following three letters are of particular interest to Members of the Royal Institution:—

Stanwick
Darlington
16th June 1849

My dear Sir.

I thank you for the paper on the effect of surrounding media on Voltaic Ignition, which you interested me about one Friday evening at the RI Instn.

Now, I have a request to make to you & will offer my thanks beforehand if you will kindly accede to it. The rules of the Rl Instn permit the President to consign his key of the Great Seal of the RI Institution to a Vice President.

May I request you to take charge of that key. For if there be any mark of respect in the trouble given by such Trusteeship, there is no one to whom such respect is more due, than to yourself—for the assistance you give to the Royal Institution by your talents; which is acknowledged by all the Members, and by none more than

Yours truly
Northumberland

W. R. Grove Esq. MA
VPRS

4 Sussex Gardens
Jany 27th.

My dear Sir,

I have a very strong wish to hear your lecture & to see your experiments, but unfortunately my health will not allow me to struggle with the crowd, at the Royal Institution, nor possibly, can I remain, during the whole evening, but having an admission ticket, I should be greatly obliged, if you can enable me to get into the Room privately & without pressure.

I could call upon you at the Institution at any time you desire, if my request is not unreasonable.

Very truly Yours,
Wm. Henry Fitton.

W. R. Grove Esqre F.R.S.

Swansea December 4th 1847

My dear Sir—

'Imprimis' accept my hearty congratulations on the attainment of so proud a pinnacle in science. I never fail to point my finger with admiration to the course along which you have travelled to the high station which *you have gained* in science, when occasion requires that I should array before my *drowsy* townsmen the incentives to study, the rewards of talent and the triumph of science. May you long live that Swansea may boast of you as her son, and that your example may be exultingly cited to inspirit and encourage others less gifted. In the next place I thank you very sincerely for introducing my humble name to the R. Instn—and especially for the warm interest and concern which you have shewn with respect to my lecture. I will tell you precisely how I am placed in regard to the subject and materials of my lecture. Since the publication of my last paper in the "Lancet" I have worked out several points of interest, and importance, I think, by operating by means of an extremely feeble Galvanic current on the nervous system of animals and shall soon hope to verify and to add to those experiments which have been published in the 'Lancet'. But at the present immature state of the enquiry I fear that I could not *decidedly* and positively *demonstrate* a sufficient number of novel points to sustain the interest of a lecture before such an audience as that at the Royal Institution. Nor could I with any propriety of conduct towards Dr. Marshall Hall, undertake such a lecture, since the paper, presented by him to the R.I. has been rejected and is still *unpublished*, to the principles developed in which it would be quite necessary that I should copiously refer. . . .

Now comes a serious question for you and for me earnestly to consider. Do you not think that this lecture will operate as a very undesirable *distraction* upon my time and energies and engagements of this all important year?—Do you not think that it is of more consequence to me to distinguish myself!! at the British Association than to deliver a successful lecture in London? The one must in *great part* be sacrificed to the other. Then would you not advise me to postpone this lecture to *next Winter*? I will act implicitly with respect to this important matter on your advice—which I am sure you will give me candidly and without reserve. Remember I am *very* ambitious to give a good lecture at the Royal Institution, and therefore *deeply* appreciate your kindness in having placed me on the list of lecturers. If under the circumstances which I have endeavoured to represent, you *recommend me* to undertake this lecture, I will do my very best, *to do it well*. I shall be very glad to hear from you immediately on the subject. . . .

(extracts from a letter by Thomas Williams)

This list gives an indication of the immense range of manuscript letters contained in the collection:—

- 29 letters from Faraday.
- 7 from Wheatstone.
- 25 from the geologist Sir Charles Lyell, mostly discussing the affairs of the Royal Society.
- 13 from Fox Talbot, the pioneer of photography.

57 from Edward Sabine.
22 from C. F. Schoenbein, the discoverer of ozone.
9 from Sir Roderick Murchison, the geologist who identified the Silurian and Devonian systems.

Other letters were written to Grove by, for example, Charles Babbage, Becquerel, Darwin, J. P. Gassiot, Thomas Graham, Niepce de St. Victor, William Odling, De la Rive and Tyndall.

Enough has been said to indicate the immense reputation which Grove had. He was at the very centre of scientific affairs in this country, and everybody—wealthy noblemen, famous scientists and even an impecunious curate—wrote to him for his advice, for his help and weighty support in matters of law and science. The curate, incidentally, wanted a free copy of *On the Correlation of Physical Forces* because he had six children and was too poor to buy it!

Here then we have a glimpse of William Robert Grove, a giant of nineteenth-century science. He was reputed to have a very bad temper; he loved exercise and used to walk daily between the Law Courts and his home in Harley Street. He achieved much in his long lifetime. He was a prominent figure in the history of the Royal Institution and frequented this place in the time of Faraday, Tyndall and Dewar.

There we must leave the subject. But the task which must be carried out is to put this great collection of manuscripts in good order. They have not received the attention which should have been given to them, and there is an immense amount of indexing, repair, binding and photocopying to be done. It will cost a lot of money, but the funds must be provided. It is a task well worth doing for science, and I look forward to coming back later to see how the Institution has got on with it. To me the manuscripts have been of intense interest while I have been your Librarian.

THE QUASI-STELLAR OBJECTS

By F. HOYLE, M.A., F.R.S.
Plumian Professor of Astronomy and Experimental Philosophy, University of Cambridge

Weekly Evening Meeting, Friday 29th April, 1966

Lord Fleck, of Saltcoats, K.B.E., D.Sc., L.L.D., F.R.S., *President, in the Chair*

THE quasi-stellar objects, or QSOs, were discovered in 1963. As often happens with a major discovery, significant clues had already lain around for several years before the actual discovery itself. For example, Sandage obtained the first spectrum of a QSO, 3*C*48, in 1961, but the spectrum was then found so inscrutable that nothing remarkable was inferred from it. Indeed, the first indication of an unusual new class of radio sources, now associated with QSOs, came nearly ten years ago at Jodrell Bank. A programme for measuring the angular sizes of the sources of the 3*C* catalogue had been carried out by Allen, Palmer, and Rowson. A dozen or so turned out to have angular diameters so small (not more than one second of arc) that they could not be resolved with the equipment then available.

The particular example that led to Schmidt's actual discovery was the source 3*C*273. An extremely precise determination of the positions of the two components *A* and *B* of this source was made possible through a technique first used by Hazard at Jodrell Bank. When the Moon occults a radio source of small angular diameter, the position of the source can be determined from the moment at which the occultation takes place, and from the length of the occultation, essentially because the Moon's position is known with high accuracy. Using this idea, Hazard, Mackey and Shimmins, working with the radiotelescope at Parkes, New South Wales, obtained the positions of 3*C*273*A* and 3*C*273*B* to within an accuracy of about 1″. The two components were well separated, by about 20″.

The positions were communicated to Maarten Schmidt at the Mount Wilson and Palomar Observatories. A direct photograph immedately showed that 3*C*273*B* was coincident with what seemed to be a 13th magnitude star. The spectrum of the star-like object contained a number of emission lines, four of which had wavelength ratios agreeing with the lines Hβ, Hγ, Hδ and Hϵ of the Balmer series. Moreover, J. B. Oke, working in the infra-red, had already observed a line which had the correct relative position for Hα. The big surprise was that the five lines were all shifted in their actual wavelengths by about 16% to the red. It is customary to write λo for the wavelength of a line as measured in the laboratory. Then, writing $\lambda o + \Delta\lambda$ for the wavelength of the same line in the observed spectrum, the red-shift z is defined as $\Delta\lambda/\lambda o$. For 3*C*273*B* the value of z was found to be 0.158. The essential point is that z had very nearly the same value for all five Balmer lines. It was indeed the existence of the well-known Balmer lines, as the strongest lines in the spectrum, that made 3*C*273 less difficult to interpret than 3*C*48. The Balmer lines, although present in 3*C*48, are considerably weaker. However, once the existence of a red-shift had been established by Schmidt for 3*C*273, it became possible to interpret the more difficult spectrum of 3*C*48. This was done by Greenstein and Matthews. The value of z for 3*C*48 turned out to be 0.367.

There are three known causes of red-shift: (1) the expansion of the Universe; (2) a Doppler shift; (3) emergence from a gravitational field. The distinction between (1) and (2) is one of geometry. Light emitted by a receding source experiences a red-shift. When the geometrical description of the recession is in terms of Euclidean geometry the shift is Doppler. When the geometrical description is non-Euclidean, as it must be for the Universe, it is as well to keep explicit note of the fact and not to use the term "Doppler shift". The practical difference between (1) and (2) is this: to obtain a considerable red-shift according to (1) it is necessary for a source to be at a great distance—cosmological distance—whereas a considerable red-shift is possible for (2) even when a source is nearby. It is only necessary in the latter case for the source to move away from us at a sufficiently great speed. When the recessional speed goes to that of light itself, the Doppler red-shift z goes to infinity, and the wave-length of the light from the source becomes infinitely long.

It is well known that the kinetic energy of a material particle decreases as such a particle emerges from a gravitational field. The same is true for light quanta. Light from the Sun is slightly red-shifted as it passes from the Sun to the Earth, although the effect is so small that it is hard to measure. However, light emerging from a very strong gravitational field can experience a large red-shift, as is found in the QSOs.

At the time of Schmidt's discovery of the red-shift of $3C273B$ nobody paid attention to the Doppler shift possibility. It was not until 1964 that James Terrell suggested the QSOs might be compact objects expelled from the nucleus of our own galaxy. Schmidt and Greenstein considered the possibilities (1) and (3), and decided against (3). However, the initial rejection of (3) turned on how massive one supposed the QSOs might be. Greenstein and Schmidt used the mass range 10^5—$10^8 M_\odot$, suggested by Hoyle and Fowler in connection with the radiogalaxies, before the discovery of QSOs. If larger masses are considered, comparable to the masses of galaxies, 10^{11}—$10^{12} M_\odot$, and if such masses are confined to regions with dimensions indicated by data which became available in 1965 and 1966, then large shifts due to gravitation are possible. But in 1963 the masses were not set high enough for this, or the volumes small enough, so discussion proceeded solely on the basis that the red-shifts of the QSOs arise from the expansion of the Universe.

The distance of $3C273B$ is then about 500 megaparsecs, and the optical emission is about 10^{46} erg sec^{-1}, large compared with the emission of even the brightest whole galaxies, which are about 10^{44} erg sec^{-1}. The emission of $3C273B$ in the infra-red turned out to be even larger, about 10^{47} erg sec^{-1}. Recently, Kellermann has estimated that the radio-emission from $3C273B$ demands outbursts of particles with cosmic-ray energies—i.e. of order 1 Bev per particle—amounting to $\sim 10^{58}$ ergs per outburst, the outbursts being about ten years apart. Since $3C273$ must be $\sim 10^6$ years old this demands an energy total of $\sim 10^{63}$ erg. (In general, the QSOs possess structure. In the case of $3C273$ there are the components A and B with a jet pointing from B and reaching to A. The time required to establish the structures shown by the QSOs, assuming motion out of a common source at the speed of light, is in general $\sim 10^6$ years.) An energy total of $\sim 10^{63}$ erg corresponds to the rest energy of $10^9 M_\odot$. Furthermore, since any process of mass-to-energy conversion is likely to be inefficient, the QSO mass must, it seems, be set considerably higher than $10^9 M_\odot$. Nuclear energy has an efficiency rather less than 1%, while gravitational processes also are about 1% effective. This would suggest masses upward of $10^{11}M_{\odot}$—i.e. masses comparable to the largest galaxies. Many astronomers now think the QSOs represent some distinctive phase in the development of the largest class of galaxy. Some favour the birth of galaxies, others suggest a connection with the radiogalaxies. While this is an attractive possibility, there is a curious fact which does not support it.

It was realised at the outset that if quasi-stellar objects occur in clusters of galaxies this would be a strong indication that they are indeed cosmologically distant, particularly if QSOs were found to have the same red-shifts as the galaxies belonging to the associated clusters. It has gradually emerged, however, that QSOs are not associated with clusters. In this respect they differ from radiogalaxies.

The essential feature of QSOs is that their optical emission comes from volumes that by galactic standards are extremely small. This was already clear from the analysis of old plate records of 3*C*273 by Smith and Hoffleit, which showed that 3*C*273 has fluctuated in brightness over the past century, by a factor of about 2 roughly periodically in $\sim$10 years. All QSOs now differ in brightness, some very markedly, from what they were at the time of the Palomar Sky Survey. Two particular QSOs, 3*C*345 and 3*C*446, have been found by Sandage and by Kinman and his collaborators to have spectacularly rapid variations, a rise and fall by a factor $\sim$2 in a single day for 3*C*446. This datum suggests that the main emitting volume at any particular time has dimensions no larger than 10^{15}—10^{17} cm.

A similar conclusion comes in a quite different way. The QSOs were first detected, as optical objects, from the use of radio data. Then, using the optical properties of the QSOs so discovered, Sandage developed a method for finding new QSOs entirely independently of radio data. The surprising result is that Sandage obtains of the order of a hundred times more QSOs by his method than are obtained from the radio data. This means that only about one QSO in a hundred is a radio source, some 99% are "radio-quiet". An object can be radio-quiet simply because it lacks the requirements for radio emission, high-energy particles in a magnetic field. Or it can be radio-quiet because the high-energy particles are confined to such a small volume that the system is self-absorbing. The radio-waves are generated within the system but they cannot escape from it. No final decision has yet been reached between these possibilities, but the suspicion is growing that the second is correct. Sources have been found, particularly by Bolton, of an intermediate kind—self-absorbing at long waves ($\sim$1 metre), not self-absorbing at shorter wavelengths ($\sim$20 cm). This suggests the existence of sources that are self-absorbing at all radio wavelengths—i.e. radio-quiet. There appears also to be a correlation between the self-absorption of radio waves and the existence of absorption lines in the optical spectrum. It was not until 1966 that the first QSO, 3*C*191, with a rich absorption spectrum was found by Burbidge, Lynds and Burbidge. In the past year a far higher fraction of new spectrum observations has shown absorption lines. This appears to be due to the high radio frequency used by Bolton in compiling the Parkes catalogue of southern radio sources, compared to the 178Mc/s used for the 3*C* catalogue. Sources that are strongly self-absorbing at 178Mc/s would be omitted in the Cambridge survey, whereas Bolton would obtain such sources provided they were not also self-absorbing at 1400Mc/s. The relevance to Sandage's radio-quiet objects is that they too tend to show absorption features in their optical spectra. They seem more similar to Bolton's partially self-absorbing sources than they do to the non-self-absorbing sources of the 3*C* catalogue. All this is evidence for small volumes, supporting the view that emitting regions have dimensions of $\sim 10^{15}$—10^{17} cm.

Masses of galactic order located in regions as small as this must produce strong gravitational fields, so emergence from a strong gravitational field must now be considered a possible way of explaining the observed red-shifts. A model for this, which overcomes certain former technical difficulties, has recently been proposed by Hoyle and Fowler.

We now have to decide between possibilities (1) and (3) for explaining the red-shift. According to (1) the distances of the QSOs range from 10^9 to 10^{10} light years, while much smaller distances, say 10^7 to 10^8 light years, would be appropriate for (3). What evidence have we that bears on this question?

By now about a hundred red-shift measurements have been

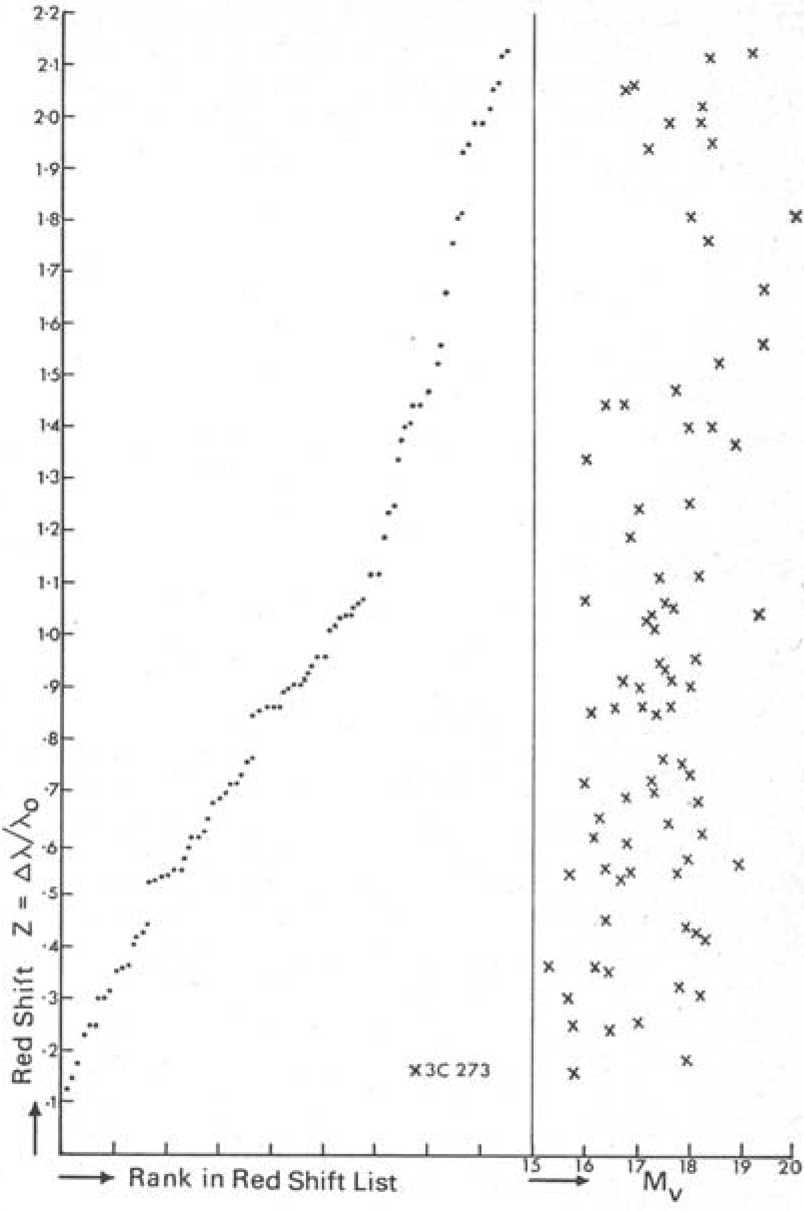

Red Shift Z = Δλ/λo
Rank in Red Shift List
Mv
×3C 273
2·2
2·1
2·0
1·9
1·8
1·7
1·6
1·5
1·4
1·3
1·2
1·1
1·0
·9
·8
·7
·6
·5
·4
·3
·2
·1
15
16
17
18
19
20

Fig. 1.

made. Imagine a table constructed in order of increasing red-shift. Number the entries in the table so that No. 1 is the QSO of least red-shift, No. 2 is the QSO with next smallest red-shift, and so on. Each QSO now has a rank number and a measured red-shift. Plotting the rank as abscissa and the red-shift as ordinate one obtains the set of points shown on the left side of Figure 1. The corresponding visual magnitudes, M_V, are shown on the right side of the figure. It is curious that 3*C*273 emerges as an exceptional case, about 3 magnitudes brighter than the general range of magnitudes, which is from 16 to 19. There is singularly little correlation between red-shift and magnitude. The batch of sources with largest red-shifts near 2 averages about magnitude 18, while the sources of smallest red-shift average about 17. The largest red-shift so far measured, *PKS* 0237-23 with $z=2.224$, has $M_V=16.7$, brighter than the average M_V for sources with small red-shift.

If the cosmological hypothesis for the red-shifts is correct, then the QSOs plotted in Figure 1 must differ intrinsically, for on this hypothesis sources with $z \simeq 2$ should be about 5 magnitudes fainter than sources with $z \simeq 0.2$. This is because sources of large red-shift are much farther away than sources of small red-shift. On the other hand the gravitational hypothesis does not correlate z with distance, so the weak dependence of M_V on z is more readily explained. Even for sources at the same distance there will be some relation between M_V and z, because z is a measure of the strength of the gravitational field from which the light has emerged, and the light loses more energy in emerging from a strong field than from a weak one. In fact, the weakening is determined by a factor $1/(1+z)^2$, so that $z=2$ should be weaker than $z=0.2$ by the factor $1/6.2$—i.e. about 2 magnitudes, not much different from the observational value of 1 magnitude.

A similar result is obtained for the radio-fluxes. These turn out to be substantially uncorrelated with the red-shifts, which again is explained most simply if there is no correlation between red-shift and distance.

The red-shifts are so large for $z \simeq 2$ that Lyman α, normally at 1216Å, is brought above 3300Å and can therefore penetrate the Earth's atmosphere. This is important because it provides a possible way of proving the cosmological postulate.

The spectra of QSOs consist of several weak emission lines superimposed on a continuum, while in about one case in five absorption features are also found. The special importance of Lyman α is that neutral hydrogen atoms existing in intergalactic space would readily blot out the continuum on the short-wave side of the emission line, if indeed the QSOs are cosmologically distant. Radiation on the short-wave side would be emitted at less than 1216Å. However, the red-shift effect would eventually lengthen the wavelength to 1216Å, at which stage it would be susceptible to absorption by the neutral hydrogen atoms.

This blotting-out effect has now been looked for in several QSOs, and it has not been found. This shows either that the QSOs are not cosmologically distant or that neutral hydrogen atoms do not exist in intergalactic space even in the very low concentration (1 atom per 10^{10} cm^3) necessary for extinction to take place.

By now we have remarked on four observational tests, any one of which would have served to prove that QSOs are cosmologically distant: (a) association with clusters; (b) the appropriate relation between M_V and z; (c) the appropriate relation between radio flux and z; (d) blotting out of the continuum shortward of Lyman α. While the fact that none of the tests has yielded a positive result does not disprove the cosmological postulate, the consistent failure of the theory to establish itself must raise doubts. These doubts are increased by the further fact that the observations drive us towards the concept of large masses concentrated in small volumes, a condition favourable to the rival gravitational hypothesis.

It remains for me to mention a remarkable new discovery of G. R. Burbidge. The two QSOs, 3*C*191 and *PKS* 0237-23, both have rich absorption spectra. Although the emission lines give quite different red-shifts, $z=1.95$ for 3*C*191, $z=2.224$ for *PKS* 0237-23, the absorption lines are found at nearly the same measured wavelengths, requiring a similar shift for the absorption lines. Spectroscopic identifications suggest that z for the absorption lines is 1.95 in both cases, although there may be additional absorption lines in *PKS* 0237-23 corresponding to $z=2.220$. It is also strange that in most of the other QSOs with absorption lines there are wavelength coincidences with the values measured for 3*C*191 and *PKS* 0237-23. This has led Burbidge to the view that the particular red-shift value of $z=1.95$ has a special significance for the whole class of QSOs. Technical spectroscopic evidence suggests that this red-shift is intrinsic to the QSOs and is not an effect arising from intergalactic gas. On this basis, Burbidge believes the gravitational hypothesis is probably correct. He argues that the QSOs so far observed are not more distant than $\sim 10^8$ light years.

To sum up: the quasi-stellar objects appear to consist of very large masses, probably of galactic order, concentrated in small volumes. The QSOs are the site of energy emission on a vast scale, much of the energy probably appearing as cosmic rays as well as electromagnetic radiation. It is not yet known whether the red-shifts of their spectrum lines arise from the expansion of the Universe or from strong gravitational fields. Tests that might have established the former hypothesis have failed to do so, and the trend of the evidence over the past two years has been in favour of the gravitational hypothesis.

EXHIBITS IN THE LIBRARY

(*a*) Photographs lent by the *Ronan Picture Library*.
(*b*) Books lent by the *London Library*.
(*c*) Books, articles and photographs from the Library of the *Royal Institution*.

THE BEGINNINGS OF CANCER

By F. KINGSLEY SANDERS, M.A., D.Phil.
Director, Virus Research Unit, Medical Research Council

Weekly Evening Meeting, Friday 6th May, 1966

Lord Fleck, of Saltcoats, K.B.E., D.Sc., LL.D., F.R.S.,
President, in the Chair

[ABSTRACT]

CANCERS consist of populations of cells which have somehow escaped the normal restraints of the body in which they reside, and which divide uncontrollably. They may have their origin in a change, perhaps taking place in a single cell; this alteration, being hereditary, is passed on to all the descendants of the first mutant cell, who consequently inherit its disposition to divide irresponsibly. The subject of this Discourse was the nature of the hereditary change which produces the cell whose descendants are thereby destined to become a cancer.

Cells can acquire a new genetic make-up in several ways. One of them is the introduction of new genetic material from outside, as in fertilisation, or in two well-known phenomena with bacteria, transformation and lysogeny. Another way is by reshuffling the chromosome constitution of a cell, so that its genetic material becomes arranged in a new way.

All sorts of agents, from chemicals to viruses, can cause cancer—that is, alter the heredity of cells. Do these agents all act in the same way? Do they do it in one of the ways already mentioned? New techniques for studying the effect of cancer-inducing agents, like viruses and carcinogenic hydrocarbons, on cells growing in culture outside the bodies of their donors, are enabling us to begin to find answers to these critical questions. As a bonus, these new methods also provide a way to study the genetics of complicated organisms like mice and men at the level of the individual cells which comprise them.

EXHIBITS IN THE LIBRARY

(*a*) A display arranged by the *Virus Research Unit of the Medical Research Council.*

(*b*) Books and illustrations lent by the *Wellcome Historical Medical Library.*

(*c*) Articles lent by the *Royal Society of Medicine.*

(*d*) Books and articles from the Library of the *Royal Institution.*

YOUR SERVANT—THE ELECTRON

By RONALD KING, B.Sc., Ph.D., F.I.M.
Professor of Metal Physics, Royal Institution;
Assistant Director, Davy Faraday Research Laboratory

Weekly Evening Meeting, Friday 13th May, 1966

Lord Fleck, of Saltcoats, K.B.E., D.Sc., LL.D., F.R.S.,
President, in the Chair

[ABSTRACT]

IN most processes occurring in nature, electrons play a decisive role. Learning to control these processes for our own purposes means, in the ultimate analysis, learning to make electrons do our bidding. As our knowledge of the laws governing the behaviour of electrons has grown, so has our ability to make them perform increased in subtlety and sophistication. This has led to developments which affect our daily lives, our comfort and our well-being, and at the same time to means of penetrating ever deeper into the secrets of nature. As but one example: in the laser, electrons are caused to release energy in unison, giving rise to highly monochromatic coherent light which may be of very great intensity. Lasers have been used, on the one hand for such a delicate task as refixing a detached retina in the eye, and on the other for the investigation of the interaction of light with light.

The part played by electrons in a number of processes was discussed and illustrated and some examples demonstrated of the ways in which we have learned to direct them in our service.

EXHIBITS IN THE LIBRARY

(*a*) A demonstration of lasers by *G. & E. Bradley Ltd.*

(*b*) A selection of apparatus demonstrating various aspects of the behaviour of electrons, provided by *Scientific Teaching Apparatus Ltd.*

(*c*) Fuel cells, provided by *International Nickel Ltd.*

(*d*) A display of electron micrographs by *Cambridge Instruments Ltd.*

(*e*) Demonstrations of solar cells and the field emission electron microscope, arranged by the *Royal Institution.*

LIBRARY CIRCLE MEETING

Monday, 23rd May, 1966

COPYING METHODS PAST AND PRESENT

By W. B. PROUDFOOT
Research Manager, Gestetner Limited

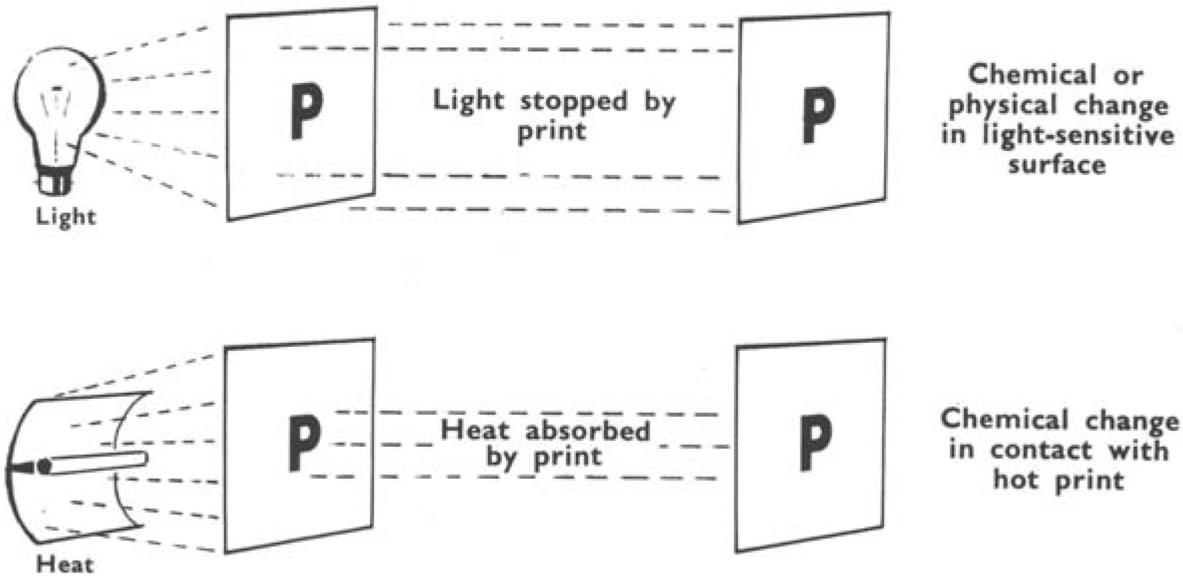
A. H. Ewen, M.A.,
Vice-President, in the Chair

Most modern offices, and library offices in particular, in this copy-crazy world, take part in the making of a daily avalanche of copies, on sheets of paper, made from all sorts of documents, books, and correspondence, using a great variety of automatic, push-button apparatus, equipment or machinery. There is much to be gained in the understanding and appreciation of such processes by going back to their beginnings—to the principles laid down by the inventors. There is much also of human interest. For instance: although the present-day forms of these highly sophisticated copying and duplicating processes result from intense research and development by scientists and technologists in universities and industry, the basic idea and essential practical details more often than not were invented by non-scientists—law students, office clerks, commercial artists, and so on. And in most cases these lay inventors, nevertheless, studied and applied scientific principles with great assiduity and ingenuity.

There are so many new processes on the market, and coming on the market, that there is much confusion and little understanding of their technical significance. Good technical and historical reviews are much needed; and it is interesting that the most rewarding studies on the subject have come, not from industrial, commercial, or laboratory people, but from librarians.

I shall be saying something about the present-day methods of copying which have invaded the offices of the world in the last fifteen years and brought about the greatest revolution in office practice the commercial world has ever known. But how was it not so long ago? Last century? Who invented the great duplicating processes familiarly known as Stencil and Spirit? What of the office copying methods of a generation ago—between the two world wars? And before that: in Dickens's time and earlier? What copying methods existed before the typewriter to assist the office

MODERN COPYING



PRINCIPLES

Fig. 1.

slave—the copy clerk? And so I shall also do some light digging into the invention and origin of modern methods of copying—explaining first of all what they do and how they work. Similarly with stencil and spirit duplicating, having shown you their present-day form and usage, I shall dig a good deal deeper into their beginnings, and beyond.

In all modern copying methods light or heat is directed on to light- or heat-sensitive surfaces in front of which is placed the original to be copied. The print, typescript, or other readable matter on the original intercepts the heat or light in such a way that the resultant chemical or physical changes in the sensitive surface produce an image of the original print. Subsequent development and, if necessary, transfer to copy paper depends on the nature of the chemical or physical change. The final result in any commercially successful process is always a right-reading legible copy of the original, more or less permanent, and produced fairly quickly, easily and economically; at least for a small number of copies.

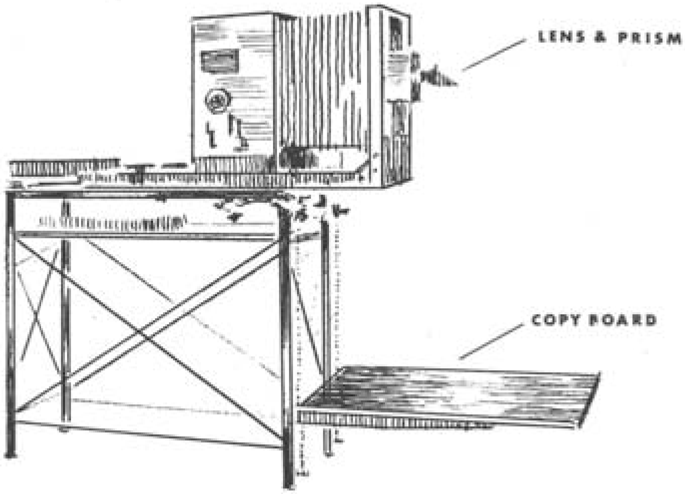
The modern copying methods, indeed, are classified into two main groups: photo-copying, which uses light; and thermo-copying, which uses heat. (See Figure 1.) A third group, also using light, depends subsequently on electrostatic charges, and is referred to usually as electrostatic copying.

Photocopying

Such is the general title of copying methods which use light to effect photographic changes—mostly without a camera. It covers many well known processes in daily use, a few of which will now be described.

The *Photostat* process employs a camera, a rather big one (Figure 2A), with a prism in front of the lens to reverse the image and give a right-reading, white-on-black negative (Figure 2B) processed by the usual (and lengthy) photographic steps carried out in a darkroom. The darkroom in the modern office, alas, holds nothing of the excitement and attraction it had for our grandfathers.

Photostat is the earliest established document copying process in the modern sense of the term. It was much used by patent offices in the early years of this century.



A. Photostat camera.


RESERVE COPY

N° 23,406 A.D. 1900

B. Photostat copy.

FIG. 2.

In the form in which it came to be used Photostat was introduced by René Graffin, Professor at the Institut Catholique in Paris in 1910, and was marketed by the Photostat Corporation of the United States. The idea, however, was originally that of George C. Beidler, a clerk in a legal office in Oklahoma City, U.S.A., in 1900. Beidler formed the Rectigraph Company in 1906 in Rochester, and in 1909 was bought out by the Haloid Corporation of the same city—later to be known as the Xerox Corporation.

Contact and reflex copying is photographic copying without a camera, using light-boxes for exposure of the original in contact with photographic papers. When a copy is made of a page in a book, or when the original is printed on both sides, the light is passed through the back of the photographic paper and reflected from the face of the original by a procedure referred to as reflex. Processing and development is in subdued light—a welcome move away from the darkroom. The equipment is simple and easy to use, but it is necessary first to make a negative (albeit a paper one), and print the final positive copy from it in a two-stage process.

Although photography was invented as long ago as 1839, it was not until a hundred years later, in the 1930s, that the American Photo Equipment Corporation (familiarly known as Apeco) marketed simple light-boxes without lenses, for the purpose of making copies of office correspondence and other documents. It is interesting, therefore, to know that a German medical student called Albrecht Breyer did in fact, in 1839, make copies of pages in books, and handwritten letters, by contact, and without a camera. The inventive spark is sometimes not bright enough, and great inventions lie dormant for many years.

In *diffusion transfer* the photographic papers used are so treated that when the negative and positive papers are held in contact under pressure during development there is a diffusion of chemicals from the one to the other. In this way a positive image is formed and is revealed on stripping the negative and positive papers apart. It is a one-stage process, simple to operate, and employs most elegant, streamlined, push-button equipment. (See Figure 3.)

Diffusion transfer was the first real breakthrough into the

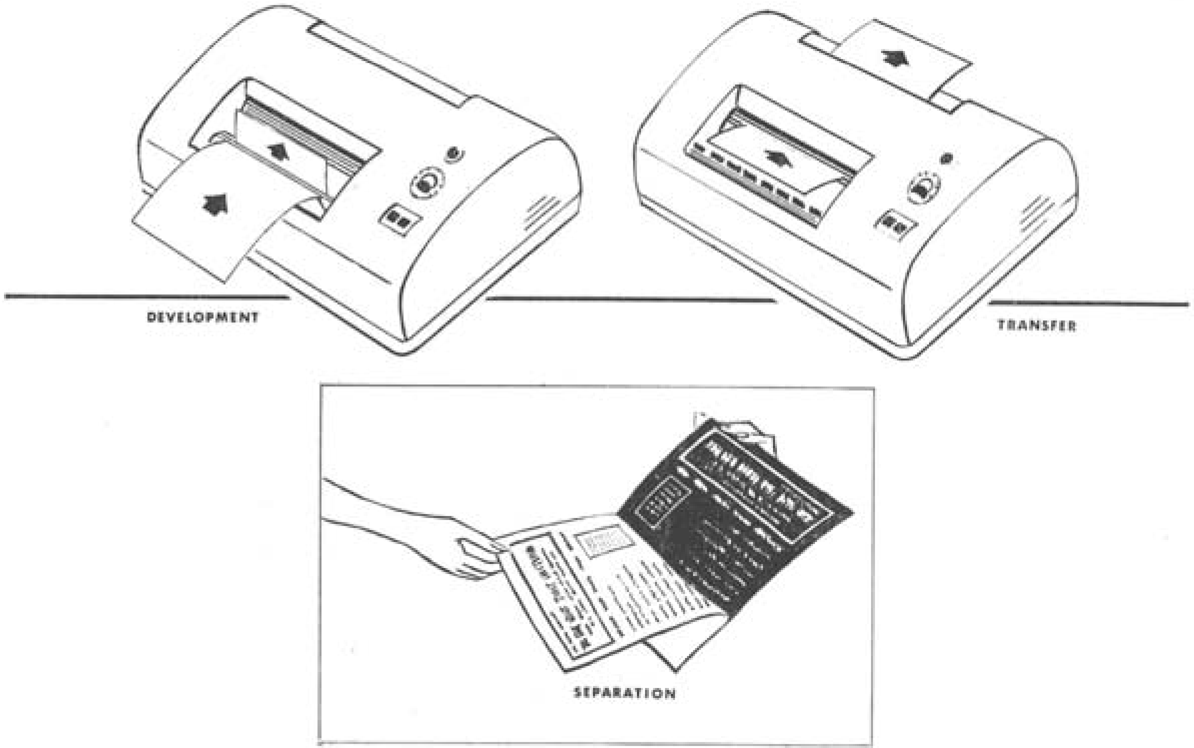


FIG. 3. Diffusion Transfer.

office copying field. It occurred in the late 1940s and the method quickly established itself as the first copying process attractive to office people for everyday use. Many companies jumped on the band-wagon, and offices, some years later, were inundated with a wide variety of equipment under various catchy names—Copycat, Photorapid, Instant Copy and so on—all exploiting the principle of diffusion transfer.

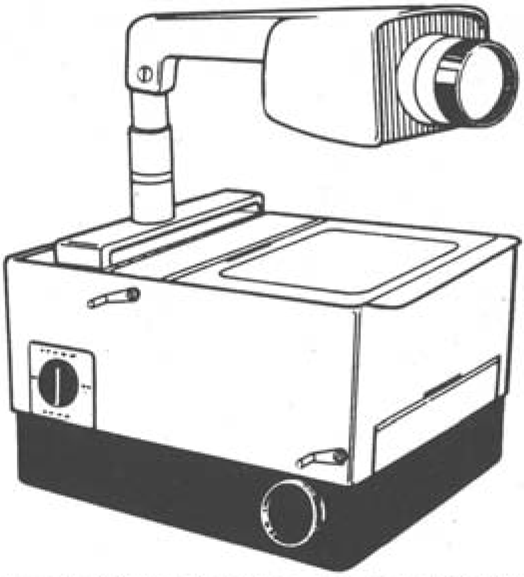


FIG. 4. Thermofax Overhead Projector. Projects clearly under wide range of room lighting. Allows presenter to face and talk to audience. Features large 10″ x 10″ transparency stage, 1,000-watt bulb.

An interesting circumstance of the discovery of this principle is that three scientists, working independently in different parts of the world, published and patented ideas based on essentially the same chemistry. André Rott of Gevaert, Antwerp, filed his first patents between 1939 and 1944; in Germany, at the Agfa Laboratories of the I.G. Farbenindustrie at Leverkusen, Dr. Edith Weyde took out patents in 1941 on the same subject; while in the United States of America, Dr. Edwin Land (inventor of the Polaroid Land Camera for making positive prints *in situ* in the camera) was independently working on the same principle, which, however, he applied to improvements in popular photography, rather than to office copying.

The necessary simple machine to operate the principle was developed by Agfa, and introduced in 1949 as the Blitzkopie. It was imported into the United States of America in 1952, and sold by Remington Rand as the Transcopy. Thus the United States, where the office copying business these last ten years has expanded at an explosive rate, imported from Europe the idea and the item that started it all.

Office copying burst into big business in 1953, and great legal battles marked the early stages of the revolution in office practice which it proved to be. One American firm in the early 1950s had to pay $5,500,000 for patent infringement.

Thermographic processes

Thermographic processes are those which use infra-red radiation (i.e. heat) to cause physical or chemical change in the image area. The most important office copying application of the principle is the *Thermofax*.

The Thermofax uses a piece of paper coated with waxy chemicals that stay put when cold, but melt and react when heated, to produce a dark-coloured compound. This paper and the original (on top) are pushed into a box in which they pass over an infra-red lamp. The black, carbon-containing print of the original absorbs the heat rays, rises in temperature, and induces the chemical reaction in the corresponding image area of the copy paper. The non-image area lets the heat rays pass through with little or no rise in temperature. Thus a copy is made.

Soon after it was introduced in 1956 this heat process rocketed into first place among copying methods, being a dry process attractive to office workers.

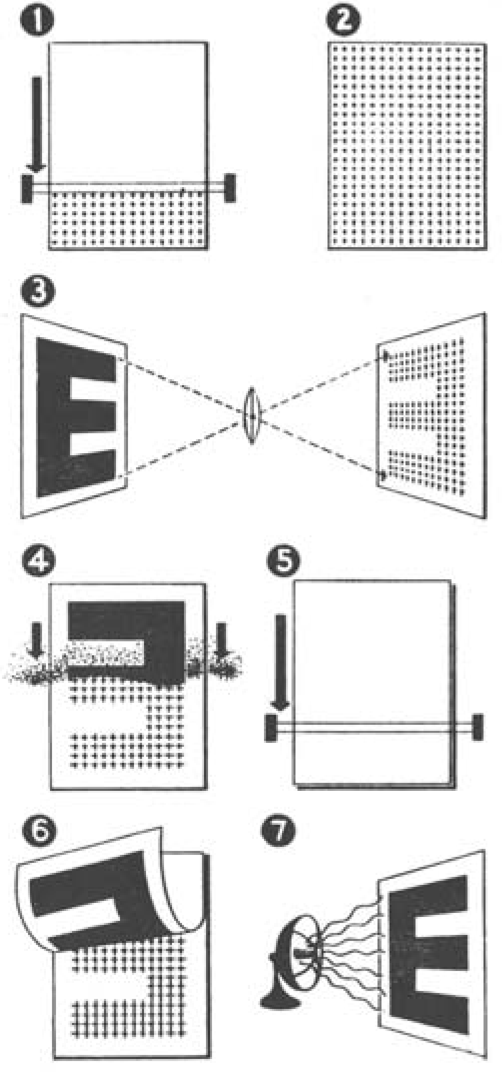
That chemicals react on heating, often producing marked colour changes, must have been known to chemists for centuries. But the simple idea of making a copying process out of the fact was left to Carl S. Miller, a physical chemistry student at the University of Minnesota in 1940. He had grown tired of the manual copying he had to do in reading for a special degree; and being of an inventive frame of mind he started experimenting. He coated a piece of cellophane with two chemicals (lead acetate and thiourea) and dried them off carefully at a low temperature. He placed the dried sheet in contact with a transparent sheet of printed matter from an address envelope, and wrapped the two together round a cardboard drum to keep them taut and in contact. A 1,000-watt lamp brought near enough provided the heat. On peeling the sheets apart he found a coloured image of the print.

That was in the spring of 1940. In July he joined the Minnesota Mining and Manufacturing Company to do a wartime job on pigments. But every spare moment he spent improving his thermal copying idea, which he eventually showed to his research chief. It was immediately recognised as an important process, and was put on the main research programme. Much hard work had to be done choosing suitable chemicals, and devising and designing a lamp, and a machine, for controlled operation. The final working model was ready in 1944. Better papers came along in 1946. In 1950 the first large, console model, the Thermofax machine, was demonstrated; and the streamlined desk-top model, famous now as the Secretary, made its début in the office world in 1955.

The Thermofax process can be used to produce copies on a clear transparent film, which can then be used on one of these ultra-modern overhead projectors, such as is being used to show the pictures and diagrams of this lecture (see Figure 4.) The film is coated with the heat-sensitive chemicals in clear transparent form. There are two kinds of transparencies produced by passing through the Thermofax, in the normal way, the original and the transparent film in contact. One of them gives a black image on the clear transparent ground. The other gives a white opaque image produced in a most interesting way by the formation of tiny gas bubbles which the heat expands. This white image nevertheless projects black on the screen, because it is light-stopping. [*Demonstration.*]

Electrostatic copying

The principle employed in this group is that electrostatic charges on a surface are dissipated by exposure to light in the non-image areas, and retained in the protected image part, which is then dusted with a powdered resin (held by the charge), and



1. Surface of specially coated plate is being electrically charged as it passes under wires. 2. Shows coating of plate charged with positive electricity. 3. Copy (E) is projected through lens in camera. Plus marks show projected image with positive charges. Positive charges disappear in areas exposed to light as shown by white space. 4. A negatively charged powder adheres to positively charged image. 5. After powder treatment (4) a sheet of paper is placed over plate and receives positive charge. 6. Positively charged paper attracts powder from plate, forming direct positive image. 7. Print is heated for a few seconds to fuse powder and form permanent print.

FIG. 5. How xerography works.

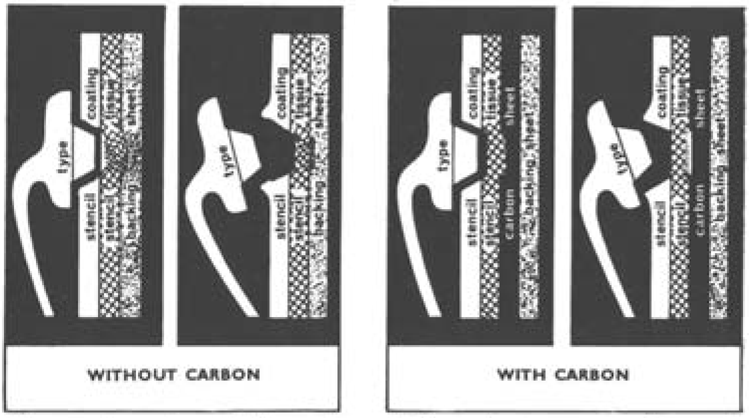
subsequently fixed by heat to form a permanent copy. There is a direct method and an indirect or transfer method. We shall deal with the latter first.

In the *transfer electrostatic* process, well known as Xerox, the charged, dry, ink image is transferred electrostatically to ordinary paper to produce the final copy, where it is fixed by heat to make it permanent. (See Figure 5.)

It is well known that plastic materials, nylon, terylene for instance, and other materials, even sheets of paper, when rubbed, acquire an electrostatic charge, which can make them stick to the wall, or cling to other surfaces. [*Demonstration of resin powder adhering to L-shaped area of plastic sheet which had been rubbed with a handkerchief.*] It is not all quite so simple when it comes to making a copying process of this electrostatic principle. It so happens, however, that there are certain substances which readily acquire and hold an electrostatic charge in the dark; but on exposure to light the charge is dissipated. Here then is the germ of the process; for if the sheet is charged in the dark and then exposed to light shone through, or reflected from, an original, the charge will be held in the image area corresponding to the print, and destroyed in the non-image area. The subsequent steps consist of dusting with resin powder, removing the surplus and fixing the image by heat.

The electrical principles involved are elementary enough; but it was left to a Patent Attorney's assistant in the late 1930s to invent the procedure that resulted in this amazing process. Chester F. Carlson is his name, at the time a physicist working in the office of P. R. Mallory, Patent Attorney in New York. He recognised the need for a quick, dry method of making copies of patents. Knowing something about electrostatic substances as a physicist, he began reading furiously in the New York Public Library (later the first organisation to install a Thermofax machine). And in the kitchen of the apartment where he lived at Jackson Heights, Long Island, New York, he set to to make the idea work. He rubbed slabs of sulphur to make them electrostatic; but they frequently caught fire, and, unpopular lodger, he had to move to a kitchen over a bar and grill in Astoria. It was here, with his confederate, Otto Karnei, a refugee physicist from Germany, that he demonstrated electrostatic copying for the first time. He coated the sulphur on a metal slide and rubbed it in the dark. On a microscope glass slide he wrote with the magic ink marker "10-22-38 Astoria", and placed the glass slide on the metal one in the dark. On exposing the slides to a 1,000-watt lamp, separating them, dusting the metal one with iron filings, and shaking off the surplus, the inventor was delighted to find a readable image, "10-22-38 Astoria", on the sulphur surface.

WHAT HAPPENS WHEN THE TYPEWRITER TYPE STRIKES THE STENCIL



Fibrous tissue is crushed against backing sheet. Result: irregular type impression.

Carbon sheet prevents damage to fibrous tissue by cushioning it from backing sheet. Result: regular impression of type on stencil, no cut out letters.

Note how some of the carbon "dope" is transferred to the exposed fibres, so rendering the type impression visible to the typist.

Fig. 6.

"Otto and I repeated the experiment to make sure it was true, and then went down to the bar and grill to celebrate." That is the entry in Chester's diary for 22nd October, 1938.

Two years later Chester F. Carlson received his final patent. But for a period of four years he unsuccessfully hawked his idea round the big companies, who always received him, he says in his diary, "with an enthusiastic lack of interest".

The turning point came when he enlisted the help of the

Battelle Memorial Research Institute in Rochester. They did great work, recommending selenium instead of sulphur. Selenium is the element used in photo-cells, and pre-eminently suitable for this photo-electrostatic application.

In 1944 Dr. John N. Dessauer, Research Director of the Haloid Corporation, of which some mention has already been made, read Battelle's report of Carlson's work and asked leave to come in on the job, as his team was all geared to develop such a challenging project. In 1948 Battelle licensed patents to Haloid, who got busy translating them into a process. In 1950 the first Xerox Model D was introduced—a piece of laboratory equipment in three parts. The process was called xerography—dry writing—or xerographic printing.

Out of this laboratory apparatus there grew, after many years of work, and the spending of many millions of dollars, the various models familiarly known as Xerox. These are elegant push-button machines, which have been dollar-spinners for the company, and have taken the revolution in office copying to a further stage of progress.

There is time only to mention the *direct electrostatic*, the other electrostatic process that grew out of the Battelle work on Xerox, but was developed more particularly by the Radio Corporation of America (R.C.A.) and announced by two of their chemists, Greig and Young, from the laboratories at Princeton, N.J., in 1954. In this process the photo-conductive surface is a sheet of paper coated with zinc oxide. It is called direct electrostatic, because there is no transfer of the final image: the copy is obtained directly on the zinc-oxide-coated paper. The name Electrofax was associated with the process in the early days of its development.

Seven long years of intensive research and development were spent, and more millions of dollars, before the direct electrostatic machines began to come on the market in 1961 and 1962. Light-sensitive dyes had to be found that would make the zinc oxide sensitive to ordinary visible light and not only to ultraviolet light, as was the case when it was first used in the early days of research. And many other problems arose—legal as well as technical. The paper on which the final copy is obtained has a slightly "photographic look" similar to that of the main photocopying processes. But on account of the greater convenience of the electrostatic method manufacturers of the original photocopying equipment are now bringing forward electrostatic models by way of natural succession.

FIG. 7. Mr. Linkinwater intimates his approval of Nicholas: an illustration by Phiz to *Nicholas Nickleby*.

The beginnings of duplicating

Older in origin than any of these recent copy processes are the two great traditional methods of duplicating: stencil and spirit; both still going strong. Perhaps these terms copying and duplicating should be defined. Briefly, by copying we mean processes using light or heat to produce a small number of copies (one to five), usually on specially coated paper, of some existing document. By duplicating we mean, in the first place, processes capable of giving a much larger number of copies (up to 2,000 or more) economically and conveniently, mainly on more or less ordinary paper, from some master normally composed for the purpose on the typewriter (or by writing and drawing). And in the case of existing documents the stencil is prepared by electronic means to which I shall refer shortly.

Stencil duplicating

A modern typewriter stencil consists of a porous tissue of fine, but strong, fibres coated with a pressure-sensitive composition. In the typewriter, or by means of a metal stylus, the composition is cleared away to leave ink-passing perforations. The uncut stencil is ink-impervious. The simple operation of turning the stencil and laying it face down on the duplicator enables right-reading copy to be made without any of the reversal or transfer operations which are necessary and integral parts of the modern copying processes just described.

The essential parts of the stencil are the coated tissue or stencil sheet, the carbon to cushion the blow of the type and give visibility in the typewriter, and the backing sheet—the supporting surface. Figure 6 shows the working of the traditional typing stencil, which has played such an important part in the history of office practice since its introduction in the 1880s.

The stencil story began in the 1870s: in the days before the typewriter, when cbaron papers were still messy and impossible things. These were the days of the sloping desk, the high stool in dark, Dickensian offices with ill-looking and ill-paid clerks copying letters laboriously by hand with quill pens. (See Figure 7.) Some method of reproducing handwriting was needed, and so about that time, in Great Britain and the United States of America, various people of inventive turn of mind began poking holes in bits of paper with the purpose of pushing ink through them and making copies of the patterns so formed. Thomas Alva Edison, the great American inventor and electrical genius, made an electrically operated reciprocating needle which could be held in the hand and used to "write" holes on paper in the pattern of handwriting. He got the idea from the use of perforated paper to effect make and break of needle-contact in the electrical circuits with which he was concerned in his telegraphic work.

The instrument was a bit clumsy and top-heavy (Figure 8). Nevertheless the idea, if not the instrument, led to the development in the United States of America in the 1880s of the stencil process—known there as mimeograph.

Back in Great Britain in 1874, a few years earlier than the Edison patents, Eugenio de Zuccato, a law student from Padua, practising or studying in London, took out a British patent for

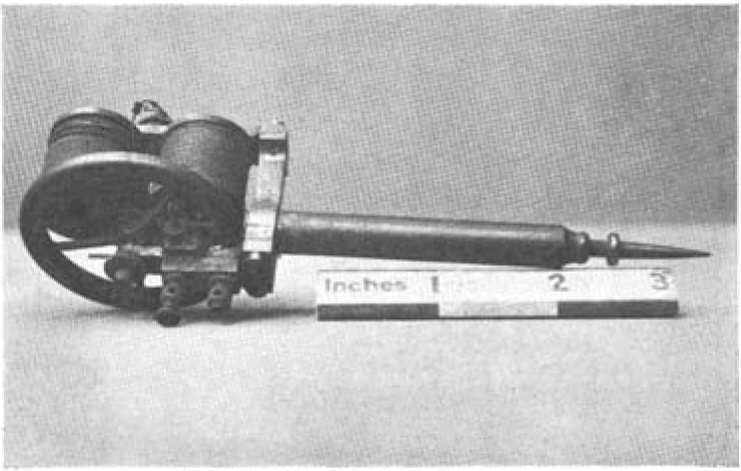


FIG. 8. Edison's reciprocating pen.

making perforations by chemical means in a lacquered sheet of paper. Ink was pushed through these dissolved clearances, or perforations, on to copy paper—using a copying press. A picture of the copying press is included in the trade mark granted for this messy process in 1874.

A little later Zuccato made an independent attempt at boring holes in a sheet of waxed paper by scratching it with a metal stylus while it lay on a rough surface such as sandpaper or a file plate. He called the method Trypograph, from the Greek verb τρυπαν, meaning to bore. A patent for this was granted in 1877 and the trade mark in 1884.

These processes were a bit difficult; and copies were faint and spidery. The real breakthrough came with David Gestetner's patented Cyclostyle in 1881. The cyclostyle consisted of a small toothed wheel, like a small gear wheel, mounted on a small steel shaft fixed to a wooden handle. It was later called a wheel-pen. Its importance in the development of stencil duplicating lay in its ability to make good ink-passing perforations by puncturing both wax and paper so that excellent facsimile copies of handwriting could be easily obtained, with simple inks and a roller, on ordinary paper. In Gestetner literature it is referred to as the little wheel that made the great revolution in the history of duplicating. (See Figure 10.)

The waxed paper stencil was written on with wheel-pen or cyclostyle on the metal block or bed of a duplicating apparatus containing also a frame for the stencil, with a handsome box to house the lot. The stencil, still in its frame, was then inked with a roller, the metal block serving as the printing bed. This was duplicating for the first time. How beautiful the copper-plate handwriting of the business document of that day copied with such fluency and accuracy!

In the 1870s David Gestetner was a young clerk in the office of a stockbroker uncle in Vienna. But he left the stockbroking business after the great financial crisis in 1873, and went to try his fortunes in the U.S.A. It was there in Chicago, after somebody had picked his pocket at the railway station, that he was forced to hawk children's kites, buttons and Japanese fans at the street corner. David, the inventor-to-be, noticed that these kites were made of a doped (lacquered) Japanese tissue of long fibre—thin, but strong. It was this paper that he later patented as the basis of the stencils used with the cyclostyle.

Back to Vienna he came in 1875, and began developing—successfully—his ideas about a method of copying handwriting for use in the office. But it is in London in 1879 that his life-long application to this purpose really takes root, and begins to express itself in a series of patents, the outstanding one of which was the cyclostyle patent of 1881, just mentioned.

David Gestetner was not content with the inventor's role. A keen business man, with faith in his product, and a sense of the needs of the time, he started manufacture in a one-room factory,

Trade Mark.	Name, Address, and Calling of Applicant.	Class of Goods.	Description of Goods.	Number given by Registrar.	Date of Application received.	If Mark used prior to 13th August 1875, how long used.
	EDWARD WOLFF, of and on behalf of the Firm of ZUCCATO AND WOLFF, 19, Charterhouse Street, London: Manufacturers.	39	Printing Apparatus, Black and Coloured Writing and Printing Inks and Paper in connection therewith.	12,390	20th June 1877.	One year before 13th Aug. 1875.
ABC *Oporto*	ANDREW BOYS CASSELS, Oporto, Portugal: Wine Merchant.	43	Wine.	12,397	21st June 1877.	Four years before 13th Aug. 1875.

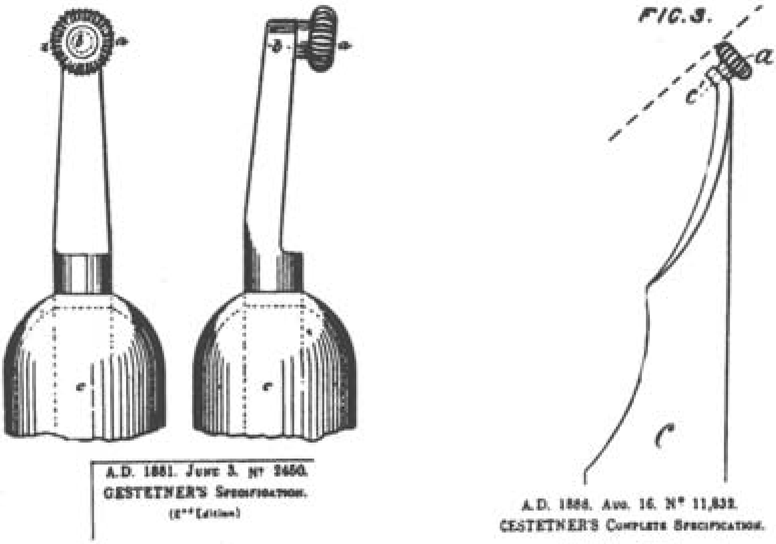
Trade Mark entry.

FIG. 9

with one girl assistant, in Sun Street in the City of London. From such small beginnings sprang the great organisation that

FIG. 10. David Gestetner and his Automatic Cyclostyle.

bears his name. Indeed, apart from his contributions as an inventor David Gestetner undoubtedly established stencil duplication as big business in the office world.



The Cyclostyle

The Neo-Cyclostyle

A. From the original patents.

B. The Neo-Cyclostyle Duplicating Apparatus.

Fig. 11.

In the year 1888 Gestetner took out his third important patent in the history of stencils—for a new and improved form of cyclostyle with the wheel set at a comfortable angle, making it much more manoeuvrable. With this was associated a new and improved Neo-Cyclostyle Duplicating Apparatus. It was this apparatus that set stencil duplicating on its feet and on the road to a great future. (See Figure 11.)

But cyclostyling did not altogether solve the copy clerk's problem—although it provided the office with a means of making multiple copy of hand-written text, and, for the first time, the circular letter in manuscript. It was the typewriter in point of historical fact that banished the copy slave from his high stool, and brought the typist into the office scene. By the 1880s the typewriter was tapping its way into established office practice. (See Figure 12.) But handwriting stencils—drumskin-like structures for puncturing with cyclostyle—were not much good in the typewriter. The type simply made no impression.

Edison tackled the problem by inventing and patenting a typewriter with a needle-faced type to puncture the wax stencil after the manner of the file plate. It failed to catch on.

Between 1881 and 1888 the patent literature is crowded with the ideas of inventors struggling to devise a stencil for the typewriter. Most of the ideas, and the names associated with them, have long since disappeared from the duplicating scene. But from it all emerged the waxed Yoshino stencil—a new product consisting of a coating of wax (plasticised with beef-tallow) on a long-fibred and very porous tissue called Yoshino—quite different in structure from that of the handwriting stencil. The type, on striking the stencil, pushed the wax along the open fibrous network to make the perforation—a very different mechanism from that of the cyclostyle. The fibres remained to keep the centres of loop letters like e and o from falling out. At least that was the manufacturer's claim.

But the typist of the 1880s often had to get down on hands and knees with a hat pin and pick up the stencil "confetti" to replace it in position on the stencil! Nor was the typewriting stencil of that time the robust product of today, and it had to be handled carefully in the typewriter, using a sheet of muslin-tissue paper on top to help remove the wax. In the duplicating apparatus it

A. The original typewriting stencil (*left*) and the original cyclostyle stencil, for handwriting (*right*).

B. The typewriter tapping its way into the Victorian office.

Fig. 12.

had to be supported on a reinforced sheet of tissue, called the diaphragm, which took the contact with the ink roller, and protected the delicate stencil with its fall-out of loop letters.

It is a fascinating study to trace from all this the development of the rotary duplicating machines that in the early days of this century began to change the pattern and pace of the office; how the paper diaphragm later became a sheet of silk; and this in turn was automatically operated with a handle which also moved the ink roller. It was a small step in thought, a big one in engineering, to curve the stencil support round rotating cylinders. The first patent was 1900; the first machine, the Gestetner Rotary Cyclostyle No. 3, 1902. The word cyclostyle had come by then to mean the machine as well as the pen. Stencil duplicating in those days was spoken of as cyclostyling. (Figures 13 and 14.)

At that time the business associate who sold Gestetner goods in U.S.A., as the Neostyle Company, dealt in a different rotary system in which the cylinder was a single drum, inked internally. He wanted to trademark it as the Neostyle, but Gestetner objected because of his own Cyclostyle. There was a court case which Gestetner eventually won—so the alternative duplicating system which was to be called Rotary Neostyle was shortened to Roneo. Its single-drum feature connects with patents of A. B. Dick and others in the United States at that time.

Wax stencils—brittle things, despair of the hobble-skirted typists of the 1900s—gave way to ones made of gelatin—moistened with water before insertion in the typewriter. In 1928 came the next breakthrough with nitrocellulose (gun-cotton) stencils, of which the modern stencil is still made with all the improvements by which research and development meets the demands of the 1960s.

I must now say something about the latest electronic stencil and the electronic scanning equipment by means of which it is possible, in the office, to make a stencil, a facsimile stencil, from any existing original. This conductive stencil is cut by means of electric sparks. The original is placed on one half of a rotating drum where a spot of light is focused on it. A photo-electric eye or photo-cell "sees" the changing illumination as the spot passes over black print or white paper. The pulsation of the light sets up corresponding electrical impulses in the cell, which are amplified

FIG. 13. A rotary cyclostyle in an early 1900 office.

to form current that discharges from a pointed stylus, cutting holes according to the pattern of the light and shade of the original. The holes vary in size according to the density of the black parts of the original, so that by passing ink through the stencil a faithful copy of the original with all its gradations is obtained. (See Figure 15.)

The work which led to this great step forward in stencil cutting by electrical means grew out of facsimile transmission in which the Times Facsimile Corporation of New York was interested. This work, begun in the 1920s, concerned a long research to find recording papers for the Signal Corps of the Army, and much work was done in conjunction with Western Union covering photo-papers, electrolytic papers, and chemically treated papers, all designed to show a recording mark when placed near a high voltage discharge from a stylus point linked electrically with the signals concerned. The most successful recording sheets were impregnated with conductive carbon and had a top-coating of a specially prepared zinc oxide.

An elegant variation on this development of recording papers was a series of patents between 1947 and 1953 of Harold R. Dalton leading to a stencil consisting of a vinyl film punctured by the sparks. Equally elegant was the Stenafax Facsimile Equipment, which enabled the original to be scanned, and the stencil to be cut, on two adjacent drums. But the Times Facsimile Corporation was not much interested in duplicating as an office procedure; and it was not until the late 1950s that electronic scanners began to appear in the office for use by the customer as equipment for making stencils.

In the late 1950s Gestetner Limited marketed the first electronic stencil-cutting machine for sale to customers for use in everyday office duplicating. It was called Gestefax. [*Demonstration;* and see Figure 16]. So ends the stencil story on this modern note of its special application to visual aids in modern methods of education.

Spirit duplicating

This is a different process altogether. In its present-day form a piece of paper is typed with a special coloured wax-carbon placed behind it with the wax side of the carbon facing the back

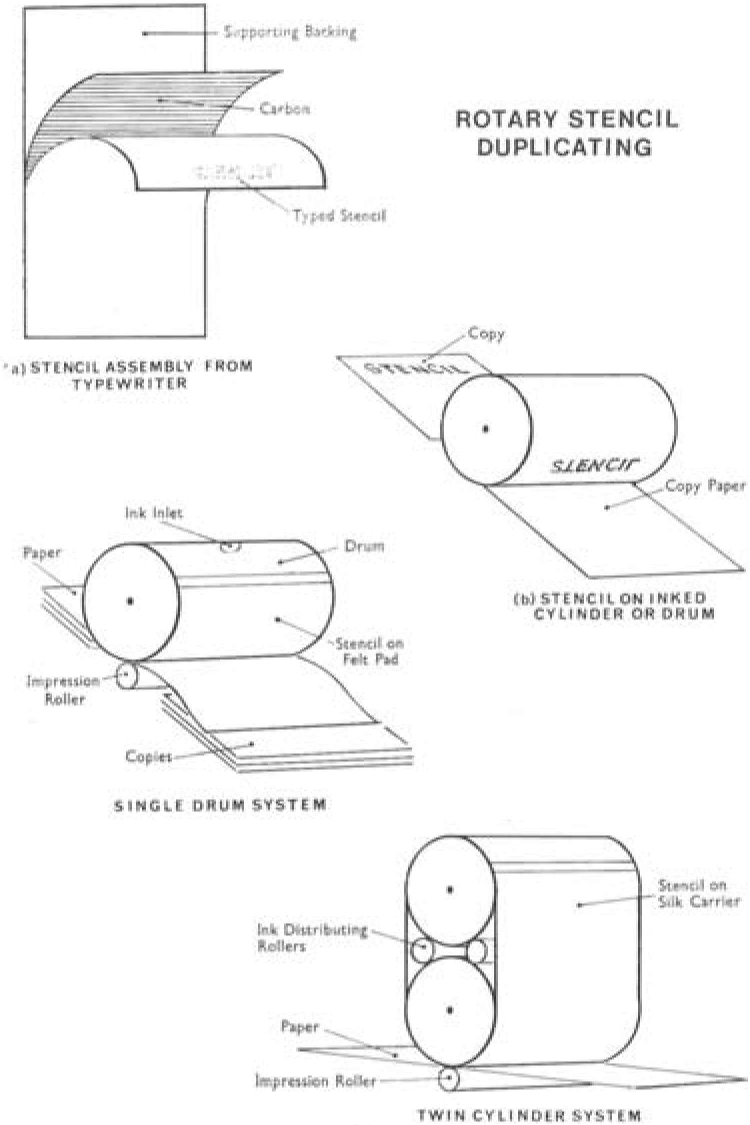

ROTARY STENCIL DUPLICATING
Supporting Backing
Carbon
Typed Stencil
(a) STENCIL ASSEMBLY FROM TYPEWRITER
Copy
Copy Paper
(b) STENCIL ON INKED CYLINDER OR DRUM
Ink Inlet
Paper
Drum
Stencil on Felt Pad
Impression Roller
Copies
SINGLE DRUM SYSTEM
Stencil on Silk Carrier
Ink Distributing Rollers
Paper
Impression Roller
TWIN CYLINDER SYSTEM

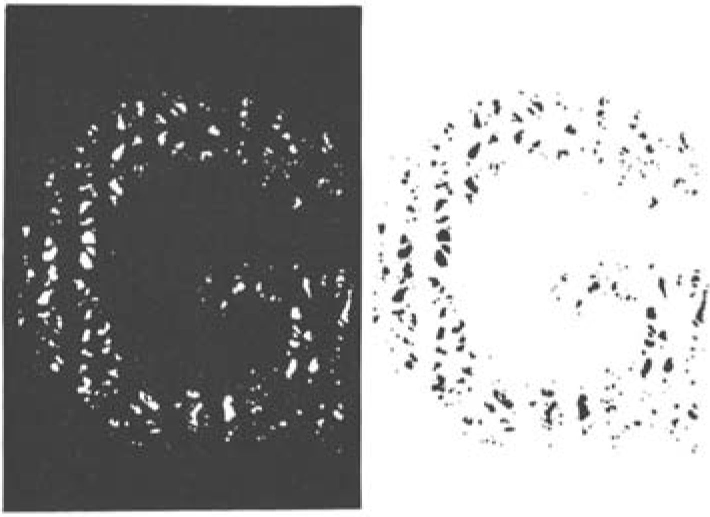
FIG. 14.

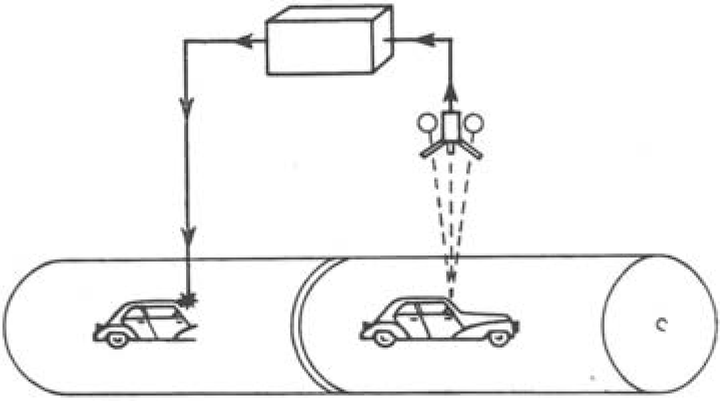
of the paper—the opposite way round to the conventional use of carbon in making copies in the typewriter. An image from this reversed carbon is obtained on the back of the paper, reading the wrong way. This is the master. It is placed on a drum; and copy paper moistened with methylated spirit (hence the name, spirit duplicating) is fed through, each sheet picking off some colour or dye to form a right-reading copy. It is a well recognised duplicating process with a proper place in the office. (See Figure 17.)

The roots of the process go back to the 1880s, when it was invented in another form, known as Hectograph (Figure 18.) Pieces of paper were written on in the ordinary way with copying ink and allowed to dry. The sheet was then placed face down on a slab of moist gelatin, when a reversed image from the water-soluble dye of the ink was formed on the surface of the gelatin. Copy paper pressed against this picked off a right-reading image. The name Hectograph came from the makers' claims to get 100 copies from one master. Research and development chemists do not always see eye to eye with their publicity and advertising departments on such matters as perfection in quality and performance!

Patents for this method of taking copy from blocks of gelatin began to appear under the names of German authors about 1879. Alexander Schapiro is such a name, associated later with an apparatus for carrying out the operation. But there is little sign commercially of the process in Germany or elsewhere until about the early 1900s, when it became established as the office boy's process. The commercial form was a tray into which the melted gelatin was poured and allowed to set. Clay compositions were also used. All sorts of contraptions were sold: gelatin-coated canvas in endless-belt form turned by a handle, and various simplified versions. They were much in use until shortly after the First World War.

It was from these handle-turned forms of Hectograph that the spirit process probably developed. It was a small but ingenious step to obtain the reversed colour-yielding image on a piece of paper instead of on the gelatin. This was done by means of a reversed carbon in a typewriter, or by writing and drawing with pencil or stylus on paper placed over the reversed carbon. Equally ingenious was the idea of moistening the copy paper





PRINCIPLE OF ELECTRONIC SCANNING

Fig. 15.

instead of the master, and with spirit instead of water. The names to be associated with these ingenious steps will be found when a search of the patent literature is made of the period 1918 to 1925. But this we know, that the first practical spirit duplicating machine to express these ideas was invented by Wilhelm Ritzerfeld, founder of the firm of Ormig, Berlin, who put the machine on the market, and made the process commercially successful in 1923. He was concerned to devise a process to assist works accountants in the posting of ledger entries. And in this connection it is interesting to note that the spirit process is pre-eminently used in systems and accounting work of this kind.

Wilhelm Ritzerfeld was an accountancy consultant—another case of the lay inventor.

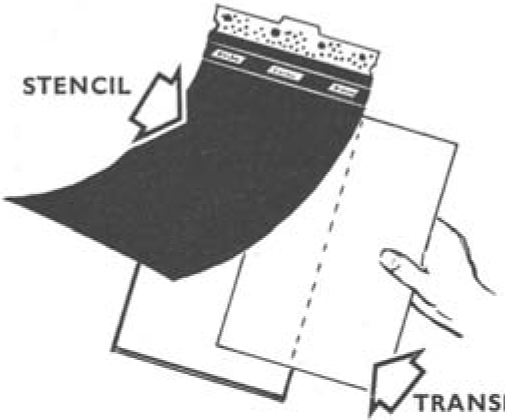
Carbons

Typewriters make us think of carbons—used in the traditional method of making copy in a typewriter at time of copying. Although the great commercial career of carbons ran parallel to the development of the typewriter, carbons were known and used much earlier.

Ralph Wedgwood, of the famous pottery family, in 1806 invented, patented, perfected, and marketed a copy-procedure based on the use of what must have been the first carbon-copying paper. Called Wedgwood's Stylographic Manifold Writer for Duplicates, it consisted of a copying book of more or less translucent sheets of paper, and a book of carbonic papers interleaved with sheets of greaseproof. The carbonic paper was the carbon—a porous sheet soaked in a suspension of carbon black and blotted off—capable of giving copy from either side. The two books were bound in a handsome folder with marbled cover boards, a lacquered writing plate, and a pasteboard guard-sheet to protect the hand (or the paper) when writing.

[*Demonstration.*] The carbonic paper was placed behind the translucent copy paper, behind that the writing sheet, and finally the writing plate. Writing was done with a metal stylus; hence the word stylographic. The reversed image on the permanent copy sheet in the book was read the right way through the sheet. The right-reading copy on the writing sheet was the outgoing letter!

Making a Transparency when cutting an Electronic Stencil



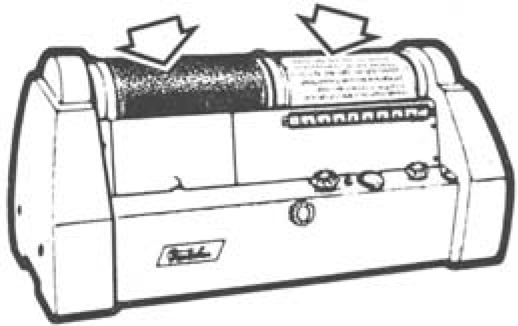
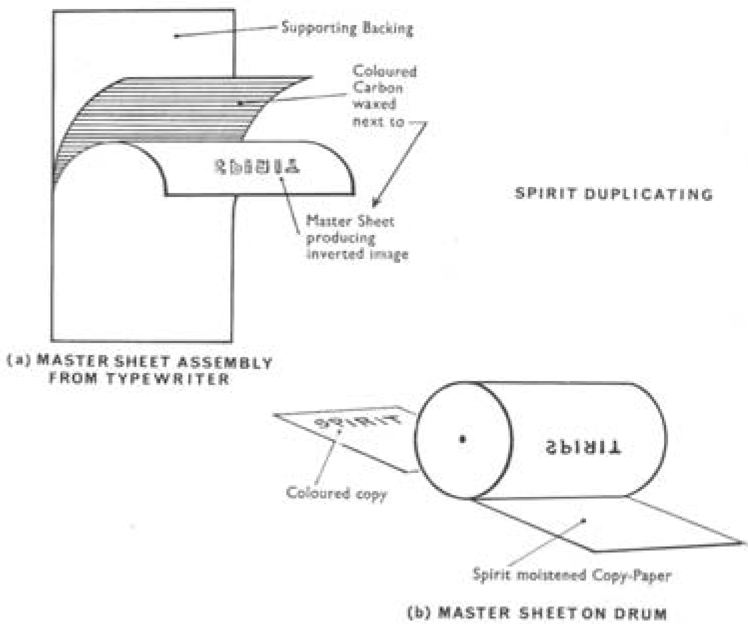


Fig. 16.

A. The original Ormig Spirit Duplicating Machine 1923.



B. Spirit duplicating.

FIG. 17.

The process was a going concern and well established by 1822. On the inside cover of the specimen in the Science Museum is a facsimile printed copy of a certificate of merit issued by none

Fig. 18. A simple Hectograph.

other than the Royal Institution, dated 1829, and signed by no less a person than Sir Humphry Davy—the equivalent of the Queen's Award for technological innovation: proof that the

Institution recognised the duplicating deficiencies of the day, and was not slow to do something about it by encouraging the humble inventor. (See Figure 19.)

FIG. 19. Royal Institution's Certificate of Merit.

Ralph Wedgwood seems to have got on to the idea when trying to invent a process to help blind people to write, in which he fixed horizontal wires on a board to act as guide lines when writing on a sheet of paper slipped behind the wires. But it was not so easy with a quill pen. So he made a piece of carbonic paper, placed it in front of the writing sheet, and, with another sheet of paper on top of the carbon for convenience, wrote with a metal stylus. It was from this that he developed his commercial product, which he hawked with considerable success during a period when he seems to have been ill-connected with the sources of the family fortune. A letter to his daughter, of which a copy was sent to me by kind courtesy of the Keeper of the Wedgwood Archives, dated 1805, makes interesting reading in its references to his Writer—a year before it was patented—and to the financial difficulties he was in at the time.

Much later, and much more messy, was the independent introduction of carbon papers into office practice. This occurred in the United States of America in the 1860s when a certain Cyrus P. Dakin of Concord, Massachusetts, made and sold a carbon paper to the Associated Press of that town for exclusive use in their newspaper business. Research has not yet shown exactly what use the newspaper people made of it, nor exactly how Dakin got on to the subject. It did reveal, however, something of the exciting sequel. It seems that in 1868 the Associated Press at their Connecticut office were covering the balloon ascent of an "intrepid aeronaut". The brave young man, named Lebbeus H. Rogers, was a grocery assistant, and the object of his aerial adventure was to advertise biscuits. But that in no way detracts from the importance of the event in the progress of the history of copying. For it was in the newspaper office, interviewed after the flight, that Lebbeus saw the carbon paper. Evidently he was so intrigued by it, and with the idea that it could be applied commercially to the copying of office invoices and similar documents, that he soon afterwards gave up the biscuit business and went into orbit with the manufacture of carbon paper.

Still more important to the progress of carbon paper in the history of copying is the further incident in 1874 in which the same young Lebbeus saw a demonstration of the then very new Sholes and Glidden typewriter, which the gunsmith Remington was introducing to the American business world. Lebbeus, ever the bold pioneer, managed to persuade the typist to include a few sheets of his carbon in the demonstration; and astounded everybody as the typewriter began to type out one, two or even three copies with the greatest of ease (Figure 20). So the pattern of the office of the future was set—a typewriter, a typist and carbons. The problem was how to make them—the carbons.

It was a messy mixture of lamp-black and oil that was used to impregnate the first sheets that Rogers, Manufacturer, coated by hand with a brush on a stone slab. But the Rogers Carbon Paper Coating Company was formed and duly established in business; and credit is due to them for proceeding to the use of wax, and hot-coatings, on much less porous paper. Carbons became one-sided or double-sided according as the wax was applied to one side or both. Their predecessors, the oil-soaked sheets, were two-sided by impregnation, not by choice.

Lebbeus Rogers lived until 1932 and saw the fruits of his early pioneering—carbons of infinite variety and usefulness—employed in every office in the world.

Before leaving Rogers and his typewriter carbons, it is interesting to mention that the typewriter was not invented as an office instrument, but came out of efforts like Wedgwood's to help blind people to write—in this case by means of a key-tapping instrument.

James Watt

It is time to go back in history to the middle of the last century—again to the copy clerk at his tall desk perched on his high stool—no typewriter, no carbons, no stencils, no hectographs. Correspondence had to be laboriously copied by hand. But he did have one mechanical aid, one piece of office equipment—James Watt's Portable Copying Machine invented a whole century earlier, in 1760, by none other than the inventor of the steam engine.

In this process the letter was written with a copiable ink on a sheet of stout, well-sized paper and allowed to dry without blotting. Preferably within twenty-four hours of being written, it was placed in contact with a dampened sheet of thin translucent tissue, to which a mirror-image of the writing was then transferred. This image could easily be read the right way through the tissue on the other side, and the process depended on this facility, and on the ability of the paper-maker to provide a thin tissue, strong and pliable when wet.

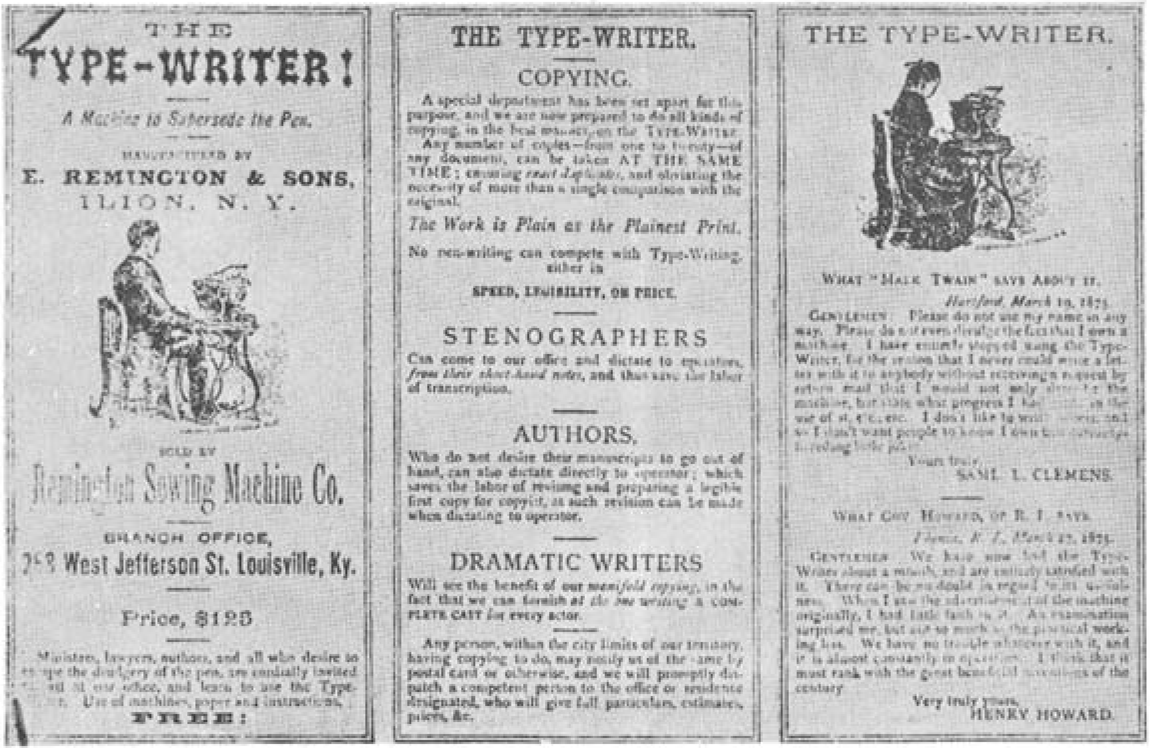


FIG. 20. An 1875 advertisement of the first typewriter.

The necessary close contact between writing sheet and tissue was ensured by the use of some sort of press. In Watt's patent of 1760 two kinds of presses are referred to: a twin-roller mangle, and the typical screwpress which became so symbolic of the Victorian office. (See Figure 21.)

James Watt worked in Soho, Birmingham, but had much correspondence with London, and apparently became so exasperated with the manual copying that he sat down and invented his copying process. All the inventive mind needs is something to invent! His method was most successful, and he soon formed a company, James Watt and Company, to make and sell it. His own office was fitted with one of his copying machines.

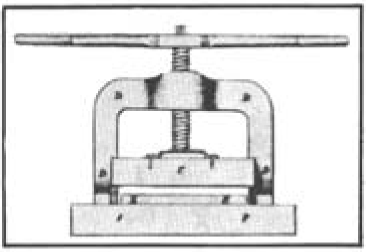
The copying book

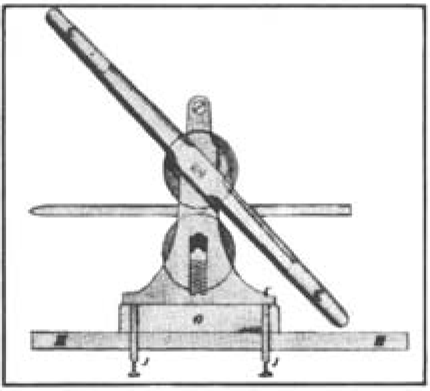
Watt's process became rationalised and established in the nineteenth century as the copying book, in which a thousand tissues were handsomely bound. They are still sold by the Solicitors Law Stationery Society Limited. Oiled sheets, dampening cloths, or brushes, were the accessories; and the book itself was placed in the press: the copy, duly numbered and indexed, remained in the book. Special absorbent smoothing sheets were used in pairs to flatten out the copy sheet and the original letter, both rather wrinkled after the dampening. (See Figure 22.)

It is salutary to reflect that the copying book, the copying press, and the Hectograph were, until as recently as the 1920s, the only office equipment for copying, except of course, for stencil duplicating, an established and advanced process by that time. Contrast the daily avalanche of the 1960s launched by the push of many buttons!

ADDENDUM

Sir Lawrence Bragg at question time recalled a letter of G. C. Stokes to Clerk Maxwell in 1878 in which mention was made of his "going up to London to get a new ribbon for his machine" (typewriter). Sir Lawrence has kindly obtained a copy of this letter from the Cambridge University Library, intrinsically interesting in that it was typed on this machine in 1878, and calls attention to the typographical failures that occasioned the need for a new ribbon. The letter is also interesting in that it raises the question of the date of introduction of carbon ribbons in relation to the dates already given for carbon papers. Accordingly reference has been made to the standard work, *The History and Development of Typewriters*, Science Museum, London (H.M.S.O. 1955), and an attempt was made to date the methods of inking the type of a





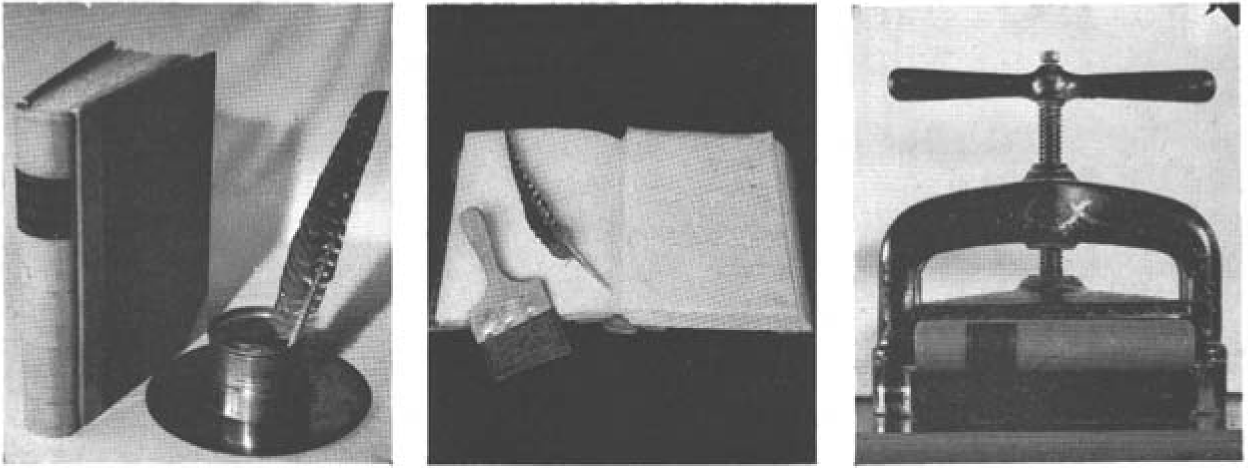
A.D. 1780.—N° 1244.

Watt's Method of Copying Letters, &c.

TO ALL TO WHOM THESE PRESENTS SHALL COME, I, James Watt, of Birmingham, in the County of Warwick, Engineer, send greeting.

WHEREAS His most Excellent Majesty King George the Third, by His Letters Patent under the Great Seal of Great Britain, bearing date at Westminster, the Fourteenth day of February, in the twentieth year of His reign, did give and grant unto me, the said James Watt, my exors, admors, and assigns, His especial licence, full power, sole priviledge and authority, that I, the said James Watt, my exors, admors, and assigns, should and lawfully might, during the term of years therein expressed, make, use, exercise, and vend, within that part of Great Britain called England, His Dominion of Wales, and Town of Berwick-upon-Tweed, my Invention of "A New Method of Copying Letters and other Writings Expeditiously;" in which said recited Letters Patent is contained a proviso obliging me, the said James Watt, by an instrument in writing under my hand and seal, to cause a particular description of the nature of my said Invention, and in what manner

Fig. 21.



A. The copying book.

B. The copying press.

Fig. 22.

typewriter. Typing with carbon papers, or carbon ribbons, is in itself not a method of making copy, but of applying ink to the type face to make the original impression. In general, as far as can be ascertained from this reference, the type faces were first of all (in and around 1830) inked with fluid ink by means of rollers, much after the manner of inking printer's type. Then between 1840 and 1860 sheets of carbon papers are mentioned as being placed between the type and the paper. This is clearly before carbon papers (other than Wedgwood's) had come into office use. There is no reference to the invention of these typeface-carbons; and I can only imagine that they were tacitly made for this purpose without being made the subject of a separate invention. Later came the idea of inking the type face by contact with a carbon ribbon, the contact with paper being made through the carbon ribbon. For this we have a separate inventor and date: Tavizza, 1867.

ACKNOWLEDGEMENTS

Acknowledgement is duly made to the following sources of illustrations: William Collins, Sons & Co., Limited; Crown Copyright Department; Gestetner Limited; Minnesota Mining and Manufacturing Company; Ormig Limited; Remington Rand Limited.

EXHIBITS

(*a*) Edison's reciprocating pen, and Wedgwood's Stylographic Manifold Writer, lent by the *Science Museum*.

(*b*) Various exhibits provided by *Gestetner Limited* and other organisations named above.

(*c*) Books from the Library of the *Royal Institution*.

MAN'S PHYSIOLOGICAL CONQUEST OF THE ENVIRONMENT

By J. S. WEINER, M.A., M.Sc., Ph.D., L.R.C.P., M.R.C.S.
Professor of Environmental Physiology, University of London, and Director, Medical Research Council Environmental Physiology Research Unit, London School of Hygiene and Tropical Medicine

Weekly Evening Meeting, Friday 25th November, 1966

Lord Fleck, of Saltcoats, K.B.E., D.Sc., LL.D., F.R.S.,
President, in the Chair

ALLOW me, if you will, to take you back one and a half or two million years. At that distant time the first few representatives of the human stock were to be found in one region of the world. I refer of course to the Australopithecine hunters of East Africa (Figure 1). Those first tool- and weapon-using groups lived in small sparse bands in the savannah bush country. These were highly active hunter-gatherer communities in an equatorial, sunny, fairly dry climate probably even hotter than today. How long the Australopithecines had been there we do not know for certain; but it is likely that they survived in East Africa and in South Africa till about a million years ago. The exposure of these groups to these conditions must have endured for something of the order of a million years: plenty of time for evolutionary selection to act as it did, and to lead to more advanced, bigger-brained, more efficient and more widespread communities of the first species of *Homo* proper (*Homo erectus*). These first representatives of *Homo* attained a wider distribution than their predecessors, but like them they were confined to warm regions of Africa and South-East Asia, and to Europe in one of its warmer interglacial episodes. So the progenitors of modern man must be thought of essentially as tropical animals.

Let us now make a large jump forward in time to a mere 10,000 years ago. We find that Man, now represented entirely by the modern varieties of *Homo sapiens*, is no more confined to his tropical homelands but has penetrated every continent. He is still a hunter and collector. What the total world population was on the eve of the agricultural and urban era we cannot be sure; probably no more than about two million since pre-agricultural groups rarely exceed one head per square mile. Though thinly spread, mankind had been able to survive and adapt to an enormous variety of terrain and climate long before domestication of plants and animals, long before settlement or irrigation, and without benefit of a metal technology. Of course the culture of hunting and fishing had undergone a continuous improvement (fire using had been started by *Homo erectus* in China some 300,000 years before) and there was a rudimentary material culture of weather and climate protection.

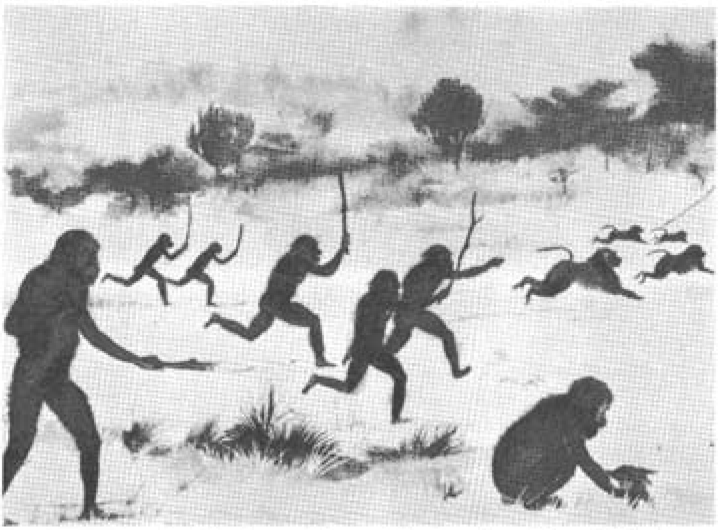


FIG. 1. The Australopithecines, widespread in South and East Africa about a million years ago, were food gatherers and hunters. (Reproduced, with permission, from R. Carrington, *A Million Years of Man*, London, Weidenfeld & Nicholson, 1963.)

There are two interconnected questions I want to consider. How far is this ability to cope with the great variety of habitats dependent on man's biological endowment and how do we reconcile the emergence of this wide versatility of *Homo sapiens* with the long earlier period of development in more restricted warmer environments?

My general thesis is that this first long period of selective evolution as an active hunter in hot climates did indeed give man a physiological equipment which enabled him to expose himself to a wide variety of natural habitats. This allowed him, so to speak, to maximise his powers of biological adjustment in the pre-technological era. In the modern era it is through the understanding of these mechanisms that man has been able to extend the range of exposure to ever greater extremes, and, paradoxically, by creating artificial micro-climates which represent a return to the ancestral warm habitat.

Now I said that the first representatives of the human stock developed essentially as hot-climate animals. The evidence for this, direct and indirect, is of five kinds—archaeological, palaeontological, climatic, anatomical and physiological.

The first independent line of evidence is archaeological. For a century or so claims were being put forward that the earliest stone tools came from various places in Europe, including those enjoying glacial conditions. Over and over again these claims were found to be unsupported—if they were truly man-made tools they turned out not to be particularly early, and when they were really early they were shown not to be artefacts. Gradually it became clear that the first and simplest implements were the African pebble tools, and the earliest of these were traced to East Africa.

The palaeontological evidence was interpreted in much the same way. The hominids were at different times thought to be mid-European (Neanderthal man), then Javanese, then an undeserving Englishman from Piltdown, then South African; but finally, as we know now from Dr. Leakey's work, the earliest have been traced back to the very same area and time as the first tools. Indeed the tools and the hominids have been found together by Dr. Leakey in Olduvai Gorge (Figure 2).

Now if man was to acquire the properties of a tropical inhabitant, the geoclimatic evidence also indicates that it had to be done in Africa. For at about the time of the emergence of the first hominids the northern hemisphere had cooled down very substantially and was moving into the Pleistocene period with its succession of ice ages.

We know of course that in the same regions of East Africa there had lived for many millions of years varieties of primitive ape-like arboreal creatures, some of which were quite plausibly ancestral to the Australopithecines. So it was here that the great challenge for survival came when some of the early apes were forced to assume a terrestrial life as bipeds. Survival was ensured by adopting the life of an active and relentless hunter in those

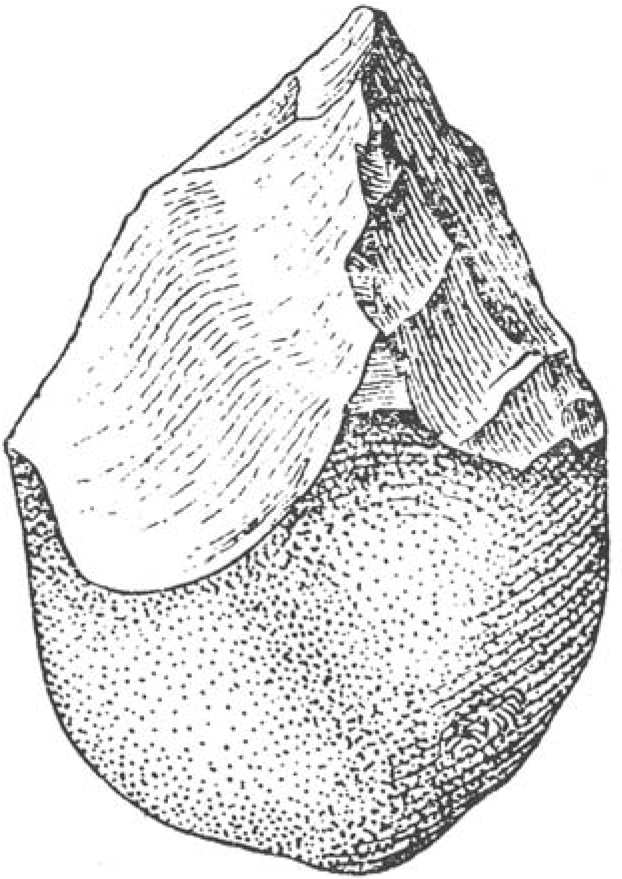


FIG. 2. A chopper of the Oldowan culture from Olduvai Gorge (half actual size).

hot sunny regions. This meant a major transformation in the morphological structure—the permanent upright posture and the free hands were the prerequisites for the development of efficient hunting techniques and weapons—as well as in the range of physiological response.

This brings us now to the anatomical and physiological evidence for man as a hot-climate creature. One of the interesting characteristics of man is that he is relatively hairless compared to his nearest relatives, the apes. In Arctic animals, the caribou for example, or in most domestic animals, the number of hairs per square centimetre is probably of the order of several hundreds, whereas in man it is much more like fifty or so per square centimetre. What significance can we attach to this state of hairlessness? I will offer a more or less speculative but, I think, not unplausible evolutionary explanation for this peculiar property of man. If you look at the skin structure in most animals, including our nearest relative the chimpanzee, you will find a great number of glands called apocrine glands in close association with the hairs; the hair and the gland develop together from the same embryonic structure. In man, the apocrine glands (Figure 3, above) are very sparse and so are the hairs; both have very largely disappeared together, and instead of the apocrine we have what is called the eccrine gland (Figure 3, below) which is found over the whole surface in high density without any close association with hair follicles.

Now, the important point is that whereas the apocrine gland produces a rather scanty secretion (and because of its persistent odour probably subserves some socio-sexual function) the eccrine gland produces sweat in great abundance, making possible a high rate of heat loss by evaporation. For sweating to be maximally effective it is a great advantage that the hairs should disappear or become very sparse. The hairs in high density will trap a layer of still air which will greatly reduce heat loss by evaporation even when there is a fairly strong air movement. Human hairlessness is therefore an essential part of man's adaptation to hot environments.

There are in fact something like two million sweat glands over the skin's surface, and this number seems to be similar for both tropical and cold-climate peoples. The associated property of hairlessness has become secondarily modified in some population groups but only to a limited extent. Evidently there must have been a great survival value for the human species in retaining these features.

Finally there is the striking physiological evidence of man's

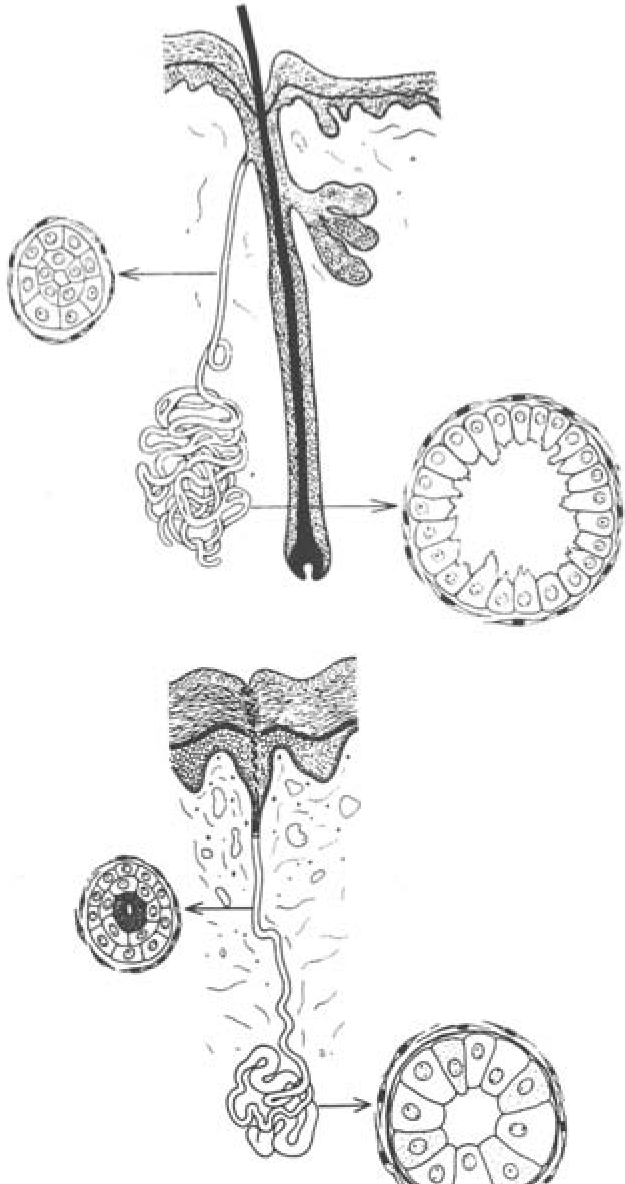


Fig. 3. Schematic diagram of the human apocrine sweat gland (above) and the sweat gland (below), showing the coil and duct in cross-section.

tropical origins. Tests of heat tolerance have now been done on samples drawn from many racial and regional varieties of mankind. In general they reveal a universal ability to cope with heat load by the phenomenon we call acclimatisation. One illustration must suffice. Two groups of young European adults were both subjected to a fairly severe heat load in identical conditions of temperature, humidity and work. The one group had never left this country; the other had lived two hot seasons in Singapore. The superior adjustment of this group was shown by the fact that under heat stress their body temperature and pulse rate rose much less and that they sweated more rapidly and efficiently. This natural state of acclimatisation can be quite easily induced artificially in the stay-at-home group by repeated exposure to hot conditions for about two weeks.

The large cooling capacity provided by the sweat glands, enhanced by acclimatisation, enabled man to become an active hunter generating a high and sustained energy output, in the face of the superimposed heat load from the high air temperatures and solar radiation of his natural habitat, to an extent of which no other animal is capable. This biological heritage enabled man to become a very active labourer in the agricultural era, to cope with hot, humid conditions quite as well as with the hot dry sunny conditions of his original habitat, and to perform even harder work in the cooler habitats to which he ultimately migrated.

There is another piece of physiological evidence of man's tropical origin. Physiologists speak of the "critical temperature", i.e. the temperature below which the animal responds by increasing its heat production, mainly by shivering. The critical temperature of a tropical animal is much higher than that of an Arctic animal, which has far more insulation in the form of hair and subcutaneous fat (Figure 4). Now man as a species falls squarely into the tropical category. In the naked state his critical temperature is about 28°C air temperature. Because of his raised "critical temperature" man's capacity to withstand the regions of cold without artificial protection is severely limited. It is true that the hunter's ability to maintain a high level of activity and heat production has proved a distinct advantage, and the skinfold thickness of temperate dwellers is on average greater than that of tropical peoples, but very few human populations have come to rely for cold tolerance predominantly on physiological and morphological adaptations.

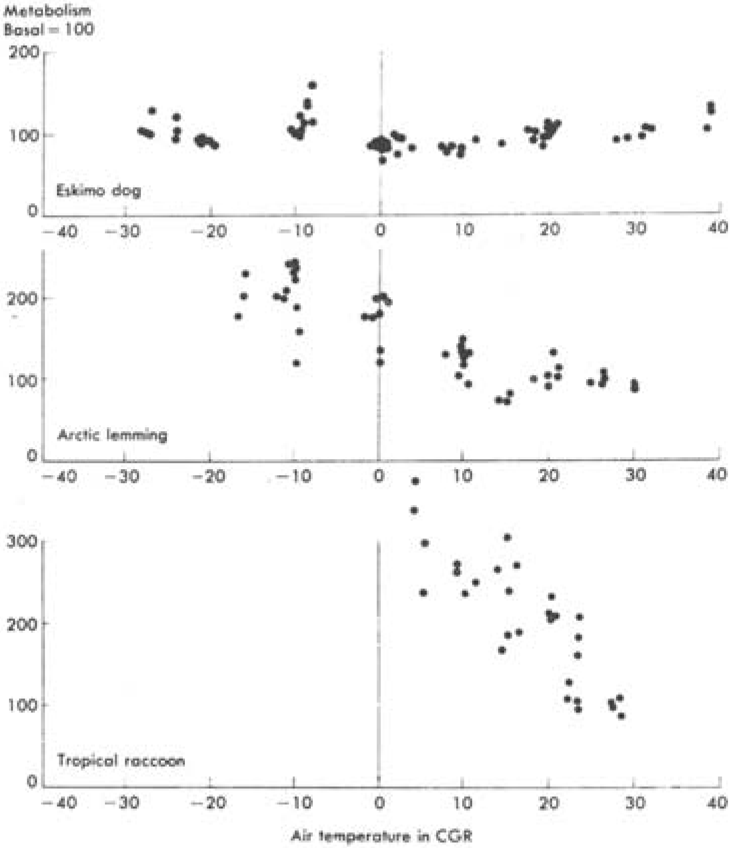


FIG. 4. Heat production versus environmental temperature in the husky, the lemming and the tropical raccoon. Resting or basal rate is set at 100. Critical temperature is below −30° in the husky, 10–15° in the lemming and 25–27° in the tropical raccoon.

The Australian aborigines, the South African Bushmen, the Patagonian Indians and some of the Andean Indians survive diurnal or seasonal conditions of extreme cold with a minimum of heating or protection. None of these groups have developed any extra thickness of subcutaneous fat. Yet they are capable of sleeping quite soundly at or near zero temperatures when their European observers find this impossible, and lie awake shivering incessantly and feeling very miserable. Another striking example is the way that the diving women of Korea and Japan (the Ama) can withstand extremely cold water throughout a whole working day in the winter. Nor have they any increase of subcutaneous fat. We are not at all sure of the processes making for this enhancement of cold tolerance; in some cases a reduction of the critical temperature seems to be responsible. There is also some experimental evidence to indicate that some degree of acclimatisation to cold can be developed by Europeans by gradual "hardening". On the present evidence it is possible, but not yet proved, that genetic selection for cold may have affected some of the Australian aboriginal groups.

The fact is that, faced with the extreme stress of cold (and we shall see other stresses), man has preferred a different solution. This is based on the provision of an artificial and fairly stable micro-climate reproducing the warm conditions of the original tropical habitat. The Eskimos were the first great pioneers of this climatic bio-engineering, which they brought to a high degree of effectiveness.

I want now to turn to the other major component of the early hominid life, namely the physical activity of hunting, and see what this has done for man as he is today. One thing it did, of course, was to turn him into a carnivore or rather to make him omnivorous in his diet; this was a very important precondition for his subsequent spread all over the world.

The difference between a physically fit man, such as an active hunter, and an untrained subject can be seen in the more efficient circulation (the smaller increase in pulse rate), and the more efficient utilisation of oxygen by the muscles (as evidenced by the lower lactate production). The muscularity and the chest size undergo some increase.

For man to spread up to high altitudes, and establish permanent communities, rather similar physiological changes are involved. Since the introduction of agriculture the population at, say, above 10,000 feet, where the oxygen tension is markedly reduced, has reached quite large numbers. The responses to the lowered oxygen tension are rather similar to the responses elicited during exercise when oxygen requirements are increased. A major prerequisite for successful survival at high altitude is an improvement in the capacity of the oxygen transport system. It is not enough that the newcomer should breathe deeper as the the lowered O_2 tension stimulates his respiratory centre. For colonisation there has to be acclimatisation and this involves lungs, circulation and the muscles themselves. In these respects there is no doubt of the superiority of the indigenous people—a superiority which strangely reminds one of the superiority of the trained athlete. Just as the trained athlete has a chest expansion and chest size enlarged, so too have the natives of the high Andes, Ethiopia, and the Himalayas.

When we consider again those strange people who spend so much of their working lives not at low but at high pressures—the Ama—we find that the adaptiveness of the respiratory system has much to do with their success in the diving profession. Like the high-altitude dweller the Ama are superior in their breathing capacity, in their vital capacity and in their chest development. Adaptations developed for hunting life would seem to provide the key to the performance of this extraordinary task.

The changes which human groups have experienced as a result of moving into cooler and less sunny habitats, if they do not represent the exploitation of potentialities already developed, are often only changes of a quantitative kind. Take, for example, the well established diurnal temperature and other bodily rhythms. These seem plausibly to be related to the regular daily cycle of the tropical environment, and some of these rhythms are very difficult and indeed impossible to shift out of phase even in the continuous light or darkness of the seasons of northern climates. But the temperature rhythm does show some adaptability to changes in the daily routine.

Much more pronounced but still only in the nature of a quantitative change has been the modification in skin colour, that is in the amount of melanin. The possession of dark skin colour (though not unique to man) is clearly an essential adaptation to the high ultraviolet light of tropical regions—it protects against sunburn and some forms of skin carcinoma; but with his movement out of regions of high ultraviolet light intensity there has

FIG. 5. Different types of body insulation among the Ama of Japan: on the left the Ama of Hekura Island, in the middle Ama from Shima Peninsula in cotton suit, and on the right the recent foam rubber suit of Ama from the Boso Peninsula. (Reproduced ,with permission, from (left to right): Fosco Maraini, *The Island of the Fisherwomen*, London, Hamish Hamilton, 1962; Y. Nakamura, *Ama in Japan*, Tokyo, Chunichi Press Co.; and Hiroo Tanaka, Mainichi Press Co.)

been some modification in this property, one incidentally which has affected all racial groups.

Environmental stress has, in the modern era, become ever more intensified: deep mining, the steel and other industries, nuclear engineering, military practice, air travel, space and deep sea exploration, have all presented challenges to the human organism which the age-old physiological endowment cannot now meet adequately. We now use our biological understanding in a different way—in the way in fact pioneered by the Eskimos. The Eskimos have learnt not to depend to any great extent on physiological acclimatisation to cold. They are the great pioneers of micro-climatological bio-engineering. The Eskimo clothing, including gloves and headwear, as everybody knows, has remarkable properties of waterproofing, of resistance to compression and of thermal insulation, which is seldom equalled even by the clothing assemblies of modern explorers. For example, the skin temperature under the clothing remains high even at air temperatures of minus ten when they are sitting still. What the Eskimo is doing is to recreate the climate of early Pleistocene times. And this is the principle which we have now adopted universally in physiological bio-engineering. In many kinds of situations we tend not to worry so much about the range of innate physiological adaptability but rather to try and reproduce, inside the protective shell, a micro-climate of desirable levels of oxygen, carbon dioxide, atmospheric pressure, temperature and humidity.

Whether it is in relation to heat or cold or diving or altitude, this endeavour to reproduce what are essentially the optimum tropical conditions is engaging the attention, skill and ingenuity of physiologists in many parts of the world. Take the Ama again. In many parts of Japan they are moving away from reliance on their physiological attributes. They have developed their own one-piece diving suits, and their underwater goggles are very ingeniously constructed, with a counter-pressure system which prevents them from pushing the eyeball back at depth. Figure 5 shows the change from the simple physiological condition to bio-engineering.

Another example concerns protection against high radiant heat. In spite of the extraordinary efficiency of physiological heat tolerance that I described earlier on, there are a number of

FIG. 6. Dynamic insulation assembly as used for steel works.

situations in the modern world where this adaptability is simply not good enough. Take for example the repairs that have to be done in an open-hearth furnace in a modern steelworks. If you relied on the man's power of heat adaptation, you would have to wait several days before the furnace was cool enough; in times of full employment there is always a hurry to get the furnace repaired and the steel-making restarted. The obvious solution is to use a ventilated suit and get a man in quickly, but this is not as

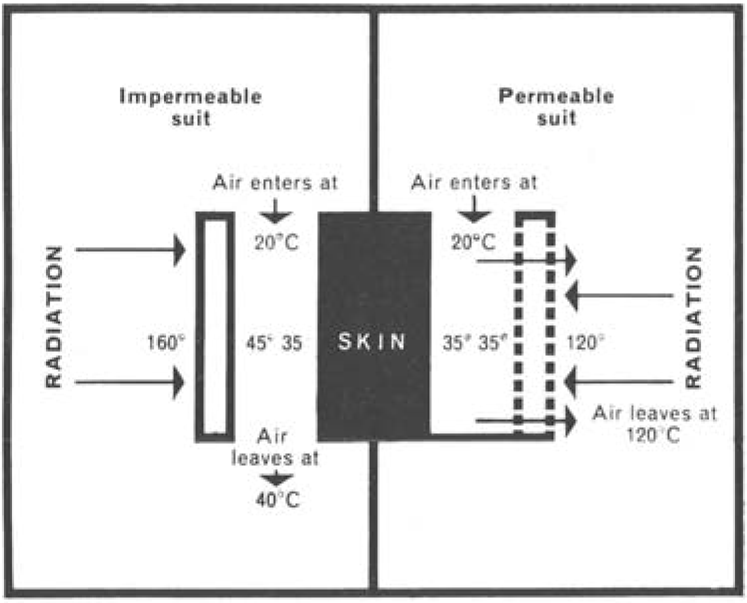


FIG. 7. Diagram of the air flow through an impermeable suit and the permeable (dynamically insulated) suit.

easy as it seems. Figure 6 shows a newly developed protective assembly—an example of a fairly sophisticated bio-engineering solution for coping with temperatures which are as high as 200°C and with quite hard work for two hours or so. The ordinary impermeable suit requires far too much cool air and has to be about 5 cm thick. In these conventional, commercially available suits the air fed into the suit escapes at the extremities or special valves; the evaporation of sweat is brought about by the air flows parallel to the body surface. Figure 7 compares diagrammatically the air flow in an impermeable suit with that through a permeable one. The fundamental difference between the two suits is that, in the impermeable one, if air enters at 20°C it must leave at a temperature close to that of the skin, say 40°C, giving a temperature rise of 20°C. In the permeable suit the air leaves at the temperature of the suit's outer surface, in our experiments about 120°C, a temperature rise of 100°C. The heat-carrying capacity of 1 lb of air in a permeable suit will therefore be about five times greater than that of 1 lb of air used in an impermeable suit. A counter-flow heat exchange system (called dynamic insulation) is in fact set up in the permeable suit material.

In modern high-flying aircraft the physiological shell has to be of still greater complexity. For now abnormal pressures on the body have to be counteracted and oxygen has to be supplied at correct tension. The oxygen helmet with speaking attachment has become a highly sophisticated piece of microclimate. For supersonic flights suits are also cooled by means of turbine coolers and blowers and impermeable suits operating on the "dynamic" principle.

Finally the astronaut. When the man on the moon is groping about those craters over that flaky surface, his whole environment provided by the technology of the biological engineer, his movements power-assisted, with oxygen, water, temperature, humidity, food, all in one self-regulated system, our lunar man will, I hope, be happy in the only environment in which he was evolved—the old Pleistocene environment of Africa.

EXHIBITS IN THE LIBRARY

(*a*) A series of exhibits demonstrating the protection of industrial workers against heat, arranged by the *Medical Research Council Environmental Research Unit*.

(*b*) Literature on the *International Biological Programme*.

(*c*) Recent books on human ecology and adaptability, lent by *Professor J. S. Weiner*.

(*d*) Books by, or partly by, *Professor Weiner*.

(*e*) Palaeontological and geological books from the Library of the *Royal Institution*.

OPTICAL GLASS

By L. H. A. PILKINGTON, C.B.E., J.P.
Director, Pilkington Brothers Ltd.

Weekly Evening Meeting, Friday 2nd December, 1966

Lord Fleck, of Saltcoats, K.B.E., D.Sc., Ll.D., F.R.S.,
President, in the Chair

"PERFECT as is the manufacture of glass for all ordinary purposes, and extensive the scale upon which its production is carried on, yet there is scarcely any artificial substance in which it is so difficult to unite what is required to satisfy the wants of science. Its general transparency, hardness, unchangeable nature and varied refractive and dispersive powers, render glass a most important agent in the hands of the philosopher engaged in investigating the nature and properties of light; but when he desires to apply it, according to the laws he has discovered, in the construction of perfect instruments, and especially of the achromatic telescope, it is found liable to certain imperfections, not essentially existing, but almost always involved during its preparation, and fatal to its use. These are so important and so difficult to avoid, that science is frequently stopped in her progress by them; a fact fully proved by the circumstance that Mr. Dollond, one of our first opticians, has not been able to obtain a disc of flint-glass four inches and a half in diameter, fit for a telescope, within the last five years, or a similar disc of five inches in diameter within the last ten years."

These were Faraday's opening words in his Bakerian Lecture first read on 19th November, 1829. The imperfections referred to by Faraday were what the glass industry knows as cord. [*Demonstration of a piece of glass melted by Faraday and suffering from this trouble, and of a good piece of modern optical glass.*]

This state of affairs described by Faraday had led the Royal Society in 1824 to appoint a Committee for the Improvement of Glass for Optical Purposes which consisted of Fellows of the Royal Society and Members of the Board of Longitude. The Government promised not only financial support but also the removal of the restrictions to experiments on glass occasioned by the Excise Laws and Regulations.

Experiments were commenced but apparently were not going fast enough, so on 5th May, 1825, a Sub-Committee was appointed consisting of Faraday, Herschel and Dollond.

The original furnace was erected at the premises of Messrs. Green and Pellatt at the Falcon Glass Works near Battersea Bridge nearly three miles from the Royal Institution, but after a time Faraday found it impossible to carry out the many experiments and give them the close attention which was required. As a result the President and Managers of the Royal Institution gave to the President and Council of the Royal Society permission to erect on these premises an experimental room and a furnace.

This was completed in September 1827; an assistant to Faraday was engaged—Sergeant Anderson of the Royal Artillery, "whose steady and intelligent care has been of the greatest service to me in the experiments".

Faraday experimented with a mixture of nitrate of lead, silicate of lead and crystallised boracic acid. He describes in detail the preparation of the raw materials and emphasises the especial need when making lead glasses to have the highest possible freedom from impurities such as iron and manganese. He also describes his furnace, his crucibles and even how to make the platinum tray into which the melted glass was poured, and it is interesting to note that the largest piece he had made was 7" square by 0.8" thick.

The result of his work in the manufacture of the glass was really the first major development in the manufacture of optical glass in this country. The Royal Institution appears to have been going through difficulty with its finances at that period and it is believed that the payments to the Institution for this work helped it to weather the storm. It is, therefore, interesting to see what was the cost of this work. Mr Kaye has provided me with a copy of a minute of the Glass Sub-Committee dated 30th April, 1831, which summarises the expenditure to that date and as there is also a note that the Sub-Committee was not reappointed we can take it that the total of £592. 5s. 2½d. was the full cost of the work. It may be interesting to compare this with the cost of producing a glass for special purposes in eighteen months in 1964-65 which involved less time but cost £49,000.

In the report of the 1851 Exhibition there is an interesting comment which reads as follows:

The Lords of the Treasury had found it advisable to make a relaxation of the Excise laws in favour of the Royal Society, or persons acting for scientific purposes under that body. But, notwithstanding this regulation, the interference of the officers, and the delay in obtaining the necessary licence, proved so onerous and inconvenient, as completely to shackle their proceedings, and preclude all attempt to improve by means of experiment; and the question as to the fabrication of flint-glass being actively pursued in France and Switzerland, the Commission ceased from its labours.

The major part of the success of Faraday's experiments was due to stirring the glass and this was inspired by Guinand, the author of the work referred to in this quotation, with whom he was in correspondence at the time. Whether or not it was the Lords of the Treasury who prevented the development of the process in this country, nothing did come of the work until M. Bontemps, after working with one of Guinand's sons in Switzerland, came over to England in 1848, at the invitation of Chance Brothers, and became manager of their optical glass department. By the time of the Exhibition of 1851 they had produced for display discs of "extraordinary dimensions" as the Exhibition catalogue says, in flint glass of 29″ and in crown glass of 20″. These were rough blanks but were regarded by the judges, Sir David Brewster, Sir John Herschel and Lord Wrothesley, as so important that they invited Chance Brothers to grind and polish them, and as a result a Council Medal was awarded.

In parallel with this the Rev. Vernon Harcourt, one of the founders of the British Association, later joined by Sir George Stokes, President of the Royal Society, investigated many types of optical glass, which they described in 1871 to the British Association. Similar work resulted from the collaboration between Abbé and Schott, and by 1886 the Schott catalogue contained forty-four glasses of which nineteen were quite new. This German work was so successful that optical glass manufacture became almost a German monopoly until 1941, but Chance Brothers had courageously continued manufacture on a small scale and were thus able to meet the military demands for optical glass during the 1914–18 war with the support of the Admiralty, and of a second source of optical glass bought by Sir Charles Parsons, and after his death absorbed by Chance Brothers. By 1920, however, the demand had slumped once again and in that year there were only two employees in Chance's Optical Department.

But manufacture continued and also, very commendably, research work, particularly into stirring. The process was then very similar to that shown in this film taken in 1934. The yield of the process was about 27% good glass. [*Film.*]

In 1940 G. W. Morey in the United States investigated the possibility of including rare earths in optical glass and this resulted in a new generation of glasses with special properties, particularly useful in correcting chromatic aberration. These, however, were in demand in small quantities and were expensive, so a modified process was developed, using platinum pots containing a weight of only a few pounds, or at most 100 lbs.

This resulted in the development of many different glasses from different sources, and because until quite recently the computation of a lens was a lengthy and laborious business, taking months rather than days, lens producers were not willing to change from one type of glass to another—even though very close in its properties. This was the position, therefore, in 1950.

The demand is not, of course, evenly distributed; it varies from over 1,600 tons per year in the case of 524592 optical crown to four tons in the case of the rather similar glass HC.519604.

This means that while there is a place for mass production for about sixty-nine types of optical glass, the remaining twelve minor types can only be made on a batch process which, of course, has the drawbacks of high cost, less certain reproducibility and sometimes long delivery.

With the pot process it sometimes happened that a mistake was made in the mixture, with the result that a few tons of glass were made with different refractive index and dispersion. The temptation was great to sell this glass to someone who was just designing a new lens and who would probably accept this off-index glass especially if it was offered at a discount. The trouble came later, of course, when the glassmaker was asked to repeat the glass for further lenses.

However, with the advent of the electronic computer the job of redesigning lenses has become much quicker, and this we hope will result in a marked further reduction in the number of optical glass types in demand—a result much to be desired by the glass manufacturers and one which in the opinion of the highest authorities in lens design will not restrict their scope or the performance of the resulting lenses, and we believe it could even

Fig. 1. Cartoon by Mr. D. Kendrick.

improve performance by allowing more types to be made continuously and with even more closely controlled optical properties. At the same time we are continuously working to produce glasses with more extreme properties.

FIG. 2. British idea, 1950, of a typical purchaser of binoculars. (Photograph by Mr. B. Tinling)

This is the appearance of the continuous process where the carefully selected and purified raw materials are fed into a melting furnace, through a refining chamber to a stirring process, and finally to a forming process which produces either strips of glass for further moulding or else pressed blanks which after further annealing are ready for the process of grinding or figuring to shape and polishing. [*Film.*]

This was installed at St. Asaph in North Wales as soon after the war as was possible, and the same process with major improvements is still running.

During the immediate post-war period there was some alarm and despondency in the optical industry. First of all the radio telescope was developed and at the same time what was at that time called "the last optical telescope" was under design (Figure 1).

In the event radio astronomy has encouraged optical astronomy and not killed it, so the industry has still quite a fair market for telescope discs here, but what was wanted by the glass manufacturer was a large and continuing market for his products which would act as his bread-and-butter line and would support the expensive research needed to develop new products and improve existing ones. This has happened in two ways. The use of spectacles has increased greatly since the Second World War, and now the ophthalmic section of the industry is very large and relatively stable. Another large and steady trade has developed, at least for the glass manufacturer if not for the instrument maker in this country. This I think is an interesting instance where possibly we in this country were tied down too much by tradition. Figure 2 gives a fair impression of our idea of the typical purchaser and the restricted market for binoculars in this country in 1950, while Figure 3 is a slightly unkind idea of the tourist as seen through Cambridge eyes.

We laugh at it, and the British optical industry laughed at it, but the Japanese and Hong Kong Chinese saw the implications and set about making binoculars and cameras to be sold to a far, far wider section of the population. They now make about fifteen million pairs of binoculars per year and I am glad to say that about one third of them contain British glass. These three outlets for glass—spectacles, cameras and binoculars – take the vast majority

FIG. 3. The tourist as seen through Cambridge eyes. (Reproduced with permission from *Varsity Handbook* 1957-58)

of the world's optical glass, but parallel with the much wider use of these instruments very important developments were taking place in the instrument industry and producing a great surge forward. This development, which is still very young, is the combination of optics and electronics in the field now known as electro-optics.

Four steps stand out clearly in this development. The first was the advent of the electronic computer which, as I have already mentioned, reduced the time necessary in the calculations for a design of a lens from months, or even years, to minutes. It enabled quite cheap zoom lenses to be designed for cine-cameras and enabled the optical designer to optimise his designs very quickly. Other things were also made possible by the computer, particularly thin film coatings which I will mention later.

The second step was the development of the conception that information could be handled by optical methods as readily as by electronics. One example of this is in the use of fibre optics. If light is passed down a rod it is reflected at the surface of the rod backwards and forwards until it emerges at the end. If light is directed onto the end of a bundle of glass fibres (preferably with each fibre coated with another glass of different refractive index) it will pass down the bundle and emerge at the other end even though the bundle of fibres is bent or coiled. This property of the bundle has been used in a number of ways from lighting up and examining the human stomach to transferring the image on a curved cathode ray tube face to a flat screen. [*Demonstration.*] Not only is the surface flat but the surface does not reflect the high power light sources directed onto it—after all the fibres will pass light in both directions!

Also in fibre optics, if glass with very high homogeneity and hence low scattering properties—very high freedom from impurities and hence high transmission—can be made into fibres it is quite possible that they could replace in the future our telephone wires, with the great advantage that very many channels or messages could be carried simultaneously over one conductor.

The third development I wish to mention is the technique of evaporating very thin films onto the surface of glass. The method of fluoride coating of lenses to reduce the reflection and allow more light through the lens was well known, but the multiple coating technique using many layers of different substances and reducing reflection to a far greater extent was only possible when all the very cumbersome mathematics could be worked out on a computer. It is very improbable that the laser itself would have been developed without this technique. They can be designed so that they transmit all the light except a narrow band of a particular colour, or reflect a pre-determined proportion of a wide or narrow band of the spectrum. This technique has resulted in tremendous strides in spectroscopy and allowed instrument makers to abandon the expensive and not always reliable pre-prisms in these instruments, and is very useful in other instruments. [*Demonstration.*] As you will see, it is possible to pass light from a multi-coloured image through a series of optics treated in this way, so that the green content of the image is diverted at one point, the blue at another, the red at a third. The implications of this in colour television are obvious and, in fact, this is the basis of the Marconi system of colour television.

The fourth step was in the development of the maser and particularly the optical maser or laser. Some wit has transposed an earlier *bon mot* to the laser in describing it as a solution in search of a problem. How totally untrue! It has provided an irreplaceable tool to many scientists, including Professor Porter, and a host of technologists. Among them are the many people in the optical glass industry who have wanted a source of coherent light for a long time and they have developed a number of far more sensitive means of measurement of optical systems than has been possible heretofore. The first of our demonstrations showed that the ordinary system with an arc lamp revealed the difference in the optical quality of two glasses, and a similar system using a laser gives a more critical evaluation; thus the laser allows us by the use of more sophisticated testing techniques to produce better lenses; accuracy until recently has been limited only by our measuring tools. It is true to say in optics that if we can measure it we can produce it. Figure 4 is an example of a photograph taken with a lens produced in this way from a height of 40,000 feet or 7½ miles.

It was not only the lens which was important in this case but the window through which the photograph was taken. Even high quality plate glass windows will cause quite considerable devia-

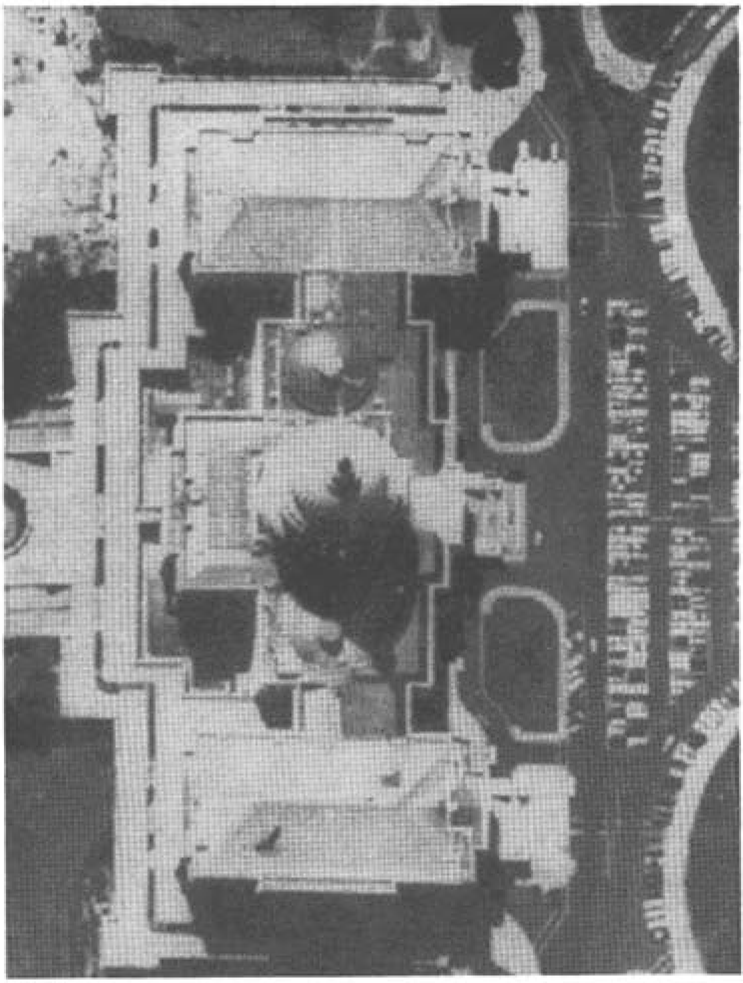


FIG. 4. Photograph of the Capitol, Washington, taken with a Perkin-Elmer camera from a height of 7½ miles.

tions of the light rays on their way through to the camera lens, and beside this imperfection further distortion is caused by the window becoming a low power lens due to the temperature and pressure effects on the window which result from flying very fast at great heights. A very elaborate window has therefore to be designed and finished to high optical standards so that the quality of the photographic image will not be impaired by it.

Similar very high grade lenses and mirrors have been produced, particularly for the American space programme. Not only are there lenses in the television cameras used in the moon-probes but there are very accurate optical systems used for tracking. High grade mirrors too have been produced for such things as the orbiting balloon-supported telescope which has already carried out missions, recording and analysing on a spectrometer light from several stars. In this connection there has been one very interesting and quite hopeful development in the experimental production in the United States of a glass with zero expansion. Hitherto astronomical telescope mirrors have been made from either borosilicate low expansion glass or fused silica, both of which have low but quite appreciable co-efficients of expansion, and when atmospheric temperatures vary quite sharply round the telescope the quality of the image of the star deteriorates abruptly.

If this new glass is found to be satisfactory the quality of the image will not deteriorate with temperature changes. Some mirrors have been made and are being tried now but so far no reports of their performance are available.

The use of laser-based optical testing is an extremely valuable technique to the optical worker, but although it has interest and use in other fields perhaps an example of the use of the laser in fields of greater everyday interest should be mentioned here.

If one could scan a scene with a laser beam at an intensity sufficiently low to avoid any possibility of damage to the eye, pick up the light reflected from the object and use this to modulate another laser beam directed onto a screen, or use it to modulate a cathode ray tube, a picture of the scene could be produced and would have several advantages. Firstly, no cumbersome lighting apparatus would be needed and pictures could be obtained either in darkness or subdued lighting, and the level of laser illumination would be barely perceptible to the eye and very much below any level able to cause eye damage. Secondly, due to the fact that there are no imaging lenses the system has an almost infinite depth of focus. Thirdly, light sources in the field will appear as grey smudges, not as bright glaring spots or stars.

There are numerous possible uses for such a system: an all-weather landing system for aircraft—an unobstrusive crime detection system which could monitor for instance the approach to a safe without any indication that surveillance was taking place, or even monitor the tops of prison walls—the observation of the nocturnal habit of animals.

By using two or more different laser sources a colour picture could be obtained. To show how this can be done a block diagram

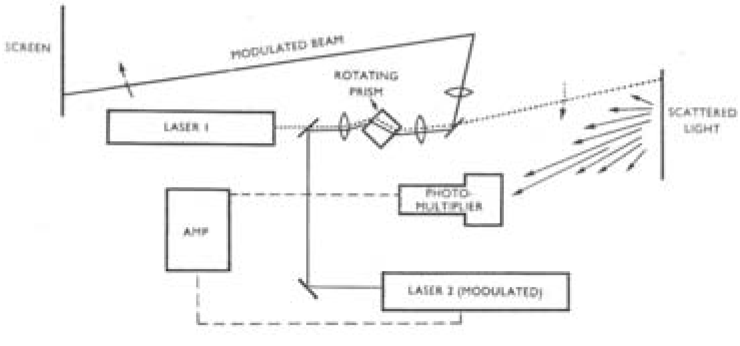


Fig. 5. A simple two-laser system for scanning an object in one dimension and reproducing an image of that object on a screen.

of a simple system is shown in Figure 5.

The light from laser No. 1 passes through the optical system, and the rotating prism causes the beam to scan a simple object consisting of bars and spaces. The light which is scanning only in one dimension strikes the bars and spaces of the object and is scattered by varying amounts. Some of this scattered light is picked up by the photo-multiplier tube which converts it into an electrical signal. After amplification this signal is used to modulate the second laser.

The varying intensities thus generated by laser No. 2 are passed through the same or a similar scanning system and form a representation of the original object. [*Demonstration.*] The laser can, in fact, act as a camera and as a display system; in fact, it could become a competitor to both the electronic television camera and the TV receiver, and the life of both these could be nearly over, particularly if non-mechanical scanning methods fulfil the promise of their present state of development.

This is the one-dimensional system and you may rightly say that for television use you must have a two-dimensional system.

Equipment of this kind still using mechanical scanning systems has been under development in the laboratories of the Perkin-Elmer Corporation in the United States. A red beam from a continuous-wave helium neon gas laser is brought to bear on a 16-sided polygonal rotating mirror revolving at 60,000 r.p.m. This scans the beam onto a second scanner, the frame scan, a 24-sided mirror rotating at 150 r.p.m. This causes the beam to scan an area 45 degrees from left to right and 30 degrees up and down at a rate of 60 times a second. The reflected light from this beam, which has a very narrow wavelength at 6,328 angstroms, can be picked up by a photo-multiplier behind an appropriate narrow-band filter and is thus transformed into a video signal for display after amplification on a standard monitor screen. Suitable synchronisation of the laser line and frame scan with those of the monitor have, of course to be provided. [*Demonstration of Perkin-Elmer camera.*] In these four steps of the development of electro-optics I started with the electronic computer. These machines consist of various logic systems, memories, power supplies and so forth. They were first built with valves; these used too much power and were cumbersome, so they were replaced by transistors. [*Demonstration.*] But as the complexity of computing machines has increased, the physical size even of the transistorised version has increased also, and the physical distance which a signal must travel has become so great that the speed—the computer's advantage—has been much reduced. The cure? Obviously shorter distance and, therefore, smaller sizes.

[*Demonstration.*] Here is what is called an integrated circuit. You will have to accept from me, because I doubt if you can even see it, not only that it is there but that it will do exactly the same job as the valve model or the transistor model. To produce these minute electronic circuits extreme accuracy of size and spacing is required, and the only method for this standard of accuracy, spacing and reproducibility is to use computer-designed optical lenses. So we are back where we started in this development of modern optical systems, and we close the loop, starting with electronics giving optics a new look, and ending with optics giving electronics a further lease of life!

All lecturers feel a sense of relief when their final demonstration is completed, and in my case I am very grateful to those who have staged them: in particular to Mr. Coates who always manages to produce an effective demonstration from the most unlikely materials; to Mrs. Conisbee the projectionist; to Mr. Freeman and Mr. Gilbertson, not only for working these demonstrations but for all the work involved in developing them; to Mr. Milne for his help in organising the demonstrations; to Mr. Ashall and Mr. Taylor for preparing the models on exhibition in the Library; also to Miss Wilcock, my secretary, for her constant retyping; to my wife for her equally constant retiming and help in editing my various drafts, and to Mr. Fenton of the Perkin-Elmer Corporation for his demonstration of the laser TV camera. To Mr. Fenton not only thanks but an apology, because you will remember I told you that his camera had an almost infinite depth of focus. Although I showed you pictures of the front of the theatre, I failed to demonstrate this aspect by showing you something at a greater distance. I must now ask him to do this. [*Demonstration.*]

ACKNOWLEDGEMENTS

Apparatus for demonstrations was loaned by Elliott Automation Ltd., Barr & Stroud Ltd., Marconi Instruments Ltd., and the Radar Research Establishment.

EXHIBITS IN THE LIBRARY

(*a*) A display of optical glass apparatus, arranged by *Pilkington Brothers Ltd.*, and lent by *Pilkington Brothers Ltd.; Chance-Pilkington Optical Works; Pilkington Perkin-Elmer Ltd.; Rank, Taylor Hobson; Wray Optical Works; J. H. Dallmeyer Ltd.; Vickers Instruments Ltd.; Hilger & Watts Ltd.;* and the *Rank Organisation.*

(*b*) A photograph taken with a modern lens system from a height of $7\frac{1}{2}$ miles, lent by *Perkin-Elmer Inc.*

(*c*) Half-size models of Faraday's rough-glass furnace and finishing furnace, presented to the Royal Institution by *Pilkington Brothers Ltd.*

(*d*) Faraday's glass furnace notebooks and the committee minute books of the Glass Sub-Committee set up by the Royal Society in 1825; lent by the *Royal Society.*

(*e*) Magic lantern with oil lamp, lent by *Miss Jennifer Digby.*

(*f*) Specimens of glass made by Faraday, from the collections of the *Royal Institution.*

(*g*) Books from the Library of the *Royal Institution.*

LIBRARY CIRCLE MEETING

Monday, 5th December, 1966

MEDICAL EDUCATION IN THE EIGHTEENTH CENTURY

By JESSIE DOBSON, B.A., M.Sc.
Curator, Hunterian Museum

H. R. Rishworth, C.B.E., F.R.C.S.,
in the Chair

EVER since man inhabited the earth there must have been those who, by chance or custom, were able to bring relief to their ailing fellows. Very early there were some who were more knowledgeable about diseases, and others whose manual skill destined them to be practitioners of chirurgery. Methods and remedies were passed on from one generation to the next, first by word of mouth and later by manuscript. Knowledge spread slowly, in ever widening circles, but the possibilities of misinterpreting the written or mishearing the spoken word gave rise to many complications. With the introduction of printing in the fifteenth century more precise information became available, and as Latin was the recognised tongue of scholarship there were fewer language barriers. When students came to expect learned works in the vernacular, authors maybe had to choose between winning gratitude in their own countries or sacrificing some of the profits from sales elsewhere. In many subjects possibly these difficulties would be of little moment; but in medicine, where precise knowledge of the structure of the human body and of the methods of cure for disease or accident or alleviation of defects may mean all the difference between life and death, or happiness and misery, the importance of being able to find the right information at the right time is readily appreciated. The physician found little difficulty in this respect, for his basic training included a knowledge of the classical languages; but the would-be surgeon was not required to be so equipped for his career. To him, being "unlatined", a proportion of his sources of information would remain, literally, a closed book. In this country, therefore, medical books in English, whether originals or translations, were a valuable asset in the sixteenth and seventeenth century, particularly for the surgeon.

In general progress towards perfection is very slow. The standards of medical practice attained in the eighteenth century resulted from the labours of seventeenth-century physicians and surgeons, just as theirs depended upon their predecessors. To go no further back than the sixteenth century, anatomy even today

Thomas Elyot (1499–1546), from a drawing by Hans Holbein, engraved by F. Bartalozzi.

PLATE I

owes a great debt to the work of that great master of the art, Andreas Vesalius. His superb engravings showing the structure of the human body were prepared from drawings of his own dissections. His *De Fabrica Corporis Humani* was published in 1543 with, of course, a Latin text. It is little wonder that Thomas Geminus gained an immediate success by republishing the plates of Vesalius with an English text ten years later in 1553. This was not the first English anatomy book but it had the advantage of being the most accurate illustrated work so far in this country.

Roughly contemporary with these was one on general medicine, *The Castell of Health*, written by Sir Thomas Elyot (Plate I), first published in 1534, with further editions up to the end of the century, of which the Royal Institution has one dated 1580. Elyot, son of a judge, was born in 1490 and died in 1546. He was fortunate enough to attract the attention of Cardinal Wolsey, who appointed him clerk of the Privy Council, but seems to have omitted the detail of assigning any salary for the post. His first book, published in 1531, was dedicated to Henry VIII, probably as a result of which he was appointed Ambassador to the Court of Charles V. His *Castell of Health* consisted of prescriptions for various ailments and included an account of the disorders from which he himself had suffered. One of these was an affliction very common at this time of year—"the stomach and the head both distempered with cold". He says (pp. 80–81):

> I my selfe was by the space of foure yeres continually in this discrasie, and was counsailed by divers physitions to kepe my head warme, . . . at the last feeling my selfe very feeble, and lacking appetite and sleepe, as I happened to read the booke of Galen, . . . I perceived that I had beene long in an errour. Wherefore first I did throw away my quilted cap, and my other close bonets, and onely did lye in a thin Coyfe, which I have ever since used both wynter and sommer, and ware a light bonet of velvet onely, . . . I boyled in vineger rootes of parsly and fenell, with Endive, Cicory, and Betany, . . . and forbare wine, and dranke only ale, and that but a little stale, and also warmed . . . and now and then I would put into my nosethrilles eyther a leafe of greene Laurell, or betany . . . I tooke for a parfume the rindes of olde rosemary and burned them, and held my mouth over the fume, cloasing mine eyes: afterwarde to comfort my stomacke and make it stronge, sometime I woulde eate with my meate a little whyte pepper . . . sometime marmelade of quinces, or a quince rosted.

The interesting word is "marmalade", for this is one of the first occasions, if not the very first, on which it was used in print.

The fact that this popular little book, written in English, was the work of one not qualified as a physician was a source of much wrath on the part of the medical profession.

It is indeed interesting to note some of the unusual sources of medical lore. Robert Burton's *Anatomy of Melancholy* does not at first sight appear very promising, but it contained a good deal of miscellaneous information useful to the medical student, interspersed with much sound philosophy. It was first published in 1621 and there were many editions even up to 1826: the Royal Institution has one of 1652. The diaphragm or midriff he describes as "a skin consisting of many nerves, membranes and among other uses it hath, is the instrument of laughing". The heart, he says, "is the seat and fountain of life, of heat, of spirits, of pulse and respiration, the Sun of our Body, the King and sole Commander of it, the Seat and Origin of all passions and affections". The book contains much good counsel for the preservation of health and good spirits. "There is nothing better than exercise (if opportunely used) for the preservation of the body. Nothing so bad if it be unseasonable, violent, or overmuch". On the other hand, he points out, "opposite to Exercise is Idleness (the badge of Gentry), the bane of body and mind, the nurse of naughtiness, the chief author of all mischiefe, one of the seven deadly sins, a sole cause of this and many other maladies, the Devil's cushion". The book had a wide appeal and the publishers made a fortune out of it.

Burton took Holy Orders at Oxford, held one or two curacies for short periods, but spent most of his life studying and writing. He styled himself "Democritus Junior" and is so referred to in his memorial tablet erected in the Cathedral at Christ Church, where he died on 25th January, 1640, at the age of 63.

In the second half of that century, Richard Lower is an outstanding figure. The Royal Institution has the third edition (Amsterdam, 1671) of his *Tractatus de Corde*, first published in London in 1669. Lower was born at Tremeer, near Bodmin in Cornwall, in 1631 and graduated at Christ Church in 1655, two years before the death of William Harvey. He worked closely with Thomas Willis, in whose great work *Cerebri Anatome Nervorumque Descriptio et Usum*, published in 1664, there is acknowledgement of his assistance in its preparation.

In his book Lower described his experiments in transfusing blood from one animal to another, gave his estimate of the rate of the circulation, noted the difference between arterial and venous blood, and suggested the cause of the brighter colour of arterial blood. "It is extremely probable," he writes, "that the blood takes in air in its course through the lungs, and owes its bright colour entirely to the admixture of air. Moreover, after the air has in large measure left the blood again with the body . . . and has transpired through the pores of the body, it is equally consistent with reason that the venous blood, which has lost its air, should forthwith appear darker and blacker."

On 17th October, 1667, Lower was elected a Fellow of the Royal Society, and on 23rd November of that year he and Edmond King demonstrated at one of the meetings the first successful transfusion of animal blood into the human subject in England. This he describes in the *Tractatus de Corde* as follows (K. J. Franklin's translation, 1932, p. 189):

> For there is no reason to think that the blood of other animals mixes less well with human blood than with animal blood. This view is abundantly confirmed by recent experiments of French workers, and I also found it so not very long ago in the case of a certain A.C. who was the subject of a harmless form of insanity. I superintended the introduction into his arm at various times of some ounces of sheep's blood at a meeting of the Royal Society, and that without any inconvenience to him. In order to make further experiments on him with some profit also to himself, I had decided to repeat the experiment several times in an effort to improve his mental condition; he, on the other hand, consulted his instinct rather than the interests of his health and completely eluded our expectations.

In the *Philosophical Transactions of the Royal Society* (**2**, 557) there is a letter from the victim himself, Arthur Coga, who calls himself "Your Creature (for he was his own man till your Experiment transform'd him into another species)"; and he signs himself "The meanest of your Flock, Agnus Coga".

Lower resided in King Street, near Covent Garden, "where he was much resorted to for his successful practice, especially after the death of Dr. Willis . . . he was esteemed the most noted phisician in Westminster and London and no man's name was more cried up at Court than his." After the discovery of the Titus Oates Plot in 1678, his religious beliefs and political views seem to have made him less popular, particularly in court circles. He died in the early morning of Saturday, 17th January, 1690/1, having caught cold when putting out a fire in his chimney. In 1700, a little book was printed and sold for a shilling, containing

Dr. Lower's and several other Physitians Receipts, compiled by one who signed himself "J.W." In the Preface it is stated that "The Preparations that bear the name of the late famous and incomparable physician Dr. Lower were all his own receipts communicated to me with his own hand a little before his death, that such great benefits to mankind might not die with him nor fall into hands where the world would reap no advantage by them." These include "a powerful remedy for rheumatic pains," one "to create a good appetite and strengthen the stomach," the method of making a cephalic plaister which gives ease to "all pains of the head, stops catarrhs and strengthens the eyesight," and many others, no doubt of great efficacy.

Born probably in the same year as Richard Lower and a schoolfellow of his, Walter Needham studied both in Cambridge and Oxford, where he attended Thomas Willis's lectures. He was appointed physician to the Charterhouse, and resided in Great Queen Street, where he died, apparently in great poverty, on 5th April, 1691. His *Disquisitio Anatomica de Formato Foetu* was published in 1667 and there were at least three further editions. His main contribution to medical education was perhaps his course of lectures delivered at Barber-Surgeons' Hall in about the year 1675, a syllabus of which, possibly in his own handwriting, is in the Manuscript Room of the British Museum, with the title: *Praelectionum Vernalium in Theatro Chirurgico de Corporis Humani Partibus Internis Celebrandorum Syllabus, a Gualtero Needham, M.D. Praelector Exhibitus.*

A third, though younger, member of this group was John Browne, born in 1642, son of Joseph Browne, tailor and freeman of the City of Norwich. He served in the Navy during the Dutch War of 1665-66, was wounded in the arm and returned to practice for the next ten years in Norwich. After this he settled in London in Cockspur Street, near Charing Cross, and now, by right or by audacity, began to assume the title of Chirurgeon-in-Ordinary to the King. He too gave a course of lectures at Barber-Surgeons' Hall and in 1683 was appointed surgeon to St. Thomas's Hospital. It was at this time that he was preparing for publication his work on "the King's Evil", which was published in 1684 with the title: *Adenochoiradelogia or, an Anatomick-Chirurgical Treatise of Glandules and Strumaes or King's Evil Swellings.* If

Browne really was one of the King's surgeons, he would have had the duty of presenting those desiring to be "touched" in order to have their scrofulous swellings cured; and in any case this book is of interest in giving an historic account of the ceremony.

Three years before, in 1681, Browne published his other important work: *A Compleat Treatise of the Muscles as they appear in Humane Body, and arise in dissection; with diverse anatomical observations not yet discover'd. Illustrated by near fourty copper plates, accurately delineated and engraven*, of which the Library of the Royal College of Surgeons has the manuscript draft. This book was highly successful, went through a number of editions and was translated into Latin and German. Each edition had the attraction of something new: the 1697 English edition had "The Appendix of the Heart," written by Richard Lower. Browne says: "This accurate and concise discourse of the heart, and its use, as also the circulation of the blood, and the parts of which the sanguinary mass is made was written by the late learned Dr. Lower and presented to a person of quality, who was pleased to favour me therewith, in order to have it added to this my graphical discourse of the muscles." The 1698 edition had a letter on Muscular Motion by Bernard Connor. In a letter written by Walter Needham "To his much valued Friend Mr. John Browne" is the remark: "It is a book I am sure the Chirurgions Hall doth much want for the younger sort to have in their hands in Order to their better attending the learned Reader, and not onely soe, but the most able Anatomists will bee glad of so compleat a Contraction of so considerable part of Anatomy in one view, where they may at any time recollect themselves as to their former Readings and Observations."

It is unfortunate for Browne's reputation that the whole work was exposed as a plagiarism in 1685 by James Young (1646-1721) in a little book with a grand title: *Medicaster Medicatus, or a Remedy for the Itch of Scribbling. The first Part, written by a Country Practitioner in a letter to one of the Town and by him prefaced and published, for cure of John Brown, one of his late Majesties Chyrurgions, containing an account of that vain Plagiary, and Remarks on his several Writings, Wherein many Thefts, Contradictions, Absurdities, Gross Errors, Ignorance, and Mistakes, are*

William Beckett (1684–1738), from an engraving by R. Parr.

Nicholas Culpeper (1616–54), from an engraving by T. Cross.

PLATE II

Displayed and divers Vulgar Errors in Chyrurgery and Anatomy refuted.

What Browne had done was to take the text of a book written by William Molins and published in 1648, the sub-title of which was *The Anatomical Administration of all Muscles of an Humane Body, as they arise in Dissection.* Browne copied Molins almost exactly, even to punctuation and the use of some unusual terms. The plates were, with a few exceptions, copied from the *Tabulae Anatomicae* of Julius Casserius (published by his successor Spicelius in the Chair of Anatomy in Padua in 1627) with slight alterations.

Browne's other work, his *Adenographia,* was also said to be a plagiarism. In 1722 William Beckett (Plate II, left), a surgeon and antiquary of some repute, published *A Free and Impartial inquiry into the Antiquity and Efficacy of touching for the cure of the King's Evil.* On page 60 he comments on Browne's work: "In reality the Body of the Book is nothing else but a Translation of Tooker's *Charisma,* which being even at that Time exceeding scarce, I suppose, thought he might securely do it, without having his Plagiarism discovered." William Tooker's book was published in 1597; he was chaplain to Queen Elizabeth I.

The gift of curing by touch was supposed to be one of the inherited gifts of royalty. Charles II and James II held the ceremonies of "touching" to cure the King's Evil, but William III refused to do so. It is said that Queen Anne was induced to resume the practice in order to prove her right to the throne; on 30th March, 1712, 200 persons were "touched" at St. James's, of whom Samuel Johnson, then aged two and a half, was one. With similar motive Prince Charles Edward "touched" a seven-years-old child in the picture gallery of Holyrood House, Edinburgh, during the rebellion of 1745; the child was reported completely cured in three weeks.

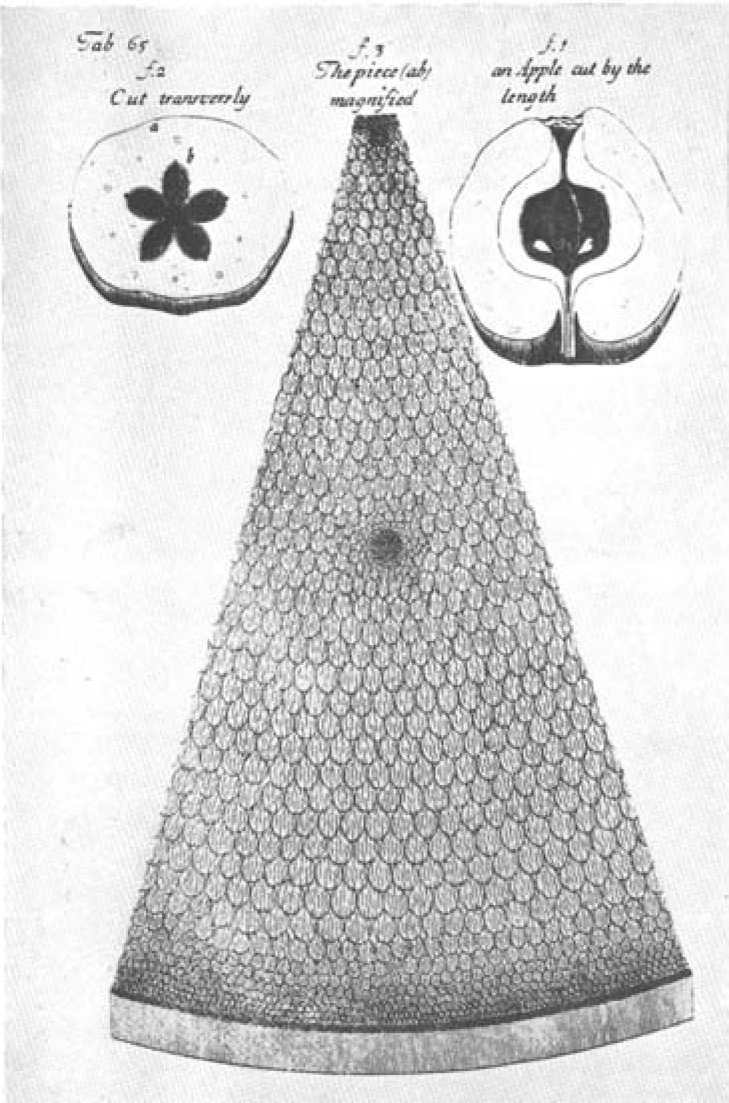
The Bernard Connor whose "Observations on Muscular Motion" had been included by John Browne in the 1698 edition of his *Anatomy* was born in about 1666 in the county of Kerry, studied in Montpellier and Paris, gained his M.D. in Rheims in 1691, and then travelled to Venice, Padua, Vienna, Cracow and Warsaw. He was particularly skilled in anatomy and chemistry as well as in medicine. In 1694 he was appointed physician to the court of King John Sobieski (great-grandfather of Prince Charles Edward), and his reputation was enhanced when he correctly diagnosed the nature of the illness of the King's sister. Connor returned to England in February 1695, and gave a series of lectures in Oxford on the work of Marcello Malpighi, Laurentius Bellini and Francesco Redi, all of whom he had met abroad. In this same year he published his *Dissertationes medico-physicae* and was elected a Fellow of the Royal Society. Two years later he published his *Evangelium medici: seu medicina mystica; de suspensis naturae legibus, sive de miraculis*, an attempt to show that the miraculous cures effected by Jesus and his disciples could well be accounted for on natural principles. This aroused much argument and criticism, and Connor felt himself obliged to write a letter to the Archbishop of Canterbury, then Thomas Tenison, defending his theories.

In the Royal College of Surgeons' Library is a copy of John Browne's *Myographia* presented to Connor by the author. Connor seems to have used it as a notebook, for on the backs of some of the plates are accounts of conversations that he had with members of the court of Peter the Great who was then working in the dockyards at Deptford in order to acquaint himself with western European developments, particularly in shipbuilding. In October 1698 Connor was attacked by a fever of which he died, at the early age of thirty-two, and was buried in St.-Giles-in-the-Fields, his funeral sermon being delivered by William Hayley.

Apart from those whose writings have been mentioned, there was the distinguished group of physicians, Harvey, Mayerne, Glisson, Sydenham, whose role as master-builders of medical achievement has always been recognised. John Woodall and Richard Wiseman were among the many outstanding surgeons of the same period who performed a similar service to their craft. Among these pioneers two "specialists" could well be included. In 1651 Nicholas Culpeper (Plate II, right) published *A Directory for Midwives*; and this was reprinted at least seventeen times, the last being in 1777, a century and a quarter's evidence of success. The book was amazingly popular; as Professor Russell remarks in his *British Anatomy*, most of the copies that have survived are in poor condition, many lacking plates and other leaves, and it is probable that some of the editions may have been thumbed out of existence. The Royal Institution copy is dated 1681. In addition to this work Culpeper wrote *The English Physician*, the celebrated *Herbal*, published in 1652, *Being a Compleat Method of Physick, whereby a man may preserve his Body in Health; or cure himself, being sick, for three pence charge, with such things only as grow in England, they being most fit for English Bodies*. This is a wonderful book: a catalogue of common plants, their location and their uses in remedies. Of the "Lilly of the Valley" he says: "They grow plentifully on Hampstead Heath. It strengthens the brain, recruits a weak memory and makes it strong again; the spirit of the flowers distilled in wine restoreth lost speech; it helps the Palsie, comforteth the Heart and Vital Spirits."

Nicholas Culpeper was only thirty-eight years old when he died at his house in Spitalfields on 10th January, 1654, but the volume of work that he accomplished in such a comparatively short time is amazing. His great contribution to the improvement of medical education was his translation of the works of foreign authors, the *Natural Philosophy* and other works by Daniel Sennert, Vesling's *Anatomy* and an English version of the *Pharmacopoeia Londiniensis*.

The other specialist is Nehemiah Grew, born in 1641, educated at Cambridge and Leyden, physician in London. In 1677 he was appointed Secretary of the Royal Society, and from 1678 edited the *Philosophical Transactions*. He prepared a catalogue of all the rarities, natural and artificial, belonging to the Society, published in 1681 with the title *Musaeum Regalis Societatis*; it included a paper on the "Comparative Anatomy of Stomach and Guts". Professor F. J. Cole pointed out, in his *History of Comparative Anatomy* in 1944, that this was the first time that this term had been used in the title of a biological work. Included among the rarities were several items of great interest. One, an unusually twisted elephant's tusk, presented to the Society by Sir Thomas Crisp of the East Africa Company, can be seen in the Odontological Museum of the Royal College of Surgeons. The Tables of Blood Vessels and Nerves, brought back by John Evelyn from Padua, are also mentioned in Grew's catalogue and now hang on the staircase of the Hunterian Museum. A description and illus-



An illustration from Nehemiah Grew's *The Anatomy of Plants* showing a thin slice of apple highly magnified.

PLATE III

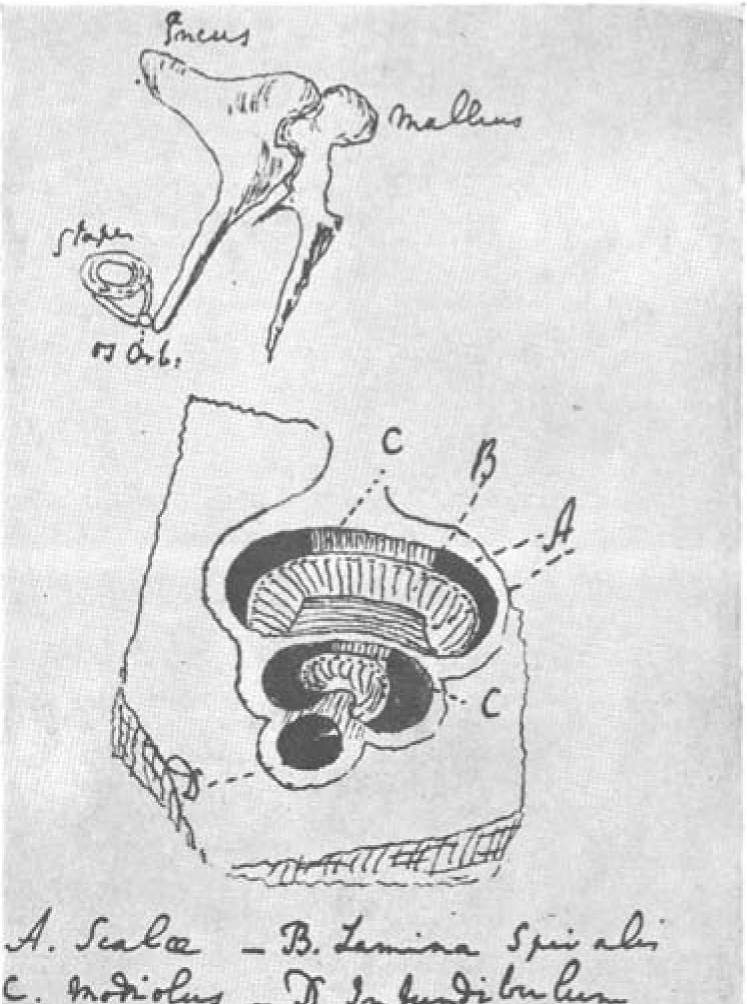
trations of these were given by William Cowper to the Royal Society and published in the *Philosophical Transactions* in 1700 (**23**, 1177–1201).

In 1682, Grew published at the desire of Christopher Wren, then President of the Society, his series of lectures on *The Anatomy of Plants*. The illustrations are superb (Plate III is an example) and may possibly have been the work of Robert Hooke the brilliant microscopist, whose own classic work, *Micrographia*, has similar fine plates.

William Cowper was thirty-two years old when he published his *Anatomy of Humane Bodies* in 1698. The book has many outstanding features; for one thing it is very large, measuring 25" by 16½", and is correspondingly weighty. But the most remarkable thing is that Cowper, like John Browne, and like Thomas Geminus before him, "borrowed" his illustrations. He used the drawings that were engraved for Godfrey Bidloo's *Anatomy Atlas* of 1685. Bidloo, a native of Amsterdam, had the advantage of studying under Friedrich Ruysch, a skilled anatomist of great experience; he was appointed Professor of Anatomy in The Hague in 1688 but spent most of the next two years in England in attendance on William III. In 1694 he was appointed to the Chair of Anatomy in Leiden, and was reprimanded by the Board of Managers for failing to give any lectures, having again spent most of his time in this country in attendance on the King.

The main value of Bidloo's work was in the plates, for the descriptions are brief and in Latin and not always accurate; so that in mitigation of Cowper's plagiarism it can be stated that in his work each illustration is described in detail so that its full value is recognised. Bidloo is said to have been "wonderfully enraged" at Cowper's action, and in a pamphlet addressed to the Royal Society in 1700 accused him of being a highwayman and "a miserable anatomist who writes like a Dutch barber".

The *Anatomy* was not Cowper's first work; five years previously he had published his *Myotomia Reformata*, which had the further explanatory title: *A New Administration of all the Muscles of Humane Bodies; wherein the true Uses of the Muscles are explained, the errors of former Anatomists concerning them confuted; and several muscles not hitherto taken notice of described; to which are subjointed a graphical description of the bones and other*



Drawings made by John Davy in the eleventh edition of James Keill's *The Anatomy of the Humane Body.*

PLATE IV

anatomical observations illustrated with figures after the life. A second edition was published in 1724, sponsored by Richard Mead. In 1696 Cowper was elected a Fellow of the Royal Society and contributed many papers to the *Transactions*, including the one already mentioned and also one describing the capillary circulation, which he demonstrated in the cat and the dog, confirming Malpighi's work. He also pointed out that degenerative disease of the aortic valve causes a peculiar type of pulse, an observation for which he is seldom given credit (*Philosophical Transactions*, **24**, 1970).

In 1703, among his house pupils, was a boy of fifteen, William Cheselden. Cowper died six years later. Of him, Thomas Babington Macaulay in his *History of England* says: "He was indeed the founder of a dynasty illustrious in the history of science; for he was the teacher of William Cheselden, and William Cheselden was the teacher of John Hunter."

Published in the same year as William Cowper's *Anatomy*, 1698, was another of the same title, the author of which was James Keill. This little book was dedicated to Dr. Edward Tyson, who had encouraged and advised him in its preparation. That the work was popular is clear from the fact that it went through no less than fifteen English editions, the last being in 1771, two known French, a Dutch and possibly a Latin translation. Part of its appeal was probably its size; it measures a little over six inches by just over three and could easily be carried in the pocket. The Royal Institution's copy is the seventh edition, published in 1723; one of those in the Library of the Royal College of Surgeons, the eleventh edition, belonged to John Davy,younger brother of Humphry Davy, and has drawings in it made by him when he was a medical student in Edinburgh in 1814(PlateIV).

James Keill was born in Scotland in 1673 and died unmarried at the age of forty-six in 1719 in Northampton, where he practised as a physician. He applied himself particularly to the study of anatomy and gained considerable reputation by lecturing on this subject in Oxford and Cambridge.

A third book with the same title, *The Anatomy of the Human Body*, is that of William Cheselden, published a mere ten years after he had entered William Cowper's house as an apprentice in 1703. It is "illustrated with twenty-three copper-plates of the most considerable parts, all done after the life". There were no less than thirteen editions, and several re-issues, as well as American editions. On 8th April, 1749, Cheselden sold the copyright for the sum of £200 (the original deed of sale is in the Royal College of Surgeons), so that all editions after the sixth in 1741 were under the new arrangement.

Cheselden was born on 19th October, 1688, at Somerby near Leicester; when he came to London he was apprenticed to James Ferne, surgeon at St. Thomas's Hospital. Having gained his diploma from the Barber-Surgeons' Company in 1710 he began to prepare *A syllabus or Index of the Anatomical Parts of the Human Body in thirty-five lectures for use in the Anatomical Theatre*. This was published on 8th October, 1711; a few weeks later he was elected a Fellow of the Royal Society, at the early age of twenty-three. He used his syllabus as a basis for his lectures for the next twenty years and, so far as can be ascertained, he was the first regular teacher of anatomy in London, holding his classes at first in his own house in Cheapside and later in Crane Court, off Fleet Street. That his lectures were popular seems to be proved by the fact that in 1714 he was reprimanded by the Barber-Surgeons' Company for "taking the bodies of malefactors from the place of execution" and holding dissecting classes at the same time as the Company's lectures were given which, as is recorded in the minutes, "drew away the members from the publick dissections and lectures at the Hall".

Cheselden's *Anatomy* maintained its place as a standard student's textbook for more than a century. It was more attractive than Keill's because it was illustrated; and it was more acceptable than Cowper's both in price and size. It is not known how much the first edition cost, but the fourth cost five shillings; later editions were larger and more expensive.

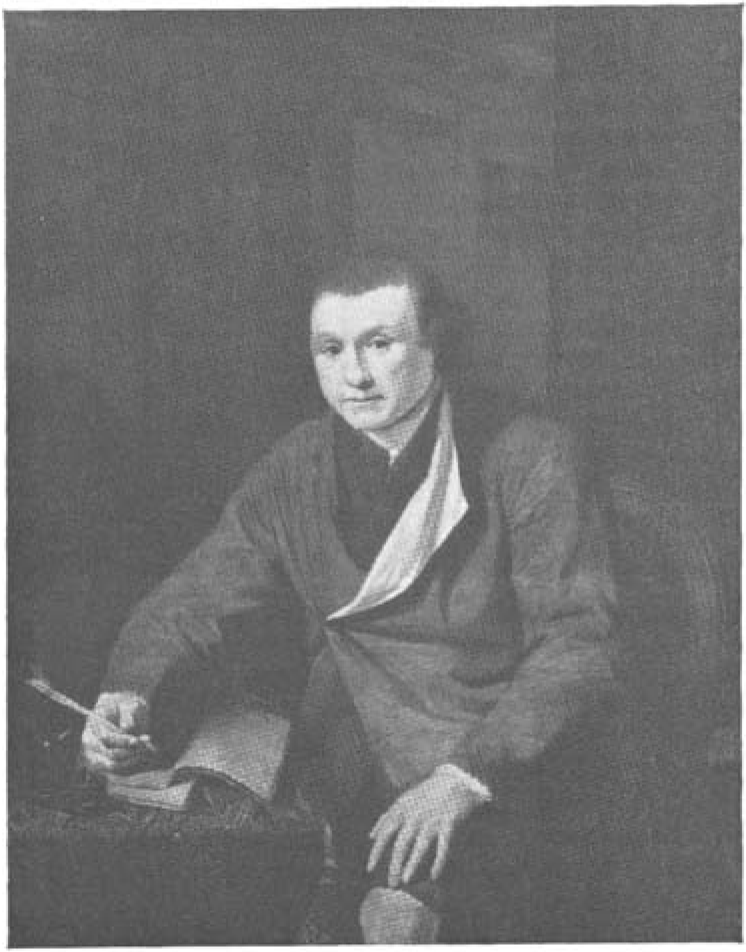
Cheselden's other great work was his *Osteographia*, published in 1733. It is magnificently illustrated. In 1957, through the good offices of Sir Zachary Cope, the Royal Academy placed on loan to the Royal College of Surgeons the original drawings from which the plates were made. Professor Russell in his comments on this work in the *Bulletin of the History of Medicine* in 1954 writes: "In spite of its magnificence, its accuracy, the good reviews that it received, and above all the enormous amount of money that Cheselden had put into it, *Osteographia* was almost a complete failure. Issued by subscription at four guineas, only 97 copies were sold out of the 300 printed." Many of the remaining copies were split and sets of plates sold separately. The eleven frontispieces to the chapters and the ten head pieces, which are skeletons of animals, were sold for ten shillings.

Cheselden's surgical success came slowly, for it was not until 1718, when he was thirty years old, that he was appointed to a surgical post at St. Thomas's Hospital. At this period he lived in Red Lion Square, where he was in the same neighbourhood as his friends, Richard Mead, James Douglas and Jonathan Richardson, the artist of the well-known portrait.

In 1737 he resigned his post at St. Thomas's and his other hospital appointments and became resident surgeon at the Royal Hospital, Chelsea. It was here that in 1750 and 1751 John Hunter (Plate V) attended his surgical classes during the summer months.

Cheselden died on 10th April, 1752, in Bath, where he had several patients and used to visit for his health. During the previous twenty years he had achieved a reputation as a lithotomist and also as an ophthalmic surgeon. He was the first ever to make an artificial pupil, and an account of the procedure is included in the fourth edition of his *Anatomy* in 1730.

Comparable as a physician to Cheselden as surgeon and anatomist in the first half of the eighteenth century was Richard Mead, who was Cheselden's senior by some fifteen years and outlived him by two years. He was born in Stepney, son of a nonconformist minister whose "obnoxious" views made it necessary for him to leave the country, so that Richard Mead at the age of sixteen studied in Utrecht and in Leyden, travelled in Italy, took the degree of Doctor of Philosophy in Padua in 1665, and then returned to Stepney, where he practised with great success. After John Radcliffe's death in 1729, Mead moved into his house and surpassed even that brilliant physician in his practice. His great influence on medical practice and education came not only from his example and his writings but also from his fine collection of books and specimens, of which it was said that "no subject in Europe had a library and a cabinet so richly and so judiciously furnished. Nor did he make this collection merely for his own use but freely opened it to others so that



John Hunter (1728–92); the original portrait, painted by Robert Home, Hunter's brother-in-law, is at the Royal College of Surgeons.

PLATE V

ingenious men were sure of finding at Dr. Mead's the very best helps in all their undertakings." His practice was to attend every day at Tom's Coffee House in Covent Garden, where he met apothecaries who sought his advice about their patients, for which service he charged half a guinea. After his death in 1754 his collection was sold, the proceeds amounting to £10,550. 17s.

One of the best known of Mead's publications is his *Mechanical Account of Poisons*, printed in 1702. Just as Bernard Connor endeavoured to explain the miracles described in the Bible, so Mead sought to diagnose some of the ailments mentioned there, in particular those of Job, Saul, Hezekiah, Nebuchadnezzar, Judas and Herod. In the case of Job he suggested that the affliction was either leprosy or elephantiasis. His other writings, which were collected and published in one volume in the year 1762, dealt with the common ailments of the time, smallpox, measles, scurvy, fevers, gout, madness, diseases of the heart, liver, kidneys and eyes.

Epidemic diseases and fevers received a great deal of study from the physicians at this time. John Huxham, born in Totnes in 1692, studied the practices of Boerhaave in Leyden, and gained much renown when he returned to his home town. It is said that the esteem with which he was regarded was fostered by his habit of having himself called out of church during the service, by carrying a gold-headed cane, and by being followed by a footman bearing his medicine case. His two best known works, *Observations on the Air* and *Epidemic Disease*, two volumes published in 1759 and 1767, and his *Essay on Fevers*, 1750, are full of original observations. His *Observations on the Air* is not only a medical work but is quite a good meteorological record for the years 1727 to 1737. The common ailments were coughs and catarrhal fevers, and smallpox was still epidemic. Huxham made a large fortune out of his practice and his writing. The Queen of Portugal is said to have owed her life to the remedies recommended by Huxham in his books.

Another well known work on fevers was that of John Freind, who has been described as "a hot-tempered physician involved in many wrangles . . . at one point he was only released from the Tower because his friend Mead refused to attend Sir Robert Walpole so long as he was confined there."

One of the puzzling illnesses of the time was hydrophobia, and in spite of the infinite variety of remedies cures were extremely rare. Christopher Nugent wrote an *Essay* on this subject in 1753, consisting for the most part of notes of the day-to-day condition and treatment of one patient, Elizabeth Bryant, a servant-maid aged twenty-two who in June 1751 was bitten by a mad dog. Nugent, a native of Ireland, had a flourishing practice in Bath; and with commendable patience and perserverance administered with great regularity a variety of remedies, the doses as recommended by Dr. Mead, the musk, cinnabar, and bleeding, over a period of three months. Kind friends assured her that she could not possibly be cured and that although she fancied herself better, she would be "dead in a week for all that". Nevertheless, Nugent persisted and the girl recovered completely. Nugent moved to London some years later and was most successful both in his practice and social life. His daughter married Edmund Burke, the politician; he was one of the nine original members of the Literary Club founded by Samuel Johnson and Sir Joshua Reynolds, that met every Monday evening at the Turk's Head Tavern, first in Greek Street and later in Gerrard Street, Soho.

The eighteenth century was a period in which methods and practice were constantly restudied and re-assessed; when ineffective drugs were discarded and new surgical techniques developed. At the same time, new theories flourished. One of the most revolutionary of these was the Brunonian system, the inspiration of John Brown, who studied education and theology at first but finding no success in either turned his attention to medicine. He was befriended by William Cullen, who was so closely associated with William and John Hunter, and finally won success by his lectures and by his book, published in 1780, entitled *Elements of Medicine*. The Brunonian system was very simple. According to Brown, life depended upon continuous stimulation. Disease was a result of excess or defect of stimulation. The diagnosis and treatment were simple; from the administering of, as a rule, large, even "heroic" doses of stimulating drugs, the cure should result. As Dr. Guthrie points out in his *History of Medicine*, "little wonder that it has been remarked that the Brunonian methods killed more persons than the French Revolution and the Napoleonic Wars taken together".

In spite of eccentrics like Brown, events and personalities in the eighteenth century combined to produce the most marked progress for many a decade, in medical practice, in surgery, and in medical education. One of the events that had such a marked effect was the separation of the Barbers and the Surgeons into their own Companies, with the result that the rules relating to the "publick anatomies" were relaxed and private schools of anatomy were established where students were able to take part in rather than just watch dissection of human subjects. One of the first of these new schools was that of William Hunter, opened with great promptness as soon as he saw the possibilities in 1746, the year after the separation of the Barbers and Surgeons. This was followed by the establishment of many other private schools of anatomy, conducted by well known anatomists such as Joshua Brookes and William Hewson, whose researches on the lymphatic system were published in 1774. Many new hospitals were opened throughout the country; in London alone there were five: the Westminster (1719), Guy's (1725), St. George's (1734), the London (1740) and the Middlesex (1745). Here it became usual for physicians and surgeons to conduct informal classes in the wards, as had long been customary on the Continent. John Hunter was a pioneer in this scheme at St. George's. This was a step towards the establishment of medical schools attached to the hospitals which developed during the nineteenth century.

Even in this brief survey it will be seen how the students of the early eighteenth century were well equipped for their studies by the magnificent work of the physicians, surgeons, philosophers and scientists of earlier periods; and how the finest of these students put this inherited treasure to good purpose in passing on this information in practical form in schools, hospitals and textbooks. Perhaps John Hunter epitomises the whole scope of this great advance. He was surgeon to St. George's; he had a large private practice; he lectured regularly on the principles of surgery; he held dissecting classes on his own premises, where he also had resident pupils. He encouraged his students to run their own medical society where they gained experience in lecturing and writing about their investigations of medical problems; he built up what was probably the finest museum of its kind in the country, a collection of specimens to demonstrate the whole of life, the structure and function of all parts of the body, the processes of development and evolution, the results of accident, disease or defect. The ideas and ideals with which he inspired his colleagues and pupils have been passed from generation to generation to the present, a glorious heritage from the eighteenth century.

EXHIBITS

(*a*) Medical books from the Library of the *Royal Institution*.
(*b*) Books and articles by *the Lecturer*.

QUALITY IN THE MIDST OF QUANTITY: THE PROBLEMS OF SCIENCE AND THE UNIVERSITIES IN THE ROBBINS AGE

By MICHAEL SWANN, M.A., Ph.D., F.R.S., F.R.S.E.
Principal and Vice-Chancellor, University of Edinburgh

Weekly Evening Meeting, Friday 9th December, 1966

L. B. W. Jolley, M.A., M.I.E.E.,
Vice-President, in the Chair

[ABSTRACT]

IT has been said repeatedly of university expansion that "more means worse". Whether or not this is true, the same allegation does not seem to have been made of science, although it has grown far faster than the universities. On the contrary, it is thought, by most scientists, that continued rapid expansion of research is wholly desirable, and indeed almost a natural law. The Discourse dealt with the question of whether this was realistic, whether quality had suffered, and of what could be done to ensure that it did not suffer, when we had nearly fifty universities, and many hundreds of Government and industrial laboratories, with a total research bill of £750 million per annum, all competing for the best scientific minds.

EXHIBITS IN THE LIBRARY

(*a*) Books on Edinburgh and its University, lent by the *London Library*.
(*b*) Booklets provided by the *Office of Scientific and Technical Information*.
(*c*) Books from the Library of the *Royal Institution*.

FROM THE PROCEEDINGS OF 1866

Alexander Stewart Herschel was the second son of Sir John Herschel and the fifth of twelve children. In 1866, after a short period at the Royal School of Mines, he was appointed Professor of Mechanical and Experimental Physics in the University of Glasgow. Though never attaining the eminence of his father and grandfather, he contributed in no small measure to the study of meteors. In this Discourse he predicted that in November there would be a vivid display of meteor activity radiating from the constellation of Leo. He showed that this activity was repeated every thirty-three years and traced records of the shower back over a thousand years. Though some of his deductions are now clearly in error, the shower indeed appeared as a magnificent display, as indeed it has on subsequent encounters, over 100,000 meteors being recorded in Arizona in the shower of 1966. Herschel's radiant for the Leonids enabled Schiaparelli to identify them with the debris of Temple's Comet. One of the more interesting comments occurs in the penultimate paragraph, where Herschel, calling attention to the work of Professor Newton and the observations of the height of formation of the meteors, comments that "the presumption is that the meteors are solid although probably in a state of fine division . . . dust". This description fits the great majority of luminous meteors currently observed and probably also the micrometeorites in space.

WEEKLY EVENING MEETING
Friday, May 25, 1866

Sir Henry Holland, Bart, M.D., D.C.L., F.R.S.,
President, in the Chair

A. S. Herschel, Esq., B.A.

On the Shooting-stars of the years 1865-6, *and on the Probability of the Cosmical Theory of their Origin*

Attention was recently directed by Professor Newton,* of Yale College, U.S., to the probability, on well-considered grounds, that in the current year, 1866, a prodigious flight of meteors, the most imposing of its kind, and visible over a large area of the earth's

* *American Journal of Science*, 2nd series, vol. xxxvii., p. 377; and vol. xxxviii., p. 53.

surface, will make its appearance—perhaps for the last time in the present century—either on the morning of the 13th, or on the 14th of November. The rare opportunity thus afforded of deciding some important questions in the theory of shooting-stars makes it a matter of special interest for persons skilled in such accurate observations, to watch for its return on each of the mornings named (wherever practicable, between one and two o'clock*), to obtain the necessary data. The phenomenon at its maximum was seen by Humboldt, at Cumana, on the morning of the 12th of November, 1799; and again by Dr. Denison Olmsted, in its greatest brilliancy, at Newhaven, U.S., on the morning of the 13th of November, 1833. Olmsted was the first to sum up, in the following general language, the chief characteristics of the display:—

1. The number, *especially of bright meteors*, is much larger than usual.

2. An uncommonly large proportion *leave luminous trains*.

3. They proceed, with few exceptions, from a common centre in some part of the constellation *Leo*.

4. They are seen from midnight to sunrise, *and in greatest abundance between three and four* A.M.

These characteristics were regarded by Olmsted as sufficient to identify for the future the return of the November shower. Observers who endeavour to verify the truth of this description for themselves will be enabled, by so doing, to furnish invaluable materials for future investigations. The same features are, moreover, of peculiar interest, since they have been found to characterize, with certain differences, a number of other meteoric showers.

The periodicity of the well-known shower of meteors on the 10th of August was discovered independently by Quetelet, in the year 1836, and by Herrick (not knowing what Quetelet had predicted) on the reappearance of the same meteors in the year 1837.† At their next return, on the 10th of August, 1839, it was shown by Littrow‡ that a star-shower, whose occurrence in A.D. 1451, on the 5th of August, N.S., is cited by Biot from the *Chinese Annals*,—compared with another that appeared, according to the same authority, in A.D. 830, on the 26th July, N.S.,—gives 365 d. 6h. 12 m. as the average

*The object in restricting the watch to a particular hour is, that as many meteors as possible *may be simultaneously observed at distant places.*

†*American Journal of Science*, 1st series, vol. xxxiii., pp. 176, 354; and vol. xxxvii., p. 338.

‡*Astr. Nachr.*, vol. xviii., p. 374.

length of the interval between any two successive returns of the August meteors; and again, that the same star-shower, compared with that of the 10th of August, 1839, gives 365 d. 6 h. 8 m. as the average length of the same period,—the mean of the two determinations being 365 d. 6 h. 10 m., which is twenty minutes longer than the civil or tropical year; *but differs less than one minute from the sidereal year*. Besides the displays of the August meteors which happened about the year A.D. 830, other returns of the August meteors, of the nature of star-showers, are recorded in the *Chinese Annals** to have happened at the end of July, N.S., about the year A.D. 933; and another is cited by Herrick which happened on the 2nd of August, N.S., in the year 1243. The meteoric year of August, therefore, coincides with the sidereal year; and a period of 103 years brings all the star-showers of A.D. 830, 933, 1243, and 1451 into conjunction with the remarkable star-shower of the 10th of August, 1863. A star-shower is cited, moreover, by Biot, which happened at the end of July, N.S., in the year A.D. 833. A return of this star-shower may not unreasonably be expected to occur on the night of the 10th of August, 1866.

Between the 13th of October and the 13th of November, during the years from A.D. 903 to 1833, not less than thirteen great star-showers have been recorded. They are separated from each other by the third part of a century, or by some multiple of this period, and are periodical re-appearances of one grand meteoric shower, *viz.* that seen by Humboldt in 1799, and by Olmsted in 1833—the star-shower expected to return in the present year, and known by the name of the "Great November Shower". Its encounter with the earth takes place one day later in the year at each of its principal returns. According to the exact calculations of Professor Newton, the next passage of the earth through the centre of the meteoric group will take place two hours after sunrise at Greenwich, on the morning of the 14th of November, 1866.† As, however, the phenomenon occurred upon the morning of the 13th, in each of the years 1864 and 1865 (and not so brightly upon the 14th), its moment of greatest brightness may, possibly, fall one day earlier than the predicted time, and a watch on both mornings, of the 13th and 14th, is accordingly recommended to be kept. The meteors being seen

*Regarding the visibility of the August meteors in China, Captain Sherrard Osborn, C.B., R.N. &c., relates that they were seen by the watch on board the *Furious*, near Yedo in Japan, on the night of the 9th–10th of August, 1858, shooting by hundreds from the north-east to the west overhead.—*Cruise in Japanese Waters*, p. 102.

†*American Journal of Science*, 2nd series, vol. xxxviii., p. 60 *et seq.*

from midnight to sunrise, the hour from one to two o'clock is the best that can be chosen, as being the most convenient for making simultaneous observations.

On the morning of the 13th of November, 1865, the meteoric shower in England was observed at the Greenwich and Cambridge Observatories, at Hawkhurst, and at other places. The hourly number of meteors is stated by Mr. Glaisher and by Prof. Challis to have exceeded all before recorded at either of those Observatories. More than 250 meteors (279) were recorded at Greenwich from midnight until five o'clock, when for a space of nearly a quarter of an hour the paths of the meteors among the stars, &c., were not noted, but their number was simply counted. The result was, that at this time meteors of the first class were appearing at the rate of 250 per hour. At least a thousand meteors must have been visible at Greenwich from one to five o'clock on the morning of the 13th. They were only seen *after* midnight, until near sunrise, and they were most abundant during the hour from one to two o'clock. The maximum display of the November meteors expected in the year 1866 is still several hundred times greater than that observed at Greenwich on the 13th of November, 1865. *Two hundred and forty thousand* meteors are computed by Arago to have been visible above the horizon of Boston on the morning of the 13th of November, 1833.* Hundreds of the meteors seen on that occasion appeared brighter than the planets; and some of them were fireballs of the largest class.

Nearly two-thirds (172) of the meteors seen at Greenwich left luminous trains, visible for several seconds after the disappearance of the meteors. Their unusual number, and the appearance of the luminous trains which they left behind them, agree with Olmsted's description of the meteors in 1833, and leave no doubt of the return of the November shower. Its reappearance in the present year, there is every probability, will entitle its next return to the name of the "Great November Shower" of 1866.

Amongst the list of shooting-stars seen at Hawkhurst last November, seventeen were identical with meteors observed at Greenwich. Fifteen other meteors of the list were identical with meteors seen at Cambridge. The heights, lengths of path, &c., of ten of these accordant meteors were calculated, and this is also the number of accordances calculated by Dr. Heis of Münster. The average heights

*Mr. Greg informs the writer that, as seen by Mr. Baxendell, F.R.A.S., on the west coast of Mexico, "The number of meteors seen at once often equalled the apparent number of the fixed stars seen at a glance!"

obtained at both places are entered in the following table for comparison:—

	Mean Heights of Ten November Meteors observed at	
	1. Hawkhurst. Brit. Stat. Miles.	2. Münster. Brit. Stat. Miles.
Mean height at first appearance	74	77
Mean ditto at disappearance	54	44
Mean ditto at centres of visible paths	64	61

The average height of the centres *is a little greater* than the commonly received height of shooting-stars. Professor Newton has shown that the ordinary height of shooting-stars at the middle of their apparent paths is *not quite sixty miles above the surface of the earth.**

The divergence of the November meteors in the year 1865 from a common centre in the constellation *Leo* was noted both in Europe and America, and the following positions were obtained:—

Place, and Observer's Name.	Position of Radiant Point, Nov. 13th. R.A.	N. Decl.
Greenwich (Mr. Glaisher)	160°	30°
Hawkhurst (Mr. Herschel)†	150	20
Münster (Dr. Heis)	148	24
Newhaven, U. S. (Prof. Newton)	148	23
Philadelphia, U. S. (Mr. Marsh)	148	24

The average of these positions is some degrees from the bright star γ *Leonis,* of which the position is in R.A. 153°, N. Decl. 2°; nevertheless the close agreement of the last three places of the list merits particular attention.

The following radiant points of special meteor-showers were recorded at Hawkhurst during the last few years, by the aid of star maps expressly suited to the purpose.—Views of the original observations drawn on punctured maps showing the radiant points were exhibited, by Dr. Tyndall's assistance, on the white screen.

**American Journal of Science*, 2nd series, vol. xxxix., p. 194.

†*Astronomical Register*, No. 37, p. 18.—The radiant point of thirty-five meteors observed during the hours *from one to three o'clock*, was in right ascension 148°, north declination 23°,—exactly the position assigned by Professor Newton. (A. S. H.)

METEORIC PERIOD*	Date of Observation.	Position of the Radiant Point R.A.	N. Decl.
Jan. 2–3	1864	234°	51°
Apr. 9–11	„	192	4
„ 19–21	„	278	35
Aug. 9–11	1863	44	56
Oct. 18–20	1864–5	90	16
Nov. 12–14	1865	150	20†
Dec. 11–13	1863–4	101	34

A number of observations of luminous meteors contained in the Catalogue of the British Association, from the year 1845 until the present time, are capable of being classified in a similar manner, and upwards of fifty radiant points of shower-meteors throughout the year are recognized as coinciding in their epochs and positions with the epochs and positions of similar radiant points observed by Dr. Heis. Charts of these meteors are now in process of completion, and a first step will be gained thereby, towards establishing a regular shower-meteor theory. When the principal meteoric showers, and their connected radiant points, and epochs are pointed out, what are commonly called "sporadic" shooting-stars will become extremely scarce.

A few instances lately brought to light will show that aërolites and fireballs are not only independent of geographical position, but that they are also fixed in their dates of appearance and directions. Two stonefalls took place on the 25th of August, 1865; one at Aumale, in Algeria, the other at Shergotty, in India. Two detonating meteors of the largest class were seen in December, 1865; one on the 7th, at the mouth of the Loire, the other on the 9th, at Charleston, U.S. Three detonating meteors, on the east coast of England alone, during the last five years (1861-5), occurred between the 19th and the 21st of November. Two of the latter meteors, whose paths could be traced, proceeded from a common centre in some part of the constellation *Cetus*. A bright fireball was seen at Hawkhurst on the morning of the 9th of December, and another at Manchester on the morning of the 13th of December, 1864, whose paths (continued *backwards*) proceeded directly from the radiant point of the period mentioned last in the foregoing list. A notable peculiarity in respect of general geographical distribution, periodical returns, and fixed

*These meteoric periods are advanced by Baumhauer, as dates on which fireballs are most common. *Poggendorff's Annals*, vol. lxvi., p. 471. 1845.

†*See* above (†).

directions would evidently connect aërolites and fireballs in true astronomical relation with ordinary shooting-stars. Nevertheless it appears that out of 72 aërolites whose hour of fall is certainly known, by far the greater number (58) occurred *after midday*, during the hours from noon to nine P.M.* Shooting-stars, on the contrary, reach their maximum at an opposite hour of the day, being found to be most abundant *after midnight*; or twelve hours later. An astronomical difference accordingly exists between aërolites and shooting-stars, to which it is not impossible that a physical difference of a kind not yet established should correspond. It is noticed, for example, that on the 10th of August, and the 13th of November, dates on which shooting-stars and fireballs are more abundant than on any other nights in the year, *but one stone has fallen* on each date. The average height of seventy-eight meteors observed in America on the 13th of November, 1863, exceeded the usual height of meteors by fifteen or twenty miles.† On these grounds Professor Newton supposes that the November shower-meteors are composed of more easily destructible, or of more inflammable materials than aërolitic bodies. An examination of the light of shooting-stars (and particularly of the November meteors) by means of the spectroscope, would at once reveal the fact if these meteors and their luminous trains are composed of substances in a gaseous state; *the presumption is that they are solid*, although probably in a state of fine division. Whether shooting-stars consist of particles in a state of dust, or vapour, which the spectroscope can alone reveal, the return of the Great November Shower is a favourable opportunity for advancing our knowledge by its use, and a discovery is in store for refracting prisms, which should not (if possible) be allowed to pass away unheeded.

The spectrum of an entire star-shower was shown, by Dr. Tyndall's assistance, upon the screen with a straight-vision prism having a direct field of view of at least 20° of the sky.‡ The meteors were illuminated first by the carbon points of the electric lamp, and afterwards by the vapour of silver in the electric arc, showing the different appearances, in the prismatic field of view, of a solid, or a gaseous source of light. Some tinder was ignited by a fire-syringe;

*Only thirteen fell in the forenoon and fifty-eight during the hours from noon to nine P.M. *B. A. Report*—1860, p. 26.

†*American Journal of Science*, 2nd series, vol. xl., p. 252.

‡A pair of such prisms, mounted upon a binocular frame, is recommended as the best instrument for meteospectroscopic observations. Mr. Browning constructs a Binocular Pattern of Dense Glass Prisms shown at the lecture, under the name of a "Meteospectroscope."

and experiments with Gassiot's Geissler tubes were shown to illustrate the difference that exists, between the diffuse glow of an electric discharge, resembling the aurora in the highest and rarest strata of the atmosphere, and the massive light of meteors, resembling an ordinary spark.

[A. S. H.]

ROYAL INSTITUTION NOTES

I

NOTES FROM THE MINUTES OF THE GENERAL MONTHLY MEETINGS OF THE MEMBERS HELD DURING 1966

IN accordance with the Bye-Laws nine General Monthly Meetings of the Members were held during 1966. At each meeting the usual election of new Members took place; the President formally admitted new Members; the names of new Corporate Subscribers and Associate Subscribers elected by the Managers were announced; the decease or resignation of Members and Subscribers was reported; presents to the Library were displayed.

At the Meeting held on 7th February, 1966:

Mr. J. Lawrie paid tribute to the late Mr. W. E. Schall, who had been Treasurer of the Royal Institution from 1956 until his death on 2nd December, 1965, and referred to the qualities of charm, sincerity, tact, wisdom, warmth and kindliness which had endeared him to all who had been fortunate enough to know him.

Mr. W. A. Dickie spoke appreciatively of the services rendered to the Royal Institution by Mr. Kenneth Vernon, who had resigned as Librarian after fifteen years in order to take up an appointment as the first Librarian of the London Graduate School of Business Studies.

At the Meeting held on 9th May, 1966:

The Chairman reported the following re-election of Professors: Professor Ronald King, B.Sc., Ph.D., F.I.M., as Professor of Metal Physics; Professor R. L. F. Boyd, B.Sc., Ph.D., as Professor of Astronomy; Professor R. J. Harrison, M.A., D.Sc., M.D., as Fullerian Professor of Physiology; and Professor George Porter, M.A., Sc.D., F.R.S., as Professor of Chemistry until 31st August, 1966.

The Chairman announced that Sir Lawrence Bragg intended to resign from the Fullerian Professorship of Chemistry as from

31st August, 1966, and that the Managers had decided to take steps to appoint Professor Porter to the vacancy.

At the Meeting held on 4th July, 1966:

It was reported that the Managers had approved the carrying out, during the summer recess, of work in refurbishing the Lecture Theatre, converting laboratories, and redecorating and altering the Director's flat, at an estimated total cost of about £40,000. They had decided to postpone the construction of the new Lecture Room until 1967. The approval given by the Members, on 1st November, 1965, to a total expenditure on these projects of £105,000 was extended to the end of 1967.

At the Meeting held on 7th November, 1966:

An alteration of the Bye-Laws regarding the Investment Fund, having been previously proposed and approved, was confirmed.

At the Meeting held on 5th December, 1966:

Alterations to various Bye-laws, having been previously proposed and approved, were confirmed.

It was resolved that a specialist company be employed to service the direction of an appeal for the period 14th December 1966 to 11th August 1967, with an option to the Royal Institution to extend the period, for a fee and expenses not exceeding £10,000; and that a Trust be formed to administer the money received from the Appeal.

II

ANNUAL MEETING

Monday, 2nd May, 1966

LORD FLECK, OF SALTCOATS,
K.B.E., D.Sc., LL.D. F.R.S.,

President, in the Chair

THE Annual Report of the Committee of Visitors and the Statement of Accounts for the year 1965 were presented by the Chairman of the Visitors, Dr. G. F. Claringbull, whose speech included the following words:

This is the last Annual Meeting that Sir Lawrence will attend while in office as Director, and so, without wishing to steal my successor's fire, I should like to compliment him on behalf of the Visitors in so arranging things that he goes out in something of a blaze of glory. We would also congratulate the Managers on obtaining the services of Professor George Porter, F.R.S., to succeed Sir Lawrence as Director.

The Visitors are very conscious of how much the finances of the Institution depend on the work of the staff in earning money, and even more of how much our image is dependent on the work of the Davy Faraday Laboratory. We know that our report and all the other reports this year would be of little significance were it not for the Laboratory's research achievements. Not only has the year seen the practically complete solution of the structure of lysozyme, but much other work is in progress which may be expected in the not distant future to yield important scientific results.

After the Report and Statement had been approved and adopted, the Director, Sir Lawrence Bragg, presented his Report for the year 1965. (All Reports, and the Statement of Accounts, are published in *The Annual Report of the Committee of Visitors* for 1965.) In his speech, a fuller version of which has already been circulated to Members, Sir Lawrence expressed his regret that this was the last occasion on which he would present his Report as Director. He commented with pleasure on the gratifying increase in the attendances at Discourses, but went on to say that the Royal Institution could no longer restrict itself to these and other "domestic occasions". Members' subscriptions now provided only a very small part of the income needed, and we must look to industry, the Government and the scientific world, aiming "to convince the country at large that the Royal Institution is a national asset which must be maintained because it makes a unique contribution to science". As examples of this contribution Sir Lawrence cited the Schools Lectures, the Schools Membership, the Research Days and Industrial Research Days, the lectures for Administrative Civil Servants, the loan of the Lecture Theatre to other societies for scientific meetings, and the making of educational films. These schemes had brought in a total income of about £16,000 last year—the largest item in our income—and could be doubled if the staff were available. Happily, Professor Porter was equally keen on developing these exciting possibilities.

Sir Lawrence paid tribute to Professor King, who was "so competent in all those things at which I am bad", and who combined common sense with a vivid imagination and great enthusiasm. There were many others he would like to thank, but he would merely say how much he owed to Mr. Vernon, who had recently taken up a new post after fifteen years as Librarian of the Royal Institution. He welcomed warmly the election of Admiral Davis as Treasurer, and expressed his satisfaction that the team working on protein research, which had made the Davy Faraday Laboratory internationally famous, would be able to continue its brilliant work at Oxford. Finally Sir Lawrence voiced his gratitude to the Royal Institution in the words used by children after a good party: "Thank you for having me."

The President wished Sir Lawrence and Lady Bragg all happiness in retirement. He then paid tribute to the fine job of work which Mr. Vernon had performed in fifteen years as Librarian, referring particularly to his work on the Royal Institution's valuable collection of manuscripts, and the displays he had arranged for the Friday Evening Discourses. The Members were today expressing their gratitude by the presentation of an atmospheric clock, activated indefinitely by small changes in temperature. After the presentation of the clock and a cheque, Mr. Vernon expressed his thanks to the Members.

The following were elected Officers for the ensuing year:

President: Lord Fleck, of Saltcoats, K.B.E., D.Sc., LL.D., F.R.S.
Treasurer: Admiral Sir William W. Davis, G.C.B., D.S.O., D.L.
Secretary: Brigadier H. E. Hopthrow, C.B.E., M.I.Mech.E.

Managers for three years:

R. Gresham Cooke, C.B.E., M.P.
C. R. Hopper
Sir Harry W. Melville, K.C.B., F.R.S.
S. Paul Osmond, M.A.
Hugh C. Tett, A.R.C.S., B.Sc., F.Inst.Petroleum, A.M.I.Mech.E.

The remaining members of the Committee of Managers were:

E. R. Davies, O.B.E., B.Sc., F.Inst.P., F.R.P.S.
A. H. Ewen, M.A.
D. H. Follett, M.A., Ph.D., F.Inst.P.
J. H. T. Goldsmith, C.B.E.
Professor Alexander Haddow, M.D., D.Sc., Ph.D., F.R.S.
L. B. W. Jolley, M.A., M.I.E.E.
Lord Kings Norton of Wotton Underwood, D.Sc., Ph.D., D.I.C.
Professor D. M. Newitt, M.C., D.Sc., Ph.D., F.R.S.
Mrs. Dorothy Ryde, M.A.
W. R. Stevens, B.Sc., M.I.E.E.

Visitors for three years:

E. A. Calnan, B.Sc., Ph.D., F.Inst.P.
Miss Thora C. Marwick, M.Sc., Ph.D., F.Inst.P.
K. Puttick, B.Sc., Ph.D., A.Inst.P.
H. P. Rooksby, B.Sc., F.Inst.P.
Miss E. E. Whittall

The remaining members of the Committee of Visitors were:

U. W. Arndt, M.A., Ph.D.
G. L. Asherson, M.A., D.M., M.R.C.S., M.R.C.P.
A. D. Baynes-Cope, M.A., B.Sc., F.R.I.C., F.R.S.A.I.
K. W. Bridger, A.Inst.P.
J. S. Chapman
J. G. Cockburn, M.Sc., Ph.D., F.L.S., F.R.M.S.
Edward Ironmonger
F. Allen Mitchell
Miss Daphne Sidebottom
Miss Brenda Winterton, M.R.C.S., L.R.C.P.

III

BOOKS ADDED TO THE LIBRARY, 1966

(This list does not include Annual Reports, Reviews, Directories, etc., which are added regularly).

Science

GENERAL

Armytage, W. H. G. The rise of the technocrats, 1966.
Brain, Lord. Science and man, 1966.
Cockcroft, Sir John, *ed.* The organisation of research establishments, 1965.
Lewis, R. S. A continent for science, 1965.
Linnean Society. The neglect of science: report of proceedings at a conference, 1916.
Ronan, C. A. The ages of science, 1966. (*Presented by the author*)
Taton, R., *ed.* Science in the twentieth century, 1966.
Zuckerman, Sir Solly. Scientists and war, 1966.

HISTORY AND BIOGRAPHY

Armitage, A. Edmond Halley, 1966.
Cope, Sir Zachary. Almroth Wright, 1966.
Crook, Ronald E. A bibliography of Joseph Priestley, 1966.
de Beer, Sir Gavin. Charles Darwin, 1963.
Gibbs, F. W. Joseph Priestley, 1965.
Grant, R. Charles Scott Sherrington, 1966.
Greenaway, Frank. John Dalton and the atom, 1966. (*Presented by the author*)
Hutton, R. S. Supplement to his recollections, 1966. (*Presented by the author*)
Keele, K. D. William Harvey, 1965.
Manson-Bahr, Sir Philip. Patrick Manson, 1962.
Smyth, A. L. John Dalton, 1766-1844: a bibliography, 1966.
Wells, H. G. Experiment in autobiography, 2 vols., reprinted, 1966.

Mathematics and Computing

Bendick, J., and Levin, M. Mathematics illustrated dictionary, 1965. (*Presented by Mr. J. Evelyn*)
Bernstein, J. The analytical engine, 1963.
Bromwich, T. J. I'A. Quadratic forms and their classification, 1906. (*Presented by Mr. J. Evelyn*)

Hardy, G. H. A course of pure mathematics, 1946. (*Presented by Mr. J. Evelyn*)

Hilton, P. J. An introduction to homotopy theory, 1964. (*Presented by Mr. J. Evelyn*)

Kendall, M. G. A course in geometry of *n* dimensions, 1961. (*Presented by Mr. J. Evelyn*)

Ledermann, W. Integral calculus, 1964. (*Presented by Mr. J. Evelyn*)

Lukacs, E. Characteristic functions, 1960. (*Presented by Mr. J. Evelyn*)

Lukacs, E., and Laha, R. G. Applications of characteristic functions, 1964. (*Presented by Mr. J. Evelyn*)

Reuter, G. E. H. Some mathematical problems in the theory of random processes, 1966. (*Presented by the Librarian, Imperial College*)

Robinson, A. Enders. An introduction to infinitely many variants, 1959. (*Presented by Mr. J. Evelyn*)

Rogers, C. A. Packing and covering, 1964. (*Presented by Mr. J. Evelyn*)

Rollett, A. P. School library mathematics list, 1966. (*Presented by the author*)

Rutherford, D. E. Modular invariants, 1964. (*Presented by Mr. J. Evelyn*)

Physics

GENERAL

Gauss, H. E. Introduction to physics, 1966.

Jardine, J. Physics is fun, 3 vols., 1964-66.

Marcus, A. Physics in modern times, 1966.

PROPERTIES OF MATTER

Dexter, D. L., and Knox, R. S. Excitons, 1965.

Hedvall, J. Arvid. Solid state chemistry, 1966. (*Presented by the author*)

International Symposium on the reactivity of solids, 2 vols., 1954. (*Presented by the publisher*)

Kelly, A. Strong solids, 1966.

Mendelssohn, K. The quest for absolute zero, 1966. (*Presented by the author*)

Ungnade, H. E., and others, *eds.* Organic electronic spectral data, vols. 2-4, 1960-66.

ATOMIC PHYSICS

Boorse, H. A., and Motz, L., *eds.* The world of the atom, 1966.

Jaworski, I. D., and King, H. W. Atomic energy, 1966.

United Kingdom Atomic Energy Authority. Glossary of atomic terms, 1966. (*Presented by the publisher*)

Wiese, W. L., and others. Atomic transition probabilities, vol. 1, 1966. (*Presented by the Director, National Bureau of Standards, Washington*).

LIGHT

Hercules, D. M., *ed.* Fluorescence and phosphorescence analysis, 1966. (*Presented by Professor G. Porter*)

ELECTRICITY AND MAGNETISM

Anderson, J. C. The science of materials, 1966. (*Presented by the Librarian, Imperial College*)

Assenheim, H. M. Introduction to electron spin resonance, 1966.

Corbett, James W. Electron radiation damage in semiconductorsand metals, 1966.

Dreyfus, H. B., The transmission of electrical power, 1966. (*Presented by the General Electricity Generating Board*)

England, Glyn. The future development of electricity supply, 1966. (*Presented by the Central Electricity Generating Board*)

Laithwaite, E. R. Induction machines for special purposes, 1966.

Lancaster, G. Electron spin resonance in semi-conductors, 1966.

Malmstadt, E., and others. Electronics for scientists, 1963.

Chemistry

GENERAL

Hedvall, J. Arvid. Chemie im Dienst der Archäologie, Bautechnik, Denkmalpflege, 1966. (*Presented by the author*)

PHYSICAL CHEMISTRY

Amis, Edward S. Solvent effects on reaction rates and mechanisms, 1962.

PHOTOCHEMISTRY

Stroke, G. W. An introduction to coherent optics and holography, 1966.

Wilson, B. J., *ed.* Radiochemical manual, 2nd edition, 1966. (*Presented by the Radiochemical Centre*)

CRYSTALLOGRAPHY

Arndt, U. W., and Willis, B. T. M. Single crystal diffractometry, 1966. (*Presented by the author*)

Swanson, H. E., and others. Standard X-ray diffraction powder patterns, 1966. (*Presented by the Director, National Bureau of Standards, Washington*)

INORGANIC CHEMISTRY

Samuel, D. M. Industrial chemistry: inorganic, 1966.

West, T. S. Inorganic trace analysis, 1966. (*Presented by the Librarian, Imperial College*)

METALLURGY

Alcock, C. B. Problems with solutions: a chemical view of high temperature materials, 1966. (*Presented by the Librarian, Imperial College*).

Hedvall, J. Arvid. Einführung in die Festkorperchemie, 1952. (*Presented by the author*)

Massalski, T. B., and King, H. W. Alloy phases of the noble metals, 1961.

Oding, I. A. Creep and stress relaxation in metals, 1966.

Stoloff, N. S., and Davies, R. G. The mechanical properties of ordered metals, 1966.

ORGANIC CHEMISTRY

Samuel, D. M., Industrial chemistry: organic, 1966.

Astronomy

Bok, B. J. and P. F. The Milky Way, 1957. (*Presented by Dr. H. Rishworth*)

Cade, C. M. Other worlds than ours, 1966. (*Presented by the author*)

Smart, W. M. The origin of the Earth, 1951. (*Presented by Dr. H. Rishworth*)

Biological Sciences

GENERAL

Beadle, G. and M. The language of life, 1966.

Kendrew, J. The thread of life, 1966.

Simondon, Gilbert. L'individu et sa genèse physico-biologique, 1964. (*Presented by the Bureau Scientifique*)

BIOCHEMISTRY

Vigneron, M., *ed.* Aminoacides, peptides, proteines, 1966. (*Presented by the editor*)

ZOOLOGY

Hewer, H. R. The length and breadth of zoology, 1966. (*Presented by the Librarian, Imperial College*)

Rudd, Robert L. Pesticides and the living landscape, 1965.

PUBLIC HYGIENE

Marsh, Arnold. Smoke, 1947. (*Presented by Dr. H. Rishworth*)

PSYCHOLOGY

Ramsay, J., *ed.* Biology and personality, 1965.

Education

Educational Policies Commission. Education and the spirit of science, 1966. (*Presented by the publisher*)

Shimmin, A. N. The University of Leeds: the first half-century, 1954. (*Presented by Sir Lawrence Bragg*)

Useful Arts

Cooper, B., and Gaskell, T. F. North Sea oil – the great gamble, 1966. (*Presented by Dr. T. F. Gaskell*)

Gilbert, K. R. The machine tool collection, 1966. (*Presented by the Director, Science Museum*)

Jackson, W. E. London's fire brigades, 1966. (*Presented by Mr. L. W. T. Leete*)

Bibliography and Libraries

British Standards Institution. Bibliographical references, 1951.

British Standards Institution. Periodicals of reference value: form and presentation, 1959.

Henderson, M., and others. Co-operation, convertibility and compatibility among information systems: a literature survey, 1966. (*Presented by the Director, National Bureau of Standards, Washington*)

Hopper, Natalie J. Periodicals and serials received in the Library of the National Bureau of Standards to October, 1965. (*Presented by the Director, N.B.S., Washington*)

National Lending Library of Science and Technology. Select list of social science serials in the N.L.L., 1966. (*Presented by the publisher*)

Standing Conference of National and University Libraries and the German Publishers and Booksellers Association. Recent German learned and scientific books, 1966. (*Presented by the Hon. Philip Samuel*)

Staur, K. G., *ed.* World guide to libraries, 2 vols., 1966.

General Works of Reference

Allen, D. G. C. The Houses of the Royal Society of Arts, 1966. (*Presented by the author*)

Cochrane, R. C. Measures for progress, 1966. (*Presented by the Director, National Bureau of Standards, Washington*)

Colby, R. Mayfair: a town within London, 1966.

Dobson, Jessie. Guide to the Hunterian Museum, 1958. (*Presented by the author*)

Staveley, R., and Piggott, M. Government information and the research worker, 1966.

Reader's Digest. Complete atlas of the British Isles, 1965.

Ward, Humphrey. The history of the Athenaeum, 1926. (*Presented by Sir Lawrence Bragg*)

MEMBERSHIP OF THE ROYAL INSTITUTION

1. FOR INDIVIDUALS

a. Membership of the Royal Institution is open to all who are interested in science, no special scientific qualification being required for admission.
Members have the use of the House of the Institution, including the Library and Lending Library; they can attend the Evening Discourses, the Christmas Lectures, the Library Circle and other meetings at the Royal Institution; they receive the *Proceedings* and the *Record.* They may introduce two friends to any Evening Discourse. There is an entrance fee of three guineas and the annual subscription is seven guineas.

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Further information about Membership may be obtained from the Assistant Secretary, The Royal Institution, 21 Albemarle Street, London, W.1. *Telephone:* 493-0669 and 5716.

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Other publications of THE ROYAL INSTITUTION

1. The Royal Institution, by Thomas Martin (revised ed. 4/-).
   A short illustrated history.

2. Michael Faraday: Advice to a Lecturer, compiled by Geoffrey Parr (3/6).
   A short selection, taken from Faraday's manuscripts, of his views on the art of lecturing.

3. The House of the Royal Institution, by A. D. R. Caroe (3/6).
   An illustrated booklet describing the history of the House and the many alterations which have been made to it since 1799. Also includes a short historical account of the district round Albemarle Street.

4. The Foundation and Early Years of the Royal Institution, by K. D. C. Vernon (3/-).
   An illustrated booklet (reprinted from the *Proceedings*) describing the activities of Rumford and others during the first years in the Institution's life from 1799 to 1803.

Orders for the above publications should be accompanied by the necessary remittance and should be addressed to the Assistant Secretary, The Royal Institution, 21 Albemarle Street, London, W.1

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5. Faraday's Diary. Edited by Thomas Martin, and published on behalf of the Royal Institution by G. Bell and Sons, Ltd. 12 guineas the set.
   The experimental notes, including drawings, made by Faraday at the Royal Institution between 1820 and 1862.
   Available from any bookseller.

6. Michael Faraday: a list of his lectures and published writings, compiled by Alan E. Jeffreys. Published on behalf of The Royal Institution by Chapman & Hall, Ltd. 42/-. (32/6, 34/- by post to Members of the Royal Institution).
   An illustrated bibliography, arranged in chronological order, of all Faraday's published articles, papers, books, letters, lectures and his manuscript lecture notes.

   Available from any bookseller. Orders from Members of the Royal Institution only should be sent to the Assistant Secretary

LONDON, Royal Institution

S1x AT 579 S.I. Rd. 2.12.64

Manuscripts at the Royal Institution

A general description of the big collections of Davy, Dewar, Faraday and Tyndall manuscripts is given in the paper by the Librarian, Mr. K.D.C. Vernon, herewith.

The mss. at the R.I. are not completely catalogued and it is probable that there are a lot more letters of people on the list from the University of Keele, but many of these letters are to do with the Institution's business and must therefore be regarded as confidential until they are ~~even~~ sorted.

There is no published guide or catalogue.

Aceess to the mss. is available to scholars, provided they give notice in advance of what they wish to consult and their purpose.

A. E. Jeffreys
March 1964.

Professor L. P. Williams, Dept. of History, Cornell University, Ithaca, U.S.A., is compiling an index of all extant Faraday mss. For Faraday mss. at the Royal Institution see also Michael Faraday; a list of his lectures and published writings by A. E. Jeffreys. 1960.

LETTERS AT THE ROYAL INSTITUTION, LONDON

(Many of the letters in the 'General' column are in the 'Davy & Faraday collections, being letters written to either Davy or Faraday)

UNIVERSITY COLLEGE OF NORTH STAFFORDSHIRE

Survey of scientific manuscripts. List no.1.

	General	Tyndall Collection
DAMS, John Couch, 1819-1892.	1	
IRY, George Biddell, 1801-1892.	2	3 (approx. no.)
BABBAGE, Charles, 1791-1871.	2	35
BARLOW, Peter, 1776-1862.	2	1
BENTHAM, George, 1800-1884.		
BOOLE, George, 1815-1864.	—	—
BRANDE, William Thomas, 1788-1866.	—	—
BREWSTER, Sir David, 1781-1868.	4	
BRINKLEY, John, bishop of Cloyne, 1763-1835.	2	8
BRODIE, Sir Benjamin Collins, 1783-1862.	1	
BROWN, Robert, 1773-1858.	1	
BUCKLAND, William, 1784-1856.	2	
AYLEY, Arthur, 1821-1895.	—	
HENEVIX, Richard, 1774-1830.	—	
OOPER, Sir Astley Paston, 1768-1841.	2	
ROOKES, Sir William, 1832-1919.	—	
ARWIN, Charles Robert, 1809-1882.	1	35
DAVY, Sir Humphry, 1778-1829. — special collection		
DE LA RUE, Warren, 1815-1889.	—	
DEWAR, Sir James, 1842-1923. — special collection		
FAIRBAIRN, Sir William, 1789-1874.	1	
FARADAY, Michael, 1791-1867. — special collection		
FOSTER, Captain Henry, 1796-1831.	—	
FRANKLAND, Sir Edward, 1825-1899.	—	
GALTON, Sir Francis, 1822-1911.	—	
GEIKIE, Sir Archibald, 1835-1924.	—	
RAHAM, Thomas, 1805-1869.	2	
ENRY, William, 1774-1836.	3	
ERSCHEL, Sir John Frederick William, 1792-1871.	3	50
OME, Sir Everard, 1756-1832.		
OOKER, Sir Joseph Dalton, 1817-1911.	—	200
HUGGINS, Sir William Huggins, 1824-1910.	—	
HUXLEY, Thomas Henry, 1825-1895.	1	300
IVORY, Sir-James, 1765-1842.	—	
JOULE, James Prescott, 1818-1889.	—	
KATER, Captain Henry, 1777-1835.	—	
KELVIN, Lord (Sir William Thomson), 1824-1907.		20
KNIGHT, Thomas Andrew, 1759-1838.	—	
LAPWORTH, Charles, 1842-1920.	—	
LISTER, Joseph, 1827-1912.	—	
OCKYER, Sir Joseph Norman, 1836-1920.	—	
ODGE, Sir Oliver Joseph, 1851-1940.	—	
YELL, Sir Charles, 1797-1875.	2	20
ACCULLAGH, James, 1809-1847.	—	
AXWELL, James Clerk, 1831-1879.	—	1

AP 3/78

R.I. ARCHIVES

Manuscript Letters and Papers of Leading British Scientists

AIRY (Sir George B.)	39
BABBAGE (Charles)	10
BRAGG (Sir William H.)	Special Collection
BRANDE (W.T.)	18 + notebooks
BREWSTER (Sir David)	11
BRODIE (Sir Benjamin C., senior)	12
CARPENTER (W.B.)	7
CLARKE (E.D.)	24
COOPER (Sir Astley P.)	4
CROOKES (Sir William)	9 + notebooks
DALTON (John)	5
DARWIN (Charles)	39 (35 in Tyndall Collection)
DAUBENY (C.G.B.)	3
DAVY (Sir Humphry)	Special Collection (approx. 350)
DE LA BECHE (Sir Henry T.)	10
DEWAR (Sir James)	Special Collection
EDDINGTON (Sir Arthur S.)	5
FARADAY (Michael)	Special Collection
FRANKLAND (Edward)	24
GARNETT (Thomas)	3
GASSIOT (J.P.)	13 + notebook
GRAHAM (Thomas)	13
GREGORY (Sir Richard)	4
GROVE (Sir William Robert)	Special Collection (over 800)
HALL (Dr Marshall)	4
HERSCHEL (Sir John F.W.)	42
HOOKER (Sir Joseph Dalton)	86
HUGGINS (Sir William)	8
HUXLEY (T.H.)	62

JOULE (James P.)	11
KEITH (Sir Arthur)	12
KELVIN (William Thomson, Lord)	37
LARMOR (Sir Joseph)	8
LISTER (Joseph, father of Lord Lister)	2
LODGE (Sir Oliver)	6
LYELL (Sir Charles)	80
MAXWELL (James Clerk)	2
MURCHISON (Sir Roderick)	14
OWEN (Sir Richard)	8
Parsons (Sir C A)	6
PLAYFAIR (Lyon, Lord)	1 notebook 19
PRIESTLEY (Joseph)	1
RAYLEIGH (3rd Baron)	12 + notebook
RUTHERFORD (Ernest, Lord)	41 (+ 29 Xerox)
SHARPEY (William)	2
SODDY (Frederick)	25
SPENCER (Herbert)	86
STOKES (Sir George Gabriel)	121
TALBOT (W.H. Fox)	12
THOMSON (Sir Joseph J.)	10
TYNDALL (John)	Special Collection
WHEATSTONE (Sir Charles)	10
WHEWELL (William)	7

CARLYLE (Thomas)	3
COLERIDGE (S.T.)	18
DICKENS (Charles)	2
JOWETT (Benjamin)	1
SOUTHEY (Robert)	7
TERRY (Ellen)	1
Scott (Sir Walter)	2

The Royal Institution's Collection of Manuscripts.

By K.D.C. Vernon, F.L.A. 1963.

The collection of manuscripts at the Royal Institution is both important and well known to scholars working on the history of science in the nineteenth century. Rumford, Davy, Faraday, Tyndall and Dewar lived, in succession, at the Institution and carried out most of their research in its laboratories. Together they spanned the whole century. The bulk of their manuscripts was left to the Institution.

Rumford

Our collection of Rumford's manuscripts is disappointingly small and consists only of some sixty letters written about the period 1800-1803. These are almost entirely connected with his personal affairs or with the business of the Royal Institution. They are mostly addressed to William Savage who was the Institution's Clerk.

It would be appropriate if any other Rumford manuscripts relating directly to the Institution's history, which may exist elsewhere could be deposited at the Institution which he founded.

DAVY

Our Davy manuscripts are of great importance. There are many of his manuscripts in other places also, but the collection at the Royal Institution is a large one.

It consists of:

(a) Three folio volumes of laboratory notebooks covering the years 1809-1813, and two others containing intermittent entries between 1821 and 1859, mainly the work of Brande and Faraday.

(b) Two volumes of Davy's papers, mainly concerned with the safety lamp, which were collected by Faraday and presented by him to the Institution on 2nd April 1849. A note which is written in Faraday's handwriting in front of the large volume says:-

> "This volume and a similiar one Post size contain certain original papers of Sir H. Davy. I had to copy these, the first rough papers, which were then usually destroyed: until I begged to have them as a remembrance of the man and the places where they were written - My request was granted and these with the exception of one or two in my copy of the Life of Davy are what I thus saved from destruction.
>
> (Signed) M. Faraday.
>
> Jany. 1832 "

We must indeed be thankful for Faraday's care. He was really a conscientious archivist.

(c) Davy's lecture notes, chiefly his lectures on agriculture and geology. They are not all in his own hand.

(d) His personal notebooks extending approximately over the period 1795 - 1823. They contain a mixture of poems, essays, scientific notes, sketches and miscellaneous jottings. Some of the pages have been torn out - Davy was in the habit of doing this - and they are written very untidily in ink and pencil, frequently being almost indecipherable.

(e) Some 350 letters which came to the Institution as a gift from Sir Humphry Davy Rolleston in 1925. About half of these are to or from Lady Jane Davy and members of the Davy family. ~~Very few~~ Many are on scientific matters and ~~many~~ Some of the letters have been published in Davy's Fragmentary Remains and other works.

The collection has been studied and worked on by numerous scholars at different times and has been used extensively by Davy's biographers.

FARADAY

The Faraday manuscripts in the Institution's possession are the largest single collection in existence and it is right that these should be preserved in the place where he lived and worked for most of his life. They have been extensively studied from time to time and their existence is well known to scholars; but because of their importance in the history of science I must indicate their extent.

The famous Diary was edited by Thomas Martin and published in seven volumes in 1932-36. The original manuscript volumes of this great work were bequeathed to the Royal Institution by Faraday who said in his will, dated 16th January 1855: "Various Philosophical Notes of experimental investigation on foolscap paper, paged in series, and partly bound in five volumes; a quarto ms. book of Philosophical Notes; a second larger quarto of similar notes; ,............ these I offer for the Library of the Royal Institution, if the Managers should think them worth a place; if not, to remain at the disposal of my executors........" Thus, this great scientific treasure has remained, since his death in 1867, in the safe keeping of the Royal Institution.

Many of the other manuscripts - his lecture notebooks, his Experimental Researches in Electricity (with ms. insertions), his precious Life of Davy by Paris (with ms. letters inserted), his collections of printed papers and books, including a few bound by Faraday himself - were presented by Mrs. Faraday in 1867. Since that time many other people have presented Faraday letters and manuscripts to the Institition, but mention can only be made of here of one more item. In 1902 Mr. T.J.F. Deacon who, through his mother, was related to Faraday gave to the Royal Institution two large folio of vols. containing portraits and letters which Faraday had collected. These vols. were evidently kept by Faraday as a record of people who hedhad met.

They are his scrap books, the engraved portraits having been put one one page with the letter from the subject of the engraving on the other facing page or below the portrait. Arago, Berzelius, Dalton, Daubeny, Sir John Herschel, Liebig, Lyell, Oersted and Whewell are a few of the scientists represented. The young Prince Albert (later Edward VII), his brother Prince Alfred, Isaac Disraeli, Louis Napoleon, Countess of Lovelace (Byron's daughter), Sir Robert Peel and Earl Spencer are a few of the other notabilities. These fascinating vols. with their strange mixture of historic documents, (such as Whewell's letter concerning the use of the terms Anode and Cathode) and near trivialities (such as an invitation to dinner) are still kept in Faraday's own bureau in the room which was his study.

This brief summary gives no more than a glimpse of our Faraday collection. Mr. Alan Jeffreys in his recently published bibliography Michael Faraday: a list of his lectures and published writings has revealed the extent of his publications. Professor L. Pearce Williams has tracked down and studied many other Faraday manuscripts in addition to those at the Royal Institution. But it is this collection which contains the bulk of his great life's work.

TYNDALL

John Tyndall was appointed Professor of Natural Philosophy at the Royal Institution in 1853. For over ten years he worked with Faraday, then he took over Faraday's laboratory and lecturing duties and stayed until 1877.

In 1947 Mr. Granville Proby, who was Mrs. Tyndall's nephew, presented all Tyndall's manuscripts to the Institution. They are a magnificent collection. Mrs. Tyndall had preserved her husband's papers with loving care. As a widow for 47 years she had spent much of this time struggling to write a biography of her husband, but the task was too much for her. We must, however, be grateful to her for having arranged the collection of manuscripts so beautifully, although we may wonder whether she was right to preserve so much material.

Mrs. Tyndall had almost all the correspondence typed out and finely bound in ten blue leather volumes each being carefully indexed. The original letters have been preserved separately in boxes. Three volumes of Tyndall's Journal and five volumes of T. Archer Hirst's Journal were similarly treated.

Then there are his notebooks, his lecture notes, his diary of experiments, and various miscellaneous collections of press cuttings which Mrs. Tyndall carefully preserved. The whole collection was extensively studied by Eve and Creasey while they were writing their <u>Life and work of John Tyndall</u>. It was also examined (except for a black tin box) by Sir Robert Robertson and Mr. Edward Ironmonger with the result that they established that the whole of Tyndall's contribution to science has already been published mainly in the journals of learned societies. But nevertheless, the Tyndall manuscripts are important from many aspects and particularly because the records of such an important figure illuminate the whole wide scene of nineteenth-century science and its 'politics'.

DEWAR

Rumford, Davy, Faraday, Tyndall and now Dewar, who succeeded Tyndall as Resident Professor in 1877 and remained at the Royal Institution until his death in 1923. His manuscripts consist of many notebooks and records of his laboratory work; the notes which he used for his Christmas Lectures at the Institution; and a certain amount of correspondence and records of other work. I think it is right to say that he was not a believer in keeping large files of letters so those which we have are not very numerous. A large quantity of laboratory notes and some letters bearing on them have since been catalogued.

From this outline it will be seen that the Institution's collection of manuscripts, although extensive, relates mainly to five great nineteenth century scientists.

We have not got a descriptive catalogue of our whole collection, although I hope that one will be produced some day; but we have got an index to many of the letters and indexing work is slowly continuing. It is difficult to decide at times whether all letters need to have a short summary included on the catalogue card, or whether the bare facts of names, dates, and addresses are sufficient.

Many of the Faraday letters (which in any case are more legible that those of Davy!) have been mounted in loose-leaf folders with a typed copy of each letter on the facing page. Whether we shall ever be able to treat the Davy letters in the same way depends on time, money and staff. But we have been careful, in the indexing work which we have done, to ensure that the various collections of letters have been kept together as they were when they came into our possession and we have not attempted any kind of arbitary rearrangement. This I think is important to scholars consulting the letters.

PART IV (OF R.I. LIST OF JUNE 1964)

MANUSCRIPTS OF R.I. PROFESSORS, ETC.

Davy Manuscripts

These MSS. are kept in numbered boxes. The letters have all been indexed, but require to be properly mounted, probably in letter books.

1. Miscellaneous lectures.

2-4. Lectures 1802-1812.

5. Honours and Certificates.

6,7,7a Laboratory Notebooks. 1805-1812. 1813-1821. (partly written by Faraday).

8. Laboratory Notebooks 1821-1859.

9. Book of poems, essays and copies of letters.

10-11. Original papers collected by Faraday.

12. Commonplace Book (mainly scientific notes 1813-1814).

13. Personal Notebooks 1795-1823.

14. " " 1827-1829.

15. " " 1801-1814 (Largely relating to Ireland).

16-17. Lectures on Geology 1805.

18. Lectures on Agriculture.

19. History of Science.

20. Scientific Observations 1799-1800.

21. Notebooks 1795, 1800. John Davy's notebook on "Consolations in travel". Lectures on agriculture.

22. Scientific experiments 1800-1805. Edmund Davy's private ledger 1809-1826.

23. "Salmonia" annotated by Davy.

24. "Elements of Chemical Philosophy" annotated by Davy.

25. Letters to Lady Davy.

26-27 Miscellaneous Letters.

Faraday Manuscripts

NOTE: Other Faraday MSS., papers and books are kept in his bookcase in the Managers Room ~~and in Sir Lawrence Bragg's Study.)~~

1. Laboratory Notebooks (Title: Experimental Notes)

v.1.	February 2nd,1831	-	April 6th, 1832
v.2.	August 25th, 1832	-	January 15th,1836
v.3.	January 15th,1836	-	November 5th,1838
v.4.	November 5th,1838	-	January 10th,1845
v.5.	January 10th,1845	-	January 21st,1850
v.6.	January 21st,1850	-	December 19th,1854
v.7.	March 3rd, 1855	-	March 6th,1860 INDEX
v.8.	1861	-	1862 (and earlier miscellaneous notes)

2. Lectures by Sir H.Davy, 1812 on the Elements of Chemical Philosophy.

3. Index to v.1, 2 & 3 of Experimental Researches. (Titles: Experimental Notes Index)

4. Notebook and Experiment Book of Things Examined in the Laboratory September 1820 to December 17, 1823 (continued in next item)

5. -do- December 10th 1823 - 14th November 1832.

6. Lectures by Mr. J.Tatum

v.1. Three Lectures on Electricity illustrated with experiments and Observations, 19th February 1810 - 19th March 1810 and 16th April 1810. Dedication to Mr. G.Riebau.

v.2. Hydrostatics 22nd August 1810, Optics 18th October 1810, Combustion 22nd October 1810.

v.3. Three Lectures on Galvanism 28th January 1811, 4th February 1811, 11th February 1811. A Lecture on Geology, 17th February 1811. Dedication to Mr. G.Riebau.

v.4 Lectures on Mechanics, 16th September 1811, 26-27 September 1811.

7. A Class Book for the Reception of Mental Exercises instituted July 1818. Members: M.Faraday, E.Deeble, E. Barnard, T.Deacon and J.Corder. (Bequeathed to the R.I. by T.J.F. Deacon, 1901).

8. Lecture Notebook. Mescellaneous Lectures 1827 - 1850.

9. List of Apparatus for Lectures: about 1819. At other end is a list of subscribers and Brande's Lectures, February 1819.

10. Michael Faraday's Flower Book, given by him to Jane Barnard, 1850, who gave it to Evelyn Barnard 1910, who in turn presented it to the R.I.

11. Correspondence.

v.1. October-November, 1813 - 11th July, 1843.
v.2. 13th July, 1843 - 28th October 1850
v.3. 8th February 1851 - 15th December 1856
v.4. 11th March 1857 - 13th December 1861
v.5. 1st January 1862 - 20th December 1864
v.6. 1865 including miscellaneous letters possibly earlier and letters by Sarah Faraday. Also 3 letters about Faraday.
v.7. Collection of 39 letters of a Scientific Nature 1824-1864. Presented by Ludwig Mond? Includes 3 photographs of Faraday.
v.8. A collection of miscellaneous letters about Faraday by Sarah Faraday and others. Mainly collected by Dr. Bence-Jones. (Requires indexing. Marked v.7 on box).
v.9. Miscellaneous collection of Faraday letters, including photocopies, typescripts etc. (Requires sorting and indexing).
v.10. Manuscript correspondence between Faraday and Sir James Chance. Presented by Sir Hugh Chance in 1960. (Partly indexed).

12. 11 Rough Notes of Lectures, by J. Tatum.

13. Manuscript of Faraday's "Chemical Manipulation."

14. Probate of the Will of Michael Faraday 23rd October 1867.

15. Press cuttings, reports, notes etc. relating to the Faraday Memorial, busts and reports of subsequent ceremonies etc.

16. Faraday Memorial. Minute Book 1868-1869.

17. Faraday's Bible. (In glass case). Apparently presented by the Barnard family.

18. Faraday's Bible formerly belonging to Miss Reed. Presented by Mr. E.H. Duckworth, 1960.

19. A collection of Ordnance Survey Maps belonging to Faraday and showing his journeys in England. Presented by Mr. E.H. Duckworth, 1960.

Dewar Manuscripts and Papers

(NOTE: Other Dewar MSS. and papers are kept in his cabinet in the Lecturer's Room).

1. Correspondence and General File

   2 boxes of letters etc. including letters from Royalty to Sir James Dewar (to be indexed).

2. Biographical Notices (1 box).

   2 notebooks; a collection of photographs (by Miss Reynolds(?) of the R.I. and its laboratories)

   3 prints of Dewar sitting at a table.

3. Christmas Lectures (1 box)

   Notebooks of Christmas Lectures given in 1878-9, 1888-9, 1890-1

4. War Work (1 box)

   2 files of letters and papers.

   Private file entitled "Board of Invention and Research" (Sir James Dewar).

5. 1 File of Miscellaneous Notes and Lab. Notebook c.1896.

6. St. Louis Exhibition Research Papers

   Includes:- Notes; diagrams; photographs; lists of apparatus etc.

7. Dewar Golden Wedding Gift. Committee Minute Book 1921-22.

8. Dewar-Scott Affair. Collection of letters from Dewar to Alexander Scott and testimonials of scientific colleagues and others in favour of Scott. (This correspondence should be indexed, but should not be made available for inspection by scholars without permission from the Managers.)

Laboratory Notebooks of Sir William Crookes

1. Vol.6 June 1881-July 1884.

2. Vol 7. Chemical Notebook.
   July 1883 - November 1885.

   Vol.7. Physical Laboratory Notebook
   July 1884 - 1886.

4. Vol.9 Notebook for the Spectroscope
   July 1884 - October 1888.

5. Vol.10 Chemical Laboratory Notebook
   November 1885 - July 1888.

6. Vol.11 Laboratory Notebook
   July 1888 - December 1889.

7. Vol.12 Laboratory Notebook
   January 1890 - January 1891.

8. Vol.13
   1891 - 1894.

9. Vol.14 Photographed Spectra.
   May 1894 - July 1903.

10. Vol. 15
    August 1894 - July 1896.

11. Vol.16
    September 1896 - May 1899.

12. vol.17

May 1899 - June 1901.

13. vol.18

July 1901 - July 1903.

14. vol.19.

November 1903 - September 1914.

15. vol.20. Chemistry

October 1903 - March 1913.

16. vol.21. Physics

October 1903 - April 1919.

Miscellaneous Manuscripts

1. Count Rumford

58 items. Letters, copies of letters, notebooks etc.

2. Thomas Webster

Autobiography.

3. E.D. Clarke

23 letters to Thomas Harrison (Secretary of R.I.)1816-19

4. John Barlow

One Scrap Book containing miscellaneous letters, biographical information about the correspondents, autographs, press cuttings, R.I. admission tickets, etc. (Purchased in 1953).

5. J.P. Gassiot

MSS. Record of early Laboratory experiments. Presented by W. Hugh Spottiswoode 1908.

6. Spottiswoode?

List of apparatus and experimental notes. 2 vols.

7. Sir William Grove

A miscellaneous collection of letters and papers presented by Mrs. Grove-Hills. (To be indexed).

NOTE

In the prospectus of the Royal Inst., issued in 1969, mention is made of the papers of Sir William Bragg and ~~Sir Lawrence Bragg~~ now being in the R.I. Library. (Royal Institution of Great Britain, What it is and does, etc. p. 10.)

N.B. There are also pprs. of Sir Wm. Bragg at the Cavendish Laboratory in Cambridge & the University of Manchester. ex inf. Archivist of Royal Institution, 9.IV.70.

TELEPHONES:
01-493 {0669 / 5716}

10th February, 1971

THE ROYAL INSTITUTION,
21, ALBEMARLE STREET,
LONDON, W.1.

ARCHIVES OF THE ROYAL INSTITUTION

Holdings of Autograph Letters from non-British Scientists of 19th and 20th Centuries

AMPÈRE (A.-M.) 1775-1836	1	CANTONI (G.) 1818-1897	1
ANDRÉ (C.) 1842-1912	1	CHANCOURTOIS (E.B. de) 1819-1886	2
ARAGO (D.-F.) 1786-1853	1	CHEVREUL (M.-E.) 1786-1888/9	1
ARDIGO (R.) 1828-1920	1	CLAUSIUS (R.J.E.) 1822-1888	80
ARRHENIUS (S.A.) 1859-1927	3	COHN (F.) 1828-1895	1
BALESTRIERI (P.) ? - ?	1	COLNET D'HUART (?de) 1821- ?	1
BAUMHAUER (E.H. von) 1820-1885	1	CORNET (G.) 1858-1915	2
BECK (P.A.) 1908-	4	CORNET (A.) 1842-1902	2
BECQUEREL (A.-C.) 1788-1878	2	CROMMELIN (C.A.) 1865-1939	1
BERGERET (D^{r}) ? - ?	2	CROULLEBOIS (M.) 1844-1886	1
BERGMANN (T.O.) 1735-1784	16	CURIE (P.) 1859-1906	7
BERTHELOT (M.) 1827-1907	3	DARCET (J.-P.-J.) 1777-1844	1
BERZELIUS (J.J., Baron) 1779-1848	3	DEBUS (H.) 1834-1916	19
BESSON (H.) ? - ?	1	D'ALCANTARA (P.) ? - ?	4
BEZOLD (W. von) 1837-1907	1	DEBYE (P.) 1884-1966	3
BIANCONI (G.G.) 1809-1879	1	DESAULX (le père J.) 1850-1940	1
BIOT (J.-B.) 1774-1862	1	DESLANDRES (H.) 1826-1891	1
BOHN (C.) 1831-1897	13	DESPRETZ (C.-M.) 1792-1863	16
BOSSCHA (J.) 1831-1911	1	DIAMILLA MILLER (?) ? - ?	1
BOUTIGNY (P.H.) 1798-1884	1	DOVE (H.W.) 1803-1879	3
BREDA (J.) 1788-1867	1	DU BOIS (H.) 1863-1918	2
BROGLIE (L.-C.-V.-M. duc de) 1875-1960	5	DU BOIS-REYMOND (E.H.) 1818-1896	34
BROMEIS (Th.) 1823-1865	2	DUBOSQ (J.) 1817-1886	5
BRÜCKE (E.W. von) 1819-1892	3	DUFOUR (C.) 1827-1902	1
BRÜHL (J.W.) 1851-1911	2	DUMAS (J.-B.) 1800-1884	15
BUNSEN (R.W. von) 1811-1899	13	DU MONCEL (T.-A.-L.) 1821-1884	9
CADET (S.) ? - ?	1	EDLUND (A.) 1819-1888	1
CANNIZZARO (S.) 1826-1910	1	EINSTEIN (A.) 1879-1959	1

ESCHER (A.) 1807-1872	1
EWALD (P.P.) 1888-	3
FAVE (L.) 1853-1920	1
FAVRE (A.) 1815-1879	2
FAZZINI (L.) 1787-1837	1
FORCHHAMMER (G.) 1794-1865	1
FRIEDEL (G.) 1865-1933	5
GAY-LUSSAC (J.L.) 1778-1850	3
GERLING (C.L.) 1788-1864	2
GIORDANO (F.) ? - ?	3
GOLDSCHMIDT (V.M.) 1887-1947	13
GOUBERT (Dr) ? - ?	2
GOVI (G.) 1826-1889	2
GUILLAUME (Ch.-Ed.) 1861-1938	2
HAAST (J.) 1864- ?	1
HABER (F.) 1868-1934	1
HACHETTE (J.N.P.) 1769-1834	2
HAHN (O.) 1879-1968	2
HANSTEEN (C.) 1784-1873	2
HELMHOLZ (H. von) 1821-1894	3
HENRY (J.) 1799-1878	2
HESS (K.) 1888-	2
HESSEL (J.F.C.) 1796-1872	1
" (son of J.F.C.) ? - ?	1
HIMSTEDT (F.) 1852-1933	1
HOFMANN (A.W. von) 1818-1892	5
HUBER (V.M.) 1864- ?	1
HUMBOLDT (F.H.A., Baron von) 1769-1859	2
INGOLD (Sir C.K.) 1893-1970	2
JAEGER (F.M.) 1877-	3
JAMIN (J.) 1818-1886	18
KAMERLINGH ONNES (H.) 1853-1926	32
KEESOM (W.) 1876-	3
KHANIKOF (N. de) 1819-1878	1
KNOBLAUCH (K.) 1820-1895	16
KOCH (R.) 1843-1910	3
KOHLRAUSCH (R.H.A.) 1809-1858	11
KREBS (G.) 1833- ?	1
LANGE (F.A.) 1828-1875	1
LANGEVIN (P.) 1872-1946	1
LA RIVE (A. de) 1801-1873	9
LAUE (Max von) 1879-1960	3
LAVELEYE (E. de) 1822-1892	3
LE CHATELIER (H.) 1850-1936	1
LECOQ DE BOISBAUDRAN (P.-E.(F.)) 1838-1912	1
LEHMANN (E.) ? - ?	1
LEWKOWITSCH (H.) 1850- ?	1
LEVERRIER (U.-J.-J.) 1811-1877	1
LEYSER (M.) 1816-1881	1
LIEBIG (J. von) 1803-1873	7
LILLIE (F.R.) 1870-1947	1
LISSAJOUS (J.) 1820-1880	4
LOGEMAN (W.) ? - ?	1
LORENTZ (H.A.) 1853-1928	4
LORTET (L.) ? - ?	3
LOZANO (E.P. de L.) 1844- ?	1
McLENNAN (Sir J.C.) 1867-1935	7
MAGNUS (G.) 1802-1879	36
MANGON (H.) 1821-1888	1
MARCET (F.) 1803-1883	1
MARCONI (G.) 1874-1937	1
MARIGNAC (J.C.) 1817-1894	1
MARK (H.) 1895-	2
MARTINS (K.F.) ?1868	1
MATHIAS (E.O.J.) 1861-1942	12
MATTEUCCI (C.) 1811-1868	72
MAURY (M.F.) 1806-1873	2
MAYER (A.M.) 1836-1897	7

MAYER (J.R.) 1814-1878	7
MELDE (F.) 1831-1901	1
MELLONI (M.) 1798-1854	2
MENABREA (Cte Marq. de V.). 1809-1896	1
MÉRITENS (A. de) 1879-	3
MILLIKAN (R.A.) 1868-1953	1
MOIGNO (F.) 1804-1884	38
MOISSAN (H.) 1852-1919	10
MOLL (G.) 1785-1838	2
MÜLLER (J.) 1846-1875	1
NEWCOMBE (S.) 1835-1909	1
NIEPCE DE ST. VICTOR (C.-F.-A.) 1805-1870	2
ODDONE (E.) 1864-1938	1
OERSTED (H.C.) 1777-1851	1
PASTEUR (L.) 1822-1895	17
PELLETIER (P.-J.) 1788-1842	1
PETIT (L.-F.) ? - ?	3
PHRAGMÉN (L.E.) 1863-1937	1
PIJPER (A.) 1886 ? - 1964	1
PILATTE (L.) ? - ?	3
PLANTE (G.) 1834-1889	1
PLATEAU (J.) 1801-1883	22
POGGENDORFF (C.) 1796-1877	7
POUCHET (F.) 1800-1872	1
PRASAD (M.) 1890-	1
QUÉTELET (L.-A.-J.) 1796-1874	2
RADAU (R.) 1835-1911	2
RAYET (G.) 1839-1906	1
REGNAULT (H.V.) 1810-1878	3
REICH (F.) 1799-1882	1
REUSCH (A.) ? - ?	1
RÉVILLE (A.) (ca.1870)	4
RIESS (P.T.) 1804-1883	2
ROSE (H.) 1795-1864	2
RUBENS (H.) ? - ?	3
RUHMKORFF (H.D.) 1803-1877	3
RUSSELL (Bertrand) 1872-1970	1
SAINTE-CLAIRE-DEVILLE (H.) 1818-1884	4
SALAZAR (E.R. de) ? - ?	2
SARASIN (E.) 1843-1891	3
SARCIA (?) fl. 1879	1
SAUERWALD (F.) 1794-1870	1
SCHÖNBEIN (C.F.) 1799-1868	24
SCHOTTE (?) ? - ?	1
SCHROEDER VAN DER KOLK (H.W.) ? - ?	1
SCHULZE (C.) ? - ?	3
SCHWOERER (E.) 1861-1923	3
SEGUIN AÎNÉ (M.) 1786-1875	7
SEREIX (R.A.) ? - ?	2
SERRIN (?) ? - ?	1
SMITS (A.) 1870-?	1
SOMMERFELD (A.) 1868-1951	3
SORET (J.L.) 1827-1890	13
STARK (J.) 1874-1957	1
STAS (J.S.) 1831-1891	1
STEGMANN (F.L.) 1813-1891	1
STUDER (B.) 1794-1887	2
TERPSTRA (J.) ca.1892?	1
THENARD (L.-J., Baron) 1777-1853	1
THILORIER (C.-St.A.) 1797-1852	3
TIMMERMANS (J.E.C.) 1885-	2
TRAMBUSTI (A.) ? - ?	2
TRAUBE (I.) 1860-1943	3
TROOST (L.-J.) 1825-1911	11
ULRICH (F.) fl. 1899	1
VAN DER WAALS (J.D.) 1837-1923	5
VEGARD (L.) 1880-	1

VIEWEG (F.)) ? - ? " Söhne)	7
VIOLLE (J.) 1841-1923	1
VOGT (W.) 1850-1919	2
VOLPICELLA (F.) ? - ?	1
VORLÄNDER (D.) 1867- ?	3
VRIESSLING (?) ? - ?	1
WAERTIJN (C.) fl. 1889	1
WALLICH (N.) 1786-1854	4
WARTMANN (E.F.) 1817-1886	6
WEBER (H.) ? - ?	1
WEBER (W.) 1804-1891	7
WEISS (C.-H.) 1893-	1
WESTGREN (A.F.) 1889-	1
WEYRAUCH (J.J. von) 1845- ?	5
WHITNEY (W.R.) 1868-1951	1
WIEDEMANN (G.) 1826-1899	27
WROBLEWSKI (L.F. von) 1845-1888	1
WULFF (G.) 1862-1928	2
YOUMANS (E.L.) 1821-1887	1
ZOCHER (H.) 1893-	1
ZÜRCHER (P.E.F.) 1853- ?	4