

**THE HISTORY OF THE TEACHING OF SCIENCE IN
SCOTTISH SCHOOLS**

D. J. S. Sutherland

**A Thesis Submitted for the Degree of PhD
at the
University of St Andrews**



1938

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THE HISTORY OF THE TEACHING OF SCIENCE
IN SCOTTISH SCHOOLS.

BEING A THESIS PRESENTED BY
D.J.S.SUTHERLAND, M.A., B.Sc.
TO THE UNIVERSITY OF ST.ANDREWS
IN APPLICATION FOR THE DEGREE OF Ph.D.



CERTIFICATE.

I certify that Douglas J.S. Sutherland has spent nine terms at Research Work carried through chiefly in London, Edinburgh, Dundee and Perth, that he has fulfilled the conditions of Ordinance No.16 (St. Andrews) and that he is qualified to submit the accompanying Thesis in application for the degree of Ph.D.

.....
9th June, 1938.

DECLARATION.

I hereby declare that the following Thesis is based on the results of research carried out by me; that the Thesis is my own composition; and that it has not previously been presented for a Higher Degree.

The Research was carried out in:-

- (a) London. Reading Room of British Museum.
Board of Education Library.
Chemical Society Library.
Public Record Office.
- (b) Edinburgh. National Library.
University Library.
Public Library.
Educational Institute of Scotland Library.
- (c) Glasgow. Mitchell Library.
- (d) Aberdeen. Public Library.
- (e) St. Andrews. University Library.
- (f) Dundee. University College Library.
Training College Library.
Public Library.
- (g) Perth. Perth and Kinross County Library.
Perth Museum.
- (h) Ayr. Town Clerk's Office.

24th. June, 1938.

CAREER.

I first matriculated in the University of St. Andrews in 1917, and followed a course leading to graduation in the Faculties of Arts and Science in 1922.

On 1st. October, 1935, I commenced the research, which is now being submitted as a Ph.D. Thesis.

I was appointed Assistant Science Master at Dumfries Academy in 1923, and Principal Teacher of Science at Caledonian Road School, Perth, in 1930, became a Member of the Science Committee of the Scottish Council for School Broadcasting, B.B.C., in 1936, a Member of the Central Science Committee of the Educational Institute of Scotland in 1935, and Convener of this committee in 1938.

24th. June, 1938.

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INTRODUCTION.

Although it was intended that the teaching of science in Scottish schools only should be considered in this work, it was found necessary for several reasons to introduce consideration of the teaching in Scottish universities also. The pioneers of the teaching of science in Scotland, the men who made it an actual part of Scottish education, were teachers in the universities, and an attempt has been made to show the gradual transition from Aristotelian beliefs to the experimental treatment of the subject.

In the early days of science, it was taught only in the universities, and it was there that the Scottish boy obtained the education which he would receive now at a secondary school, for the students then were mere boys. In consequence, university teaching at that time has been considered in considerable detail. As John Stuart Mill stated in his Rectorial address to the University of St. Andrews in 1867:-

"But schools of a still higher description have been, even in Scotland, so few and inadequate, that the Universities have had to perform largely the functions which ought to be performed by schools; receiving students at an early age and undertaking not only the work for which the schools should have prepared them, but much of the preparation itself. Every Scottish University is not a University only, but a High School, to supply the deficiency of other schools. -----

Youths come to the Scottish Universities ignorant and are there taught."

As science became a subject of instruction in burgh schools and academies, of which at least one was established as a rival to the universities, the teachers of science transferred from school to university, and from university to school, and their work has therefore been considered here in both these spheres. Later, as science became more firmly established in schools, and more specialised in universities, the paths of the school and the university diverged, so that less consideration of university teaching in more recent times is given in this work.

The contributions made by both university and school to scientific teaching in adult education have been considered, and the system of the Science and Art Department has been described in all its aspects, as there was little distinction made in it between the schoolboy and the adult.

The text books known to have been used in the teaching of science in Scotland have been traced, and the study of these, frequently with typical extracts illustrating the methods adopted, has shown the treatment and scope of the teaching of the subject. Unfortunately, few manuscript note books used in schools have been preserved, but sufficient remain to give an idea of the work done by the pupils, and these books have been utilised here.

Statistics serve to prove the share taken by science in the education of the youth of Scotland, while contemporary reports, official and otherwise, have been used to show the development of science teaching and the many phases through which it has passed.

This study covers a period of more than four centuries and ends with a reference to the changes ordained to take place within the next few years.

CHAPTER I.UNIVERSITIES BEFORE 1700.

The teaching of Science in Scotland has passed through many phases and has been carried on by many types of teacher, in three different languages, Latin, English and Gaelic, while throughout the centuries it has undergone a process of evolution. The youth of Scotland has received instruction in many surroundings, in cloister, in physic garden, in burgh school, and in earthen floored parochial schoolroom, as well as in modern laboratory. As the years have passed, attention has been focussed on the teaching in one centre after another, St. Andrews, Kinloss, Ayr, Perth, Dollar, Watten, and many other places, large and small.

Although Science, as we know it, is essentially modern, there existed in the Middle Ages a modicum of scientific knowledge, mainly a legacy from Greek philosophers, and some branches of Science were studied in mediæval places of learning. In the Fifteenth Century, Scotland does not appear to have been noteworthy for the attention paid to this branch of knowledge, and for the first mention of the teaching of Science in this country, we must turn to the University of St. Andrews, the oldest

Scottish university. The Chancellor from 1478 to 1496 was Archbishop Schevez,⁽¹⁾ whose fame as an astronomer (or perhaps more correctly an astrologer) extended throughout Europe, and it is probable that he encouraged the study of astronomy at St. Andrews. To this Chancellor was dedicated a booklet by a Jasper Laet on the "sentiments of the astronomers" regarding the solar eclipse in 1491, and Schevez is praised for having "brought from the darkness of obscurity into the light of day the mathematical sciences which through the negligence of the Scotch had become nearly forgotten."

Before the Reformation in Scotland, higher education was given not only in the universities, which were then in existence, St. Andrews, Glasgow, and Aberdeen⁽²⁾ (Kings' College), but in some of the monasteries. The Abbot of Kinloss, for instance, was fortunate in securing the services of Ferrerius, an Italian scholar, to impart knowledge in the Abbey of Kinloss. Some of the instruction dealt with scientific subjects, as we learn from the list of books used by Ferrerius, when he had been lecturing to the monks at Kinloss immediately prior to 1543. Among those which he records⁽³⁾ are:-

" Item, Sphaeram a Sacrobosco, Dialogum

(1) Votiva Tabella p.170

(2) Founded in 1411, 1453 and 1495 respectively.

(3) Records of Monastery of Kinloss, ed. J. Stuart. p.XIV.

primum Physicorum Tabri - - - - Item, libros quinque
Physicorum Aristotelis". This abbot, Robert Reid by name,
was keenly interested in education, and later, when Bishop
of Orkney, built at Kirkwall in 1558, a large college⁽¹⁾
"for instructing the youth of Orkney in Grammar, Philosophy
and Mathematics."

In the universities of the Middle Ages,⁽²⁾ the
curriculum consisted of the Trivium - Grammar, Logic, and
Rhetoric, and the Quadrivium - Arithmetic, Geometry, Music,
and Astronomy. These subjects were taught by the same
tutor or Regent, as he was termed, who carried the class of
students through the entire course. The Regent appointed
at King's College,⁽³⁾ Aberdeen in 1549 had to lecture in
the first year on logic, in the second year on physics and
natural philosophy with the treatise on the sphere, and in
the third year on arithmetic, geometry, cosmography and
moral philosophy.

Cosmography, it is stated,⁽⁴⁾ included references
to natural philosophy, natural history, astronomy,
astrology, hydrography, topography, chorography, navigation,

(1) J. Grant. Burgh Schools of Scotland. p.163

(2) Rashdall. Mediaeval Universities.

(3) R.S. Rait, Univ. of Aberdeen. p.88.

(4) Foster Watson. Beginnings of Modern Subjects. p.98.

geometry, and history, taking man and his dwelling place, as its complex theme.

The Reformation in Scotland, following John Knox's famous sermon at Perth in June 1559, had its effect on education and by the First Book of Discipline in 1560, ⁽¹⁾ the three colleges in St. Andrews were to be reorganised, and the curriculum for philosophy was to be three years in duration. To the second year were allotted Mathematics - Arithmetic and Geometry, Cosmography and Astronomy, and to the third year Natural Philosophy. ⁽²⁾

In the scheme of reform of St. Andrew's University, drawn up by George Buchanan in 1570, ⁽³⁾ students were to be eligible for the degree of Bachelor after two years study of Dialectic, Logic and Moral Philosophy. "After a further year and a half devoted to Metaphysics, Mathematics and Natural Philosophy, they were to be eligible for the Licentia. Within a certain period, generally not more than a year, of the dies licentia, the holder had to present himself for the degree of Master."

James Melville, in his diary, ⁽⁴⁾ states that, when a student at St. Andrews in 1574, "the fourt and last year of our course, quhilk was the 17 year of my age, and 18

(1) A. Grant. Univ. of Edinburgh. p.63.

(2) It was in 1563 that John Napier of Merchiston was a student at St. Salvator's College, St. Andrews.

(3) A. Morgan. Scottish University Studies. p.61.

(4) Jas. Melville's Diary. 1556-1601. (Bannatyne Club) p.22 & 38.

running, we lerned the buiks De Coelo and Mateors, also the Spher, more exactlie teachit be our awin Regent." In the same year, he refers to the course covered by his uncle, Andrew Melville, teaching in Glasgow University, thus:-

"From that he enterit to the Mathematicks, and teatched the Elements of Euclid, the Arithmetic and Geometrie of Ramus, the Geographie of Dyonisius, the Tables of Hunter, the Astrologie of Aratus - - - - from that to the Naturall Philosophie he teatched the buiks of the Physics, De Orta, De Coelo, etc. also of Platō and Fernelius". James Melville became a regent at Glasgow in 1575.

The "Erectio Regia" at Glasgow by James VI, in 1577, allotted ⁽¹⁾ to the Third Regent all the Physiology and Natural Philosophy of Aristotle, Geography, Astrology, and Universal Chronology. In the Bajan Year were studied Latin and Greek and in the Semi Year were Rhetoric, Arithmetic, and the Organon of Aristotle.

In Edinburgh, ⁽²⁾ from 1583 to 1628, the Regent of the Third or Bachelor Year, at the end of the session, gave a description of the Anatomy of the human body. The Regent of the Magistrand Year dealt with De Coelo of Aristotle, and De Sphera of Sacrobosco. Demonstrations of Practical Astronomy were given, then he dealt ⁽³⁾ with De Ortu, De

(1) A.Grant. Story of Univ. of Edinburgh p.86, and J.Coutts, Hist. of Univ. of Glasgow. p.66.

(2) A.Grant. Story of Univ. of Edinburgh. pp. 148-9.

(3) Alex.Bower. Hist. of Univ. of Edinburgh. p.91.

De Meteoris, the Meteorologica, De Anima and Hunteri Cosmographia.

The Foundation Charter of Marischal College, Aberdeen, in 1593, laid down ⁽¹⁾ the subjects of study, including Geography and Outlines of Astronomy. The Third Regent had to teach Aristotle's Organum Physicum, and the Principal was to "set forth all the rest of Physiology from the Greek text of Aristotle, to which he shall add a short explanation of Anatomy".

From these examples of the work done in the various Scottish universities, we conclude that up to 1600, the scientific subjects taught were principally those of mediaeval times, the Natural Philosophy contained in Aristotle's works, De Coelo, De Ortu, De Meteoris, with Aristotelian physiology, to which were added geography, anatomy, and practical astronomy, with the addition of that text book renowned in the Middle Ages, De Sphera by Johannes de Sacro Bosco, or John of Holywood, suggested by Veitch ⁽²⁾ to have been a Scotsman, and by Edgar ⁽³⁾ to have been born in Dumfries-shire and to have been a canon of Holywood there, ⁽⁴⁾ but generally reputed to be of Halifax,

(1) P. Anderson. Hist. of Univ. of Aberdeen. p.148

(2) John Veitch. Philosophy in the Scottish Univs., Mind. Vol.II. 1877.

(3) J. Edgar. Hist. of Early Scottish Educn. p.303.

(4) One Scotsman, however, who achieved fame, was Michael Scott, said to be born at Balwearie, near Kirkcaldy, about 1175, studied at Oxford & Paris, made astronomical calculations at Toledo, became astrologer to Frederick II, died 1234.

Yorkshire. He studied⁽¹⁾ at Oxford, then settled at Paris about 1230, taught mathematics and natural philosophy, and died in 1256 being buried in the Cloister Sodalium Mathu-
inalium, his astrolabe being placed on his tomb.

His book De Sphera Mundi was made known⁽²⁾ about 1256, and was studied not only in this country, but throughout Europe. Manuscript copies were very common, the first printed edition being published in 1472, another 24 editions before 1500, and about 40 more up to 1647. It was the most popular book in astronomy until 1496, when John Muller of Konigsberg (Regiomontanus) brought to light the writings of Ptolemy in Greek, but it remained in common use long after that date. Part of its popularity may be due to its brevity, as it consisted of only four chapters, of which the contents may be learnt from the book itself, as follows:-⁽³⁾

"Proemium Authoris.

Tractatum de Sphaera quatuor capitulis distinguimus. Dicturi primo compositionem Sphaerae, quid sit Sphaera, quid sit eius centrum, quid axis Sphaerae, quid sit polus mundi, quot sint Sphaerae, and quae sit forma mundi. In secundo de circulis ex quibus Sphaera materialis componitur, & illa supercoelestis (quae per istum imaginatur) componi intelligitur. In tertio de ortu & occasu signorum, & de diuersitate dierum & noctium, & de divisione climatum. In quarto de circulis & motibus Planetarum, & de causis

(1) D.E.Smith. Hist. of Maths. p.231.

(2) Foster Watson. Beginnings of Modern Subjects. p.356

(3) 1547 edtn. pub. Antwerp. No pagination.

eclisum".

We can obtain an idea of the physics taught in 1621 from the dissertations of the candidates at St. Salvator's College, St. Andrews. The subjects to be debated were printed and a copy preserved in the National Library is entitled "Positiones et Disputationes aliquot philosophicae quas deo auspice sub praesidio Roberti Baronii in publico philosophantium confessu, Adolescentes ex Salvatoriano Collegio hac vice cum laurea emittendi pro virili propugnabunt, Vigesimo Julii, 1621". Then follows a list of the 32 candidates, alphabetically arranged under their Christian names, e.g.

Alexander Fothringhamus

Alexander Montcreiffus

Andreas Myrtonus.

- There are 48 of the Assertiones Physicae, including,
4. Potentia est de essentia materiae in prima notione.
 13. Anima rationalis, qua talis, est natura.
 16. Motus in genere neque est forma fluens, neque fluxus formae.
 19. Non datur in rerum natura quantitas actu infinitis.
 20. Magnitudo Mathematicae considerata non minus est augmentabilis in infinitum quam numerus; at Physice considerata sic se non habet.
 23. Centrum mundi non est locus coeli.
 26. Tempus realiter differt a motu.

35. Probabile est orbes coelestes specie inter se distingui.

40. Nutritio & accretio differunt realiter & essentialiter."

These are just what might be expected from the text books of this period, mainly the works of Aristotle.

Further provision was made for education in Scotland by the foundation of the Town's College at Edinburgh in 1580, and the University of Fraserburgh in 1600. The latter was founded by Sir Alexander Fraser,⁽¹⁾ with Charles Ferme (or Fairholm), a Regent at Edinburgh, as Principal, but it vanished five years later. The buildings were utilised however, "when plague broke out in Aberdeen in 1647, and cut off one fifth of the population, the students of King's College were removed to Fraserburgh," while those of Marischal College went to Peterhead. Glasgow University⁽²⁾ carried on its work from 1645 to 1647 at Irvine, and after that, until 1648 at Paisley. There had been an outbreak of plague in Edinburgh in 1585 and again in 1604.⁽³⁾ In 1645-6 the University of Edinburgh met in the five aisles of the Great Kirk at Linlithgow owing to the plague.

At Aberdeen during session 1628-29⁽⁴⁾ and the twelve succeeding sessions, the professional system was in force, but in 1641, the regenting system recommenced. In the time of

(1) J.M.Bulloch, Hist. of Univ. of Aberdeen. pp. 77, 89, 118.

(2) J.Coutts. Hist. of Univ. of Glasgow. p.116

(3) A.Bower. Hist. of Univ. of Edinburgh. p.93.

(4) T.Crauford. Hist. of Univ. of Edinburgh. p.58.

R.S.Rait. The Universities of Aberdeen. p.119.

Principal Guild⁽¹⁾ (1640-1651) at King's College, the work of the third class was⁽²⁾ "The first fyve books of the generall phisicks, with some elements of geometrie. To the fourt classe, the bookes de Coelo, de Ortu et Interitu, de Anima, the Meteoris, Sphera Jo. de Sacro bosco with some beginnings of geography and insight in the globbs and mappes." At Marischal College,⁽³⁾ in 1647, the teaching included "to the fourt, the bookis de Coelo, de Generatione, the Meteors, de Anima, Joannis a Sacro ~~o~~ bosco on the Spheare, with some geometrie."

In 1648 at St. Andrews,⁽⁴⁾ the course of study included "the books De Coelo, the elements of astronomy and geography, the books De Ortu et Interitu, the Meteors, some part of the first, with the whole second and third books De Anima, and if so much time may be spared, some compend of anatomy." About 1643, an observatory was built at the instance of the first Professor of Mathematics. During the period we have been

(1) Ibidem p. 154.

(2) A.Bower. Hist. of Univ. of Edinburgh. p.245.

(3) R.S.Rait. The Universities of Aberdeen. p.284

(4) A.Bower. p.244.

considering, Scotland had been passing through troublous times. It was in 1637 that the new liturgy was read in the churches with disastrous results, on 28th. February 1638 the Covenant was signed at Greyfriars Church, Edinburgh, and in 1651 Cromwell's troops under General Monk had entered Aberdeen. Perhaps it was a sign of better times to come in the world of learning, when Robert Gordon of Straloch published through Bleau of Amsterdam, in 1654, Timothy Pont's Atlas of Scotland.

One of the hindrances to advance in education in Scotland was the system of rotation of Regents,⁽¹⁾ and this had been denounced by Melville and the more enlightened Reformers; in fact, Andrew Melville actually abolished it in the College of Glasgow and substituted Readers in each separate subject. Previously, each Regent had to be a walking encyclopaedia. Gradually, a professorial system was adopted in certain subjects. A Professor of Mathematics was appointed at Edinburgh in 1620, when one of the Regents of Philosophy,⁽²⁾ Mr. Andrew Young, took on these additional duties. He died in 1623, but the post was not filled until 1640, when the Rector of the High School, Mr. Thomas Crawford, was appointed. He acted also as a Regent of Philosophy, and died in 1662. Again there was a vacancy until 1674, when Mr. James Gregory, Professor of Mathematics at St. Andrews from 1668, became Professor.⁽³⁾ From his death in 1675, there was a vacancy

(1) A. Grant. Hist. of Univ. of Edinburgh. I. 147.

(2) A. Bower. II. pp. 336 & 341.

(3) A few days after becoming totally blind when showing the satellites of Jupiter through his telescope to his students. He invented the reflecting telescope when only 24 years of age.

until 1683 when David Gregory, his nephew, was appointed. It was he who was interested in the formation of a School of Navigation in Heriots' Hospital. He left in 1691 to become Professor of Astronomy at Oxford. In 1687, Newton's Principia was first published, and David Gregory first introduced the Newtonian Philosophy into Edinburgh University. He was succeeded by his brother Mr. James Gregory. We learn that, on the appointment of one of the Regents to be Professor of Mathematics in 1668, ⁽¹⁾ "as to the Professor of Mathematics, he was appointed to teach publicly Arithmetic, Geometry, Cosmography, Astronomy, Optics upon Tuesdays and Fridays, in the afternoon from 2 to 3 during the winter season, but after the beginning of March from 3 to 4, all the Regents with their respective scholars being present; at least the Hebdomadar ⁽²⁾ must be present with the scholars." According to a manuscript volume ⁽³⁾ of David Gregory's course, taken by Francis Pringle, and in the possession of Edinburgh University Library, his lectures included Geodesy, Optics, Dynamics and Mechanics. This appears to be very extensive, but Mathematics at this time was a very wide subject, as is shown by Wm. London's Catalogue of the Most Vendible Books, which was issued in 1658. ⁽⁴⁾ In it he

(1) A. Dalzel. Hist. of Univ. of Edinburgh p.199

(2) The Regent entrusted with certain supervisory duties for that week.

(3) A. Grant. Univ. of Edinburgh II. 296.

(4) Foster Watson. Beginnings of Modern Subjects. p.279

includes "Books of the Mathematicks, viz. Arithmatick, Geometry, Musick, Astronomy, Astrology, Dialling, Measuring of Land and Timber, Gageing Vessels, Navigation, Architecture." In some books, mention is made of Gnomonicks, i.e. dials, the making of sun dials being of considerable importance then.

Interest in natural science was also increasing, Sir Robert Sibbald and Dr. Andrew Balfour decided to establish a medicine garden in Edinburgh, ⁽¹⁾ and "obtained of John Brown, gardener of the north yards in the Abbey ane inclosure of some forty feet every way" i.e. ground belonging to Holyrood House, Mr. James Sutherland was put in charge and collected 800 or 900 plants from Scotland and abroad. ⁽²⁾ Various physicians helped financially. In 1674, the Town Council leased to Sutherland the garden of Trinity College, a low-lying site, east of what is now the North Bridge. King Charles II in 1682 commanded Sir Robert Sibbald to publish a "naturall history of the country, and the geographical

(1) Bower p.363. Grant p.218. Royal Botanic Garden, Edinburgh p.VI.

(2) e.g. a letter from Sutherland to Dr. Richard Richardson, North Brierley near Bradford, regarding exchange of plants, and dated Edinburgh, 20th.May, 1700, is preserved in the British Museum, (Stowe 747, folio 123).

description of the kingdome." (Prodromus Historiae Naturalis Scotiae). At this time the study of natural history was in its infancy and such knowledge as was possessed was not acquired in this country, but in France, where Sibbald had studied. Another example of his work in natural history is his description of whales which had been stranded on the shores of Scotland shortly before this work was published in 1692. (Phal-ainologia nova sive Observationes de Rarioribus quibusdam Balaenis in Scotiae Littus nuper ejectis.)

In 1676, the Town Council⁽¹⁾ awarded an annual salary of £20 to "James Sutherland, present Botanist - - - - considering the usefulness and necessity of encouragement of the art of Botany and planting of medicinal herbs they unite, annex, and adjoin the said Profession to the rest of the liberal sciences taught in the College, and recommend the Treasurer of the College to provide a convenient room in the College for keeping books and seeds relative to the said Profession." In 1695 the Town Council formally appointed him Professor of Botany in the College.

At Marischal College, Aberdeen in 1690,⁽²⁾ the prescribed courses show that third year students "are instructed in the General Physiologie and principles of Natural Philosophie conform to the old and new Philosophie. Ther is taught to them ane idea of all the hypotheses, both ancient and modern."

1) A. Grant. p.220

2) J.Kerr. Scottish Education. pp. 143 & 138

The fourth year students "are instructed in the knowledge of Metaphysicks and Speciall Physiologie, are informed how to explain all the particular phenomena of nature - - - are instructed in the principles of Astronomie - - - undergo ane tryall and examen of their proficiency in all the four years' courses befor the Principall and Masters, and thereafter doe emitt public theses, which they defend in ane solemn maner in presence of all the Doctors, Professors, and learned men of the University". As Kerr suggests, Physiology at that time probably meant Zoology or Nature Knowledge, and what is now termed Physics.

It was at the end of this century under consideration, in 1697 and 1698 that it was proposed ⁽¹⁾ to transfer the Colleges and University of St.Andrews to the city of Perth.

Considerable development had taken place during the Seventeenth Century. Melville's course at Glasgow exemplifies ⁽²⁾ this, as it is a mixture of the study of Aristotle with the revolt against him, as in the writings of Talaeus, and Ramus and Fernelius. The way had been paved by Roger Bacon, regarded by some as the only Scientist in mediaeval times in England, owing to his own original work, and by the statement in his Opus Magnus, about 1255: "There are two ways of knowing, viz: by means of argument, and by experiment."

(1) J.M.Anderson. City and University of St.Andrews. p.67.

(2) A. Grant. I. p.82.

Later, in 1536, ⁽¹⁾ Petrus Ramus (Pierre de la Ramee), in a thesis for his degree, was bold enough to express doubt about the truth of what Aristotle had written, and this caused a sensation among all European scholars. The idea of infallibility of method of Aristotle's Organum was therefore shattered by Humanists such as Ramus and Vives, and they prepared the way for the Novum Organum of Bacon in 1620 and for the Discours de la Methode by Descartes in 1637. The progress of natural philosophy has been expressed clearly by Bower, ⁽²⁾ thus:-

"From the earliest ages the attention of philosophers had been directed to the wonderful phenomena of nature: and they speedily set about composing systems; by which their knowledge might be arranged, and engaged in the agreeable pleasure of explaining, as they imagined, the causes and reasons of what they had observed in the natural world. - - - Aristotle had engaged in the same undertaking; and the authority he had obtained as a philosopher upon other subjects added greatly to the popularity of his system of physics. In the middle and dark ages, his works, or those supposed to be his, relative to this subject were the text books of the public professors. Whilst the discoveries and just reasoning of Copernicus, Kepler and Galileo were held in contempt,

(1) Foster Watson. Beginnings of Modern Subjects. pp. 98 & 213.

(2) A. Bower. Hist. of Univ. of Edinburgh. II. p.80

the peripatetic system still maintained its ascendancy. Lord Bacon, the contemporary of the two last mentioned philosophers was the first who pointed out the only just method of philosophising. He clearly shewed that Aristotle accommodated his physics to his logics, instead of doing as he ought to have done, giving such a kind of logic as would have been of real use in physics."

In 1683, George Sinclair, ⁽¹⁾ one of the first in Scotland to be interested in the study of physics, published a book entitled, "Natural Philosophy improven by New Experiments, touching the Mercurial Weather Glass, the Hygroscope, Eclipsis, Conjunctions of Saturn and Jupiter, by New Experiments touching the Pressure of Fluids, the Diving Bell and all the curiosities thereof, to which is added Some New Observations and Experiments lately made of several kinds, together with a true relation of an Evil Spirit, which troubled a Man's Family for many days, Lastly, There is a large Discourse anent Coal, Coal sinks, Dipps, Risings, and Streeks of Coal, Levels, Running of Mines, Gaes or Dykes, Damps and Wild Fire."

(1) Was Professor of Philosophy at Glasgow but in 1666 had to relinquish this post as he would not conform to Episcopacy. After the Revolution, or in 1689, he was reappointed, and later became Professor of Mathematics. He died in 1696. He used the newly invented diving bell in 1655 to explore the contents of the Spanish Armada ship Florida off Mull and was one of the first in Scotland to use the baroscope (i.e. barometer) to measure altitude and depth. In 1673 he supervised the laying of pipes to bring a water supply to Edinburgh.

The Hygroscope is described by him thus:- (1)

"The Awin or Beard of a Grain of Oats, secured within a round Box, whose inside is divided in 24 equal parts. There is affixed to the top of it a small slender Glass Index, which goes about with the Awin, as it is altered with the moisture or dryness of the Air. - - - - The Hulk or Hool of the Mouse-Pea (as we call it) or the Wild Vetch will make a Hygroscope, but it is somewhat dull and slow. - - - Though we cannot well know, for what use and end, the Oat Grain hath an Awin, and why it is twisted, yet we must remember, that God, and Nature never made any thing in vain".

In Hydrostatics he makes use of the terms, Pondus of the Water and Potentia of the Air. Quite interesting is his description of testing for "damp" in May 1669, when there was "need of a new sink on the East side of Tranent for winning of coals." A dog was tied in a bucket and lowered, then a chicken was lowered in the same way, to find whether there was gas present.

Although Sacrobosco's De Sphera ceased to be a text book used in the Scottish Universities, its subject matter was, to a large extent, the same as that of various text books written in English. One such example is a book published in 1688 by George Sinclair, formerly Professor of Philosophy in the College of Glasgow. The somewhat lengthy title is, "The Principles of Astronomy and Navigation, or,

A clear, short, yet full explanation of all circles of the celestial and terrestrial globes and of their uses, being the whole Doctrine of the Sphere, and Hypotheses to the Phenomena of the Primum Mobile, to which is added A Discovery of the Secrets of Nature which are found in the Mercurial Weather Glass etc., As also, A New Proposal for Buoying up a Ship of any Burden from the Bottom of the Sea."

In the preface it is explained that the Doctrine of the Sphere forms the very rudiments of Astronomy and Navigation and of many other mathematical sciences. The various chapters deal with Circles of the Sphere in general, Equinoctial, Zodiack, Colures, Horizon, Meridian, Tropicks, Polars, Other Circles of the Sphere, Zones, Rising and Setting of the Stars according to the Poets, Natural and Artificial Days, Years, and Divers Phenomena which are to be seen in the various positions of the Sphere.

The full title of the second part of the book is "Proteus bound with Chains, or, A Discovery of the Secrets of Nature which are found in the Mercurial Weather Glass, unfolding the Reasons and Causes, why before Fair Weather the Quicksilver Ascends, and before Foul Weather it Falls down and Descends, A Subject not hitherto treated of."

From time to time we find a tirade against some of the author's critics and various quotations from Scripture, but the following⁽¹⁾ is typical of most of the book:-

(1) p.10.

"The Natural Ballance is the Mercurial Weather-Glass, wherein the Mercury counterpoiseth the Air, and the Air the Mercury, both of them observing an equal Altitude, according to their natural weights: for since the Mercury is reckoned 14,000 times heavier than the Air, the pillar of the one must be 14,000 times lower than the other; and so both are of the same height, according to their Specifical weights. - - - - -

But how are these Vapors condensat and thickened together, and fall down in Rain? I shall do this, by a most evident and clear example. We cannot more fitly compare these Vapors, ascending and descending again in Rain, than to an Alembick, or Distillater. For these Fumes being carried upward within the Pot, and meeting with a cold Receptacle (for the Pipe descending goeth ordinarily thorow a Vessel full of cold Water) they are presently reduced to their first condition, and fall down in Liquor. So are the Vapors, which ascend from the Stomach to the cold Brain received and distilled."

After discussing the variations in the height of the mercury, the utility of the barometer is discussed, ⁽¹⁾
"Might the Weather Glass be useful in Ships? I answer, Yes; but the commotion of the Ship, (you say) renders it useless. I answer, it might be so suspended, that it might hang always perpendicular."

The final portion of his book about buoying up a

(1) p.31.

ship is quite amusing. An "ark" is formed of wood and the sunken ship is tied to iron rings on the ark thus forcing it below the surface. Pails of air, mouth down, are passed down and poured under the edge of the ark, so buoying up the sunken ship. This method, in fact, was a forerunner of the modern pontoon. He describes the various attempts made to salve a ship of the Spanish Armada from the ocean bed near Argyllshire.

The great improvement in the teaching of physics during the Seventeenth Century is shown by the statement of work professed by students of St. Salvator's College, St. Andrews, when candidates for degrees in 1690. The conclusion is as follows: "Specimána haec Philosophica, suprascripti adolescentes e Collego Sancti Salvatoris Nostri ad lauream Magisterialem aspirantes, in publico Universitatis S. Andreae auditorio ad diem Julii, favente Deo, sub praesidio Jacobi Gregorii, eruditorum examini subjicient."

There were 21 candidates and a list of their names is given. The work professed is quite different from that professed in 1621, and described already. The improvement is probably due to the able teaching of James Gregory⁽¹⁾ who later became Professor of Mathematics in the University of Edinburgh and the profession of work includes mention of gravity, the work of Newton and Huyghens, and the Copernican System.

(1) James Gregory, born 1666, died 1742, occupied the Chair of Philosophy at St. Andrews from 1685 to 1691, and the Chair of Mathematics at Edinburgh from 1691 to 1725. (Agnes G. Stewart, *The Academic Gregories*, p.84).

(1)
It has been stated that the progress in science was due to the rise of inductive philosophy which had altered the world of thought, and made necessary a complete alteration in the methods of teaching in Arts. While deductive methods of reasoning were customary, the student had to start with a basis of general principles then lead on to particulars. Accordingly, the course of study began with logic and ended with natural philosophy, and this was the custom in universities until the Seventeenth Century. When the value of particulars, however, was realised, and the extent of knowledge increased, it became essential to have specialist teachers, who would concentrate on one subject. In consequence, the system of regenting fell into decay and the professorial system began to take its place, thus marking the dawn of the modern period of academic education.

Progress. To 1700. Universities.

1. Teaching of Cosmography and Astronomy in addition to Aristotle's works and Sacrobosco's De Sphera.
2. Teaching of Natural Philosophy improved by inclusion of more modern books.
3. Andrew Melville's reforms: (i) books, (ii) readers instead of regents.
4. Medicine garden established in Edinburgh 1670.
5. Introduction of work of Newton and Huyghens.

(1) J.M.Bulloch. Hist. of Univ. of Aberdeen. p.146.

CHAPTER II.

UNIVERSITIES. 1701-1800.

The method of instruction by Regents was a great disadvantage in the teaching of scientific subjects, but gradually it ceased in the various universities.

At Edinburgh University the method of rotating Regents ceased in the Faculty of Arts in 1708,⁽¹⁾ and the work was thereafter carried on by specialist Professors. The curriculum at that date consisted of:-

- 1st. Year - Latin.
- 2nd. " - Greek.
- 3rd. " - Logic.
- 4th. " - Natural Philosophy.

There were also voluntary classes in Mathematics and Moral Philosophy.

Regenting was abolished at Glasgow in 1727, St. Andrews in 1747, Marischal College in 1753 and King's College in 1799.

The curriculum prescribed⁽²⁾ in 1753 at King's College, Aberdeen consisted of:-

- 1st. Year - Greek.
- 2nd. " - Greek, Mathematics, Natural History, Civil History, Geography.

(1) A. Grant. Hist. of Univ. of Edinburgh. I. 263.

(2) R.S. Rait. The Universities of Aberdeen. pp. 202 & 300.

- 3rd. Year - Mathematics, Natural Philosophy.
4th. " - Philosophy of the Human Mind and the
Sciences that depend upon it.

In the same year, the curriculum at Marischal College
was:-

- 1st. Year - Greek.
2nd. " - Greek, Latin, History (Natural and
Civil), "along with the elements of Geography
and Chronology, on which Civil History
depends", Elementary Mathematics.
3rd. Year - Mechanics, Hydrostatics, Pneumatics,
Optics, Astronomy, Magnetism, Electricity,
"and any others which further discoveries may
add,"⁽¹⁾ Criticism and Belles Lettres,
Mathematics.
4th. Year - Pneumatology, Natural Theology, Moral
Philosophy, Logic, Metaphysics.

(2)

* At Edinburgh, the Statuta Solemnia of 1767 required
medical students to attend classes in Chemistry and Botany
among other subjects, and there was no change made until
1825, when they were required to go through a three months
course in any two of Natural History, Practical Anatomy,
Medical Jurisprudence, etc.

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- (1) Expressed in the New Statistical Account p.1172 as, "and
such other branches not reducible to any of these, as either
are in some measure invented already, or may be invented
hereafter".
(2) A.Grant. I. p.330

NATURAL PHILOSOPHY.

The first Professor of Natural Philosophy at Edinburgh University was Robert Stewart who was appointed in 1708, and who later became Sir Robert Stewart of Coltness. At the same time this subject was evidently taught also by James Gregory, the Professor of Mathematics, and, when he resigned in 1725, by his successor Mr. McLaurin, who was appointed⁽¹⁾ on the recommendation of Sir Isaac Newton, after being Professor of Mathematics at Marischal College since the age of 19. He had carried⁽²⁾ out a regular course as a student at Glasgow, and obtained⁽³⁾ the degree of M.A. in his fifteenth year. His thesis had been on the power of gravity and he defended it in a public disputation, as was then the custom.

Professor Robert Stewart had been brought up in the Cartesian system and was slow in adopting the theories of Newton, but eventually he gave up the standpoint of Des Cartes. The number of students matriculated in Natural Philosophy⁽⁴⁾ in session 1710-11 was 50, and in the next four years the numbers were 50, 44, 43 and 10 respectively.

(1) A.Bower. Hist. of Univ. of Edinburgh. II. 84.

(2) A.Dalzel. Hist. of Univ. of Edinburgh. p.343.

(3) A.Bower. II. pp. 233 & 246.

(4) Dalzel. pp. 307-314. & 371.

In the Scots Magazine of August 1741, we find "A short account of the University of Edinburgh, the present professors in it, and the several parts of Learning taught by them", including:-

"Mr. Robert Stewart, Professor of Natural Philosophy.

He teaches first, Dr. John Keill's *Introductio ad veram Physicam* and the Mechanics from several other authors. After that he teaches Hydrostatics and Pneumatics from a manuscript of his own writing. Then he teaches Dr. David Gregory's Optics, with Sir Isaac Newton "Of Colours", describes the several parts of the Eye and their uses, with the phaenomena of Vision and describes all the different kinds of microscopes and telescopes. Then he teaches Astronomy from Dr. David Gregory's Astronomy, with some propositions of Sir Isaac Newton's Principia, and the Astronomical observations both ancient and modern. He likewise shews a set of Experiments, Mechanical, Hydrostatical, Pneumatical and Optical.

He expects that before any student enter his class, he had read Geometry etc. with Mr. McLaurin one year at least. He begins his lessons the 10th. of October and continues to the first of June.

Mr. Colin MacLaurin, F.R.S., Professor of Mathematics.
1st. College - Surveying, Fortification and other practical parts.

2nd. College - Dialling, Theory of Gunnery - - - concludes this college with the elements of Astronomy and Optics. He begins the third College with Perspective; then he treats more fully of the Astronomy and Optics. Afterwards he prelects on Sir Isaac Newton's Principia. - - - At a separate hour he begins a college of Experimental Philosophy, about the middle of December, which continues thrice every week till the beginning of April; and at proper hours of the night describes the constellations, and shews the planets by telescopes of various kinds."

From this notice in the Scots Magazine, there appears to have been considerable overlapping in the subject matter taught by the Professors of Mathematics and Natural Philosophy. In the 18th. century, however, the several branches of physical science were not then so clearly distinguished from each other as they are now, ⁽¹⁾ e.g. the subject of heat was treated as a branch of chemistry, while chemistry itself was usually treated as a mere addition to medicine, as we shall see when we consider that subject.

In 1741, McLaurin intimated ⁽²⁾ that he "proposes to give a course of experimental philosophy this summer, to begin the 22nd. of June, and all the money subscribed for shall be applied to build an observatory. He has purchased

(1) J.Mackintosh. Hist. of Civilisation in Scotland. IV. p.325

(2) Bower. p.251.

an orrery; and proposes to give some astronomical lectures upon it." There appeared an advertisement in the Caledonian Mercury of January 7, 1745, in which McLaurin stated that he would give a course of popular lectures in St. Mary's Chapel, Niddry's Wynd, Edinburgh, on Mondays, Wednesdays and Fridays, "for the behoof of Miss Gregory, daughter of the deceased James Gregory, his predecessor." The '45 however intervened, and McLaurin was occupied with the fortification of Edinburgh against the Jacobites. In consequence, he found it advisable for his own safety to flee to York, and he died in 1746, soon after his return in stormy weather, and partly as a result of a fall from his horse.

Robert Stewart was succeeded⁽¹⁾ as Professor of Natural Philosophy by John Stewart in 1742. The following occupant of the chair was Adam Ferguson, who was appointed in 1759.⁽²⁾ It is stated that he mastered Natural Philosophy in three months in order to be able to teach it. Previously he had served as chaplain of the Black Watch for nine years (1745-54) and had been present at the Battle of Fontenoy. He appears to have presented his subject in an attractive and popular manner and carried on his work satisfactorily. According to correspondence between Hume and Wm. Robertson the historian, which was acquired by the National Library in 1937, James Russell, an Edinburgh surgeon, was a rival for

1) A. Grant.

2) II. p.349 et seq.

this Chair and was better qualified for the post. When Ferguson transferred to the Chair of Moral Philosophy, where he later made his name renowned, Russell was appointed Professor of Natural Philosophy in 1773. His successor in 1774 was John Robison, who had been Professor of Mathematics to the Imperial Sea Cadet Corps of Nobles at Cronstadt, and had served with the British forces at Quebec, then was successor to Black as Lecturer in Chemistry at Glasgow from 1766 to 1769. His first course of lectures at Edinburgh in 1774-5 included the sciences of Mechanics, Hydrodynamics, Astronomy, Optics, Electricity and Magnetism, also the history of science, but his lectures appear to have been illustrated by very few experiments. It was he who published Black's Lectures on Chemistry in 1803 and his own Elements of Mechanical Philosophy in 1804.

(1)

Regenting was abolished at Glasgow in 1727, and Robert Dick was the regent who was selected as Professor of Natural Philosophy. Prior to this, apparatus and various instruments appear to have been used in teaching. About 1704, various physical instruments and pieces of apparatus were obtained, to be used by the regent who had charge of the class learning natural philosophy that session, and by the Professor of Mathematics. In 1712, it was ordered that all apparatus would be received according to inventory by the regent

(1) J.Coutts. Hist. of Univ. of Glasgow. p.195

responsible, and must be handed on in good condition to his successor. The regent had also to "stent" his students to maintain the instruments, but this levy was not regularly obtained. This stock of apparatus was increased in 1726, when £30 was spent on additional apparatus, and further increases were frequently recorded after that date. From 1730, the Professor appears to have had the help of a laboratory assistant or demonstrator in the conduct of the class of Experimental Philosophy, which met twice a week. He was a hammerman by trade, and was named Henry Drew. This was an evening class, and was merely a series of demonstrations,⁽¹⁾ not what we should call a practical class.

Robert Dick, M.D., succeeded his father in 1751, and four years later there appeared an advertisement that he "will begin a course of Philosophical Lectures and Experiments on Thursday, the 23rd. day of December at seven o'clock in the evening." It "will comprehend (1) Mechanics, Hydrostatics, Pneumatics and Optics as usual. To these will be added Astronomy and the Phenomena of the Celestial Bodies will be illustrated by an Orrery. (2) Specimens of a Philosophical History of Nature, that is, a methodical arrangement of Animals, Vegetables and Minerals, and an enquiry into their nature, properties and uses in Philosophy, Medicine and Arts." In addition, during April, he carried on an experimental

¹⁾ D.Murray. Memories of the Old College of Glasgow. p.111 et seq.

course at 4 p.m.

It was in the previous year that James Watt came to Glasgow. Professor Dick took an interest in him, and advised him to obtain workshop experience in London.

On the death of Dick in 1757, John Anderson was appointed his successor. Anderson continued, and did not, as has been suggested, originate the evening class in Experimental Philosophy, which continued at this hour until 1846, when Professor Wm. Thomson discontinued this practice. During the time of Anderson the class reached large dimensions, and in different rooms, he arranged experiments to be witnessed by detachments of the students. In 1768 he had two divisions of his class at separate hours, owing to its size, and in the following year he obtained increased accommodation. A large proportion of his students were townsfolk, including many mechanics, who did not take a complete university course. In 1794 he was assisted by Mr. McIlquham, who, in 1795, had changed his name to Meikleham, and left in the following year to become the first Rector of Ayr Academy. Anderson died in 1796, and was succeeded by James Brown, minister of Denino, whose work was done mostly by substitutes, until he relinquished the post in 1803 on receiving a pension.

From the Statistical Account ⁽²⁾ we learn that at Glasgow in 1799, "the lectures in Natural Philosophy comprehend

(1) J.Coutts p.385

(2) Stat. Acc. XXI. Append. p.39.

a general system of physics, and one calculated, in like manner, to keep pace with those leading improvements and discoveries, in that branch of science, by which the present age is so much distinguished. The theoretical and experimental parts make the subjects of two separate courses. The apparatus for conducting the latter is believed not to be inferior to any in Europe".

At St. Andrews in 1747, ⁽¹⁾ when regenting was abolished, on the union of the Colleges, Natural and Experimental Philosophy was created a separate Chair, although David Young ⁽²⁾ had really been Professor of Natural Philosophy since 1716.

There appears to have been an Experimental School at Marischal College, Aberdeen, ⁽³⁾ as, at various times between 1721 and 1756 mention is made of money gifted by the Magistral class when they left the university, the purpose being described as "scholæ experimentalis;" or "instrumentis experimentalibus," and once (1740), as "ad scientiam naturalem promovendam."

In 1726 there was an endeavour on the part of the Senatus to set "on foot a compleat class of Experimentall ⁽⁴⁾ Philosophy in the Marischal Colledge of Aberdeen." It was

(1) Votive Tabella. p.170

(2) University Calendar.

(3) P.J.Anderson. Hist. of the Univ. of Aberdeen. p.152.

(4) R.S.Rait. The Universities of Aberdeen. p.295.

hoped that they would obtain "a Compleat Sett of Instruments necessary in Astronomy, Mechanicks, Opticks, Chymistry, Hydrostaticks, and Anatomy - - - - the Best Books which treat of Natural and Experimental Philosophy and Models of the newest Machines in Husbandry". To obtain all these, it would have been necessary to raise the sum of two hundred guineas, but this project failed.

At King's College in 1753, ⁽¹⁾ the Tertian class was taught "experimental philosophy in its several branches, mechanics, hydrostatics, pneumatics, aerology, magnetism, electricity etc. The philosophical apparatus has lately been much improved by donations from ~~alumni~~; and by means of a considerable annual revenue now set apart for that purpose, promises to be soon placed upon the most respectable footing". The Professor of Mathematics at Marischal College, "in the first year includes principles of geography, and use of the globes, in the second year navigation (with spherical trigonometry, etc.)"

George Skene was the first professor in Marischal ⁽²⁾ College to teach Natural Philosophy as a separate subject in 1760, when he was only 19 years of age. His successor in 1775 was Patrick Copland, who was a good practical worker, and developed popular physics in the university. In 1785 he commenced evening lectures of a popular nature in mechanics, and similar courses were held frequently during the following thirty years.

(1) Statistical Account. XXI. Appendix pp. 85 & 120.

(2) P.J.Anderson. p.153.

ASTRONOMY.

(1)
In 1693 the University of Glasgow owned a telescope 8 feet long, and in 1756 the University received as a legacy from a former student, Alexander Macfarlane, who had been a merchant in Jamaica, his collection of astronomical instruments. For the cleaning and repair of these, £5 was paid to James Watt, who was a relative of Professor Muirhead. In the following year Watt, (b.1736. d.1819) became mathematical instrument maker to the University, with an apartment there, and a shop where he made mathematical, nautical and musical instruments. At the request of Professor Anderson, he repaired the model of the Newcomen engine, and in 1766 was paid £5.11/e for this work. He devised a separate condenser for the steam, and from this discovery was built up his fame. Until he left Glasgow in 1773, he kept his workshop at the University.

A Chair of Practical Astronomy was founded at Glasgow University in 1760 by George II, and the first Professor and Observer was Alexander Wilson, M.D., but his class was not compulsory for graduation. On his resignation in 1783, his son Patrick Wilson, LL.D., F.R.S., succeeded him, but resigned in 1799, then Wm. Meikleham was appointed. In 1799 the Professor of Mathematics, in the third course, included astronomy⁽²⁾, "to teach the application of the speculative

(1) D.Murray p.260-2. J.Coutts. 195, 229 & 264.

(2) Stat.Acc. XXI. Appendix pp.39 & 34.

doctrines to the various practical arts makes a very important object in this useful department of education."

At Edinburgh University, George III created a Chair of Practical Astronomy in 1785, ⁽¹⁾ and Robert Blair M.D. was ⁽²⁾ appointed, but as he had neither observatory nor instruments, he could not commence a class. He did not even attend university meetings. His death took place in 1828.

The Town Council of Aberdeen in 1780 gifted a sum of 20 guineas for purchasing instruments, ⁽³⁾ and in 1781 a site on Castle Hill for an observatory, which was soon built. When a powder magazine for the barracks was built in 1795, the observatory was transferred to Marischal College.

CHEMISTRY.

In 1713, Dr. James Crauford petitioned the Town Council of Edinburgh for permission to teach in the Town's College the subject of chemistry, ⁽⁴⁾ which he had studied under Boerhaave at Leyden. Crauford became Professor of Physic and Chemistry, and was also Professor of Hebrew. At the end of the previous

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- 1) A. Grant I. p.339.
 - 2) In 1620, the "great quadrant" left to the College by John Napier of Merchiston was put up "in an house built of timber" for the purpose" - Thomas Crauford, Hist. of Univ. of Edin., 1646.
 - 3) R. S. Rait p.304.
 - 4) A. Grant. I. p.296.
II. p.392

century, chemistry was a subject which was unpopular owing to the attacks upon the Iatro Chemists by Dr. Pitcairne, and it was looked upon with contempt. Crauford's successor was Andrew Plummer, who lectured from 1726 to 1753, mainly about the preparation and chemical properties of medicines. It is recorded in 1724 that ⁽¹⁾, "Messrs. Rutherford, St. Clare, Plummer and Innes, shewing that these gentlemen having purchased a house for a chemical ~~laboratory~~, adjoining to the college garden formerly let to Mr. George Preston - - - - ". Andrew ⁽²⁾ Plummer and John Innes had been appointed jointly in 1726 to the Chair of Medicine and Chemistry. Such were the beginnings of chemistry in Edinburgh and now let us turn our attention to the subject in Glasgow.

In 1747 it was proposed that "Chemie" should be taught ⁽³⁾ in Glasgow University and £52 was voted for the necessary equipment. The first lectures were given by John Carrick, a young surgeon, assistant to the Professor of Anatomy, and to Dr. Cullen in Botany and Materia Medica, but, owing to illness he had to give it up, and Dr. Cullen continued the course. Dr. Plummer in Edinburgh treated the subject as chemical pharmacy, but Cullen "dealt with the subject as a branch of knowledge whose phenomena and laws were to be investigated and ascertained, and which had relations to other sciences, as well

(1) A.Bower II. p.204 & 407

(2)

(3) J.Coutts p.489

as arts and industries, and yet formed a wide and to a great extent unexplored science by itself." In his lectures ⁽¹⁾ he adopted a division into the general and particular doctrines of Chemistry, ⁽²⁾ comprehending under the first the laws of combination and separation, and under the second the chemical history of bodies which he arranged under the five classes of salts, inflammables, waters, earths and metals. He added the various properties of vegetable and animal substances, and ended with an account of the application of chemistry to some of the more useful practical arts. In connection, mainly with the first division of his lectures, he dealt at some length with the sources, transmissions and effects of heat, and made a number of researches and calculations."

It is interesting to turn aside for a moment to consider this professor who established chemistry as a subject in Scottish education. He was born in 1710 at Hamilton, and after attending

1) Manuscript Notes on Dr. Wm. Cullen's Lectures on Chemistry, written by Dr. John White of Paisley are preserved in the Public Library, Paisley. These books were given by Dr. John White to Dr. John Thomson, author of "An Account of the Life, Lectures and Writings of William Cullen, M.D." 2 vols, 1832-59. A note by Dr. John Thomson reads:- "These notes must have been taken prior to 1758, since the diagrams Dr. Cullen began to give that year of some cases of double elective attraction are not mentioned."

Another volume preserved at Paisley consists of Manuscript Notes on Professor Hermann Boerhaave's Lectures on Chemistry, written in Latin by Geo. Forbes, sometime between 1710 and 1730.

2) J. Thomson. Life of Cullen. p.44.

3) J. Thomson. Life of Cullen. p.1. et seq.

Hamilton Grammar School and Glasgow University, became apprentice to Mr. John Paisley, a doctor in Glasgow, at that time the only method of training for the medical profession, then he acted as surgeon to a merchant ship trading to the West Indies, after which he attended the shop of an apothecary, Mr. Murray, in London, and returned to Scotland in 1731 or 1732. After some experience in a medical practice, he attended medical classes at Edinburgh (in 1734-6), where a regular school of medicine had been first established about 1720, with Chemistry taught by Dr. Plummer, and Botany by Dr. Alston. In 1736 he commenced business as a surgeon in Hamilton, where he was twice elected a bailie, and in 1740 he took the degree of Doctor of Medicine at Glasgow, to which he removed in 1744, then begun teaching medicine in addition to becoming one of the foremost physicians of the city. In 1746, he gave lectures on theory and practice of Physic, evidently for the first time in the University, and as the University had fitted up a laboratory, Dr. Cullen, in session 1747-8 gave lectures on Materia Medica and Botany, in addition to lectures on Physic. In 1750 he was appointed Regius Professor of Medicine, and, although the established mode of instruction was by lectures in the Latin tongue, he ventured to make a change by the use of English instead. He planned the establishment of a regular Medical School in the University of Glasgow, and as one of the essentials was a course of lectures in chemistry,

he proposed that Mr. John Carrick should give these. As we have seen, however, he had soon to take entire charge of the chemistry himself.

Shortly before this time, chemistry had begun to assume a systematic form, and to be recognised as constituting a distinct branch of natural science. ⁽¹⁾ "The great and tempting field of philosophical chemistry lay unexplored when it was entered on by Dr. Cullen, who first perceived its value." In addition, his "Essay on Bleaching" is evidence of his interest in the practical applications of chemistry.

In Glasgow, the number of students in his Materia Medica and Physic class was less than 20, but in Chemistry the number was much greater, as the lectures were designed not only for medical students, but for the students of the University in general, and for gentlemen engaged in any business connected with chemistry.

In 1755, Cullen was elected Professor of Chemistry at Edinburgh. As an introduction to his chemistry course there, he gave a set of seven lectures on the history of chemistry. In Edinburgh, his first course was attended by 17 students, ⁽²⁾ his second by 59, and the number increased until there were 145 on the roll.

As Sir Lyon Playfair has stated, ⁽³⁾ "Chemistry owes

(1) J. Thomson. Life of Cullen. pp.36 & 39. 74, 25, 91, 99.

(2) A. Grant. II. 394.

(3) Sir Lyon Playfair. A Century of Chemistry. p.10.

but little to Cullen as a discoverer, but much to him as a clear and philosophical expounder - - - - Like other chemists of his time, he seems to have accepted only four primary elements (fire, earth, air and water) as the basis of his prelections - - - - He, of course, taught the theory of phlogiston, which was then doubted by no one". The importance of Cullen's teaching has been expressed by Robison⁽¹⁾ thus, "Dr. Cullen quickly succeeded in taking chemistry out of the hands of the artists, the metallurgists and pharmacutists, and quickly exhibited it as a liberal science, the study of a gentleman."

When Dr.Cullen left Glasgow, he was succeeded in the Chair of Medicine by Dr. Robert Hamilton,⁽²⁾ but the latter died soon after his appointment, and Dr. Joseph Black, who had been appointed Professor of Anatomy and Botany and Lecturer in Chemistry in 1756, was appointed Professor of Medicine in 1757.⁽³⁾ It is interesting to notice that Black's lectures on chemistry and pharmacy at Glasgow commenced at 7 p.m.

Black had studied at Glasgow, first in Arts then in Medicine, and had been a pupil of Dr.Cullen, but completed his medical course at Edinburgh, owing to the better facilities

(1) J.Robison. Lectures of Joseph Black. p.XXII.

(2) J.Coutts. p.491.

(3) D.Murray. p.113.

there. At Edinburgh he studied caustic and mild alkalies and the production of "fixed air", later named "carbonic acid", which he had discovered. Some of his experiments involved quantitative as well as qualitative analysis. His inaugural thesis in 1757⁽¹⁾ was his dissertation for the degree of M.D. at Edinburgh in 1754, and was entitled "De humore Acido a cibus orto, et de Magnesia". Soon after this, was printed his paper on "Experiments on Magnesia, Quicklime and other alkaline substances."

The number of students in the Chemistry class at Glasgow increased rapidly,⁽²⁾ and it was necessary to provide increased accommodation in 1763. The existing laboratory was "too small and was damp and disagreeable, the floor never having been laid or the wall plastered, so that students would be deterred from attending if the lectures were delivered there. The lecturer had to teach in another room while the processes were going on in the laboratory."

While at Glasgow, Black discovered latent heat. He was handicapped by the lack of an ice house in the city, and waited until December 1761, before he carried out his experiment concerning latent heat when he found "145 degrees of heat in the water". In 1764 was performed his experiment on the latent heat of steam, and by timing he obtained a result of

(1) J. Robison. Lectures of Black. pp. IXIII XXXVI et seq.

(2) Coutts p. 492

810 degrees of heat, though, with better apparatus and the assistance of Watt, who had heard two courses of his lectures, he later obtained a value of not less than 850.

In 1766 he was appointed successor to Cullen at Edinburgh as Professor of Chemistry. ⁽¹⁾ In that year, 160 students at Edinburgh University had petitioned the Town Council to appoint Cullen as Professor of Practical Medicine, and Black as Professor of Chemistry. ⁽²⁾ It is said that most of the medical students at Glasgow followed Black to Edinburgh.

Black's successor at Glasgow from 1766 to 1774 was Dr. Robison who states that ⁽³⁾ "Dr. Black now formed the firm resolution of directing his whole study of the improvement of his scholars in the elementary knowledge of chemistry. He saw too many of them with a very scanty stock of previous learning. He had many from the workshop of the manufacturer, who had none at all, and he saw that the number of such hearers must increase with the increasing activity and prosperity of the country; and these appeared to him as by no means the least important part of his auditory. To engage the attention of such pupils, and to be perfectly understood by the most illiterate, was therefore considered by Dr. Black as his most sacred duty. Plain doctrines, therefore, taught in the

(1) J. Thomson. Life of Cullen. p.155.

(2) Coutts. p.494

(3) J. Robison. Lectures by Black. pp. LXIV. 11, 35, 106, 147, 160, 175, 227, 255, 292-7, 321, 343, 377, 405; also II pp.2, 222, 273.

plainest manner, must employ his chief study. That no help may be wanting, all must be illustrated by suitable experiments, by the exhibition of specimens, and the management of suitable processes."

Dr. Robison published the lectures delivered by Black, who termed them "Lectures on the Effects of Heat and Mixture", and by the study of these in detail, we obtain an idea of the state of chemistry, as it was understood at that time.

Black gives as definition, "Chemistry is the science or study of those effects and qualities of matter which are discovered by mixing bodies variously together, or applying them to one another with a view to mixture, or by exposing them to different degrees of heat alone, or in mixture with one another, in order to enlarge our knowledge of nature, and to promote the useful arts." He states "these general effects of heat are Expansion, Fluidity, Vapour, Ignition or Incandescence, and Inflammation or Combustion". In the section, "Of Fluidity", he explains "melting or congealing point", "erroneous supposition of Frigorific Matter", "Explanation of the effects of Frigorific Mixtures and Latent Heat," while in the section "Of Vapour", he mentions the terms Volatile and Fixed "bodies which are with greater difficulty converted into vapour, or require a higher temperature for this conversion". As a source of heat, a "clear fire of coaks" was used.

"When a fluid body is raised to its boiling point by

8/ the continual and copious application of heat, its particles suddenly attract to themselves a great quantity of heat, and by this combination, their mutual relation is so changed, that they no longer attract each other, separating to at least ten times their former distance, and would separate much further were they not compressed by the weight of the atmosphere, and in short, they now compose a fluid, elastic and expansive like air." He proceeds to discuss steam cookery, the Marquis of Worcester's steam engine (1660), Newcomen's engine, Watt's improvement, evaporation, distillation, sublimation, the fact that evaporation produces cold, and the Indian process for making ice.

He describes Inflammation as "the phenomenon familiarly known by the name of Burning or Combustion", and Deliquescence as "running per deliquirum" and Solvent as "menstruum", (as "running per deliquirum" and Solvent as "menstruum"), then he states:- "The salt which is produced by the mixture of vitriolic acid and the salt of hartshorn, is called vitriolic ammoniac. It has no smell. If this be dissolved in water, and we pour into it an equal quantity of soap-maker's ley, called by the chemists caustic alkali, we shall instantly be struck by the most pungent smell of the salt of hartshorn, greatly exceeding the usual pungency of that salt." Mention is then made of some operations which are often performed to promote the chemical action of bodies upon one another, such

as Digestion, Circulation, and Cohobation⁽¹⁾ and various pieces of chemical apparatus are described:-⁽²⁾ Phiala Chemica, Matrass or Bolthead - to promote the action of the ingredients on one another.

Circulating apparatus or Pelican.

Crucibles - The Hessian or blackhead and the Ipsian or Austrian.

Various terms are explained:-

Heating a vessel set in boiling water - balneum mariae.

" " " " " " sand - " arenae.

" " " " " " steam - " vaporis.

"The term Spirit is often applied to the fluids obtained by distillation, Sublimate or Flowers to matters condensed in sublimation, and the residue is the Residuum, or if solid and black is Caput Mortuum."

Distillation may be either Distillatio per ascensum or Distillatis ad latus.

Next he describes the various means of producing heat, furnaces and their chimneys, althantor or perpetual furnace, lamp furnace and blow pipe. The best fuel is stated to be charcoal, either of wood or fossil coal. Subsequently he deals with The Chemical History of Bodies, and the following statements are somewhat striking:-

"Atmospheric Air has been demonstrated to be a compound mass of more than two or three different kinds of matter - - - Water is also believed now to be a compound

(1) p.292. "Cohobation is merely the pouring back into the matrass the liquor which has been collected by properly condensing the vapours."

(2) Ibidem p.9 et seq.

body." He proceeds, "I do not pretend to determine what are the ultimate elements of bodies. I content myself with distinguishing and dividing the principal objects of chemistry into a number of classes, each of which comprehends substances that have a marked resemblance or analogy with one another in their chemical properties and differ from those comprehended in the other classes. - - - - In the arrangement which has prevailed for some time past among the chemists and which I have found to be the most suitable for our purpose, the objects of chemistry are distinguished into five classes - Salts, Earths, Inflammable Substances, Metals and Water."

He discusses Fossil Alkali, from sea-plants called Kali and Salfola, after the burning of which the ashes are called Soda, or Soude or Barilla Ashes, in the Edinburgh Pharmacopoeia called Soda, and in the London one, Natron. With such a variety of names, chemistry must have proved difficult to the student in those days. Mention is made of the Fossil Acids, namely Sulphuric or Vitriolic, Nitric and Muriatic. "Phials of coloured tinctures of vegetables are used, and slips of paper stained with these juices are called Test Papers. The tincture or dye called archil, cudbear or litmus is the most sensible to acids, - - - though Mr. Watt recommends the plant juice from red cabbage."

Black gives a table of neutral salts:-

	Vitriolic Acid	Nitrous Acid	Muriatic Acid	Acetous Acid	Tartarous Acid	Sedative Salt
Vegetable Alkali	Vitriolated Tartar	Nitre	Sal Digestivus	Sal Diureticus	Tart.Solub. & Tartar	
Fossil Alkali	Glauber's Salt	Cubical Nitre	Common Salt		Sal Rupellenfis. Rochelle Salt.	Borax
Volatile Alkali	Vitriolic Ammoniac	Nitrous Ammoniac	Sal Ammoniac	Spiritus Mindereri		

He proceeds to discuss Earths - Alkaline and Plastic Earths (Clays and Alum), Hard Strong Bodies (flints, gravels, etc.), Fusible Stones (feldt spar, porphyry, garnet, lavas), Flexible Stones (talc, mica, asbestos), and Precious Stones, - then the Inflammable Substances - Inflammable Air, Phosphorus, Sulphur, Charcoal, Spirits of Wine, Oils, and Bitumens, and finally he describes the preparation of Hepatic Gas, and Cahoutchouc, the manufacture of soap, and the properties of tar, pitch and pit coal.

Such was the chemistry studied by Black's pupils.

Lectures in chemistry at Glasgow were delivered from 1766 to 1769 by John Robison, then on his departure for Russia, Dr. Wm. Irvine continued the work until his death in 1787. From 1787 until 1791 Dr. Thomas Charles Hope was lecturer in chemistry, then Dr. Robt. Cleghorn, a busy physician became

lecturer, but was not keen on investigation, so there was no practical class, and the laboratory was not utilised.

(1) At Marischal College, Aberdeen, George French became Professor of Chemistry in 1793.

BOTANY.

At Edinburgh, in 1702, another Botanic Garden was established, (2) immediately adjacent to the College Buildings, so there were now three separate Physic or Botanic Gardens in Edinburgh, the Royal Garden, the Town's Garden and the College Garden, all under Sutherland's care. On his retiral in 1706, (3) James Sutherland was succeeded by Dr. Charles Preston in all his posts except that of King's Botanist, which he retained until 1714, with the oversight of the Royal Garden at Holyrood. In the Edinburgh Courant of May 16, 1707, it is stated that "Doctor Preston teaches his lessons of botany in the Physick Garden at Edinburgh, the months of May, June, July and August, 1707." Botany had scarcely reached the status of a science, (4) and was suitable more for demonstration than systematic teaching: probably the students were shown the plants, and told their names and medicinal properties, and whether they were indigenous or

(1) Aberdeen Univ. Calendar.

(2) Royal Botanic Garden, Edinburgh. p.VI

(3) Bower II. p.40

(4) A.Grant. II. pp. 379, 318, 382.

exotic. George Preston, by profession an apothecary and druggist, was the next occupant of the Chair from 1712 to 1738, when Dr. Charles Alston was appointed Professor. He had previously been appointed Regius Keeper of the Physic Garden at Holyrood, in a commission dated 30th. June, 1716, in succession to William Arthur, who, for a short time held the post after Sutherland. The College Garden was used for other purposes after 1724, as it had been neglected for some time. Dr. Alston had studied botany at Leyden under Hermann Boerhaave (1668-1738) the leading authority on this subject, and whose reputation attracted students from all parts of Europe. Dr. Alston established a regular course of lectures in botany, and continued this for the next 22 years.⁽¹⁾ In the Scots Magazine of 1741 we find that "in summer he teaches Botany in the Town's Physic Garden."

Dr. John Hope, Professor from 1761 to 1786, worked ceaselessly to introduce the Linnaean System into Scotland. He got the Physic Garden transferred in 1776 from its low swampy sunless position (now the site of Waverley Station) to a more suitable site beside Leith Walk. This garden also incorporated the old Holyrood garden, so that now there was only one Botanic Garden. He laid out a pond for aquatic plants, built hot-houses and arranged the plants according to the Linnaean system. In 1768, Materia Medica seems to have been separated from Botany, and was

(1) A MS. volume of lectures on botany delivered at the King's Physic Garden at Edinburgh in 1724 by Alston is preserved at the Royal Botanic Gardens, Edinburgh.

taught by a separate lecturer, Dr. Francis Home. Hope's successor was Daniel Rutherford, who held the post from 1786 until his death in 1819. While only in his 22nd. year, in 1772, he had discovered Nitrogen gas. He was an uncle of Sir Walter Scott.

A lectureship in Botany was established at Glasgow⁽¹⁾ and a physic garden commenced in 1704. John Marshall, a surgeon was appointed "to have the charge and oversight thereof", and to "instruct the scholars who shall apply to him for the study of botany." Until his death in 1719, he continued to teach this subject, and was styled Professor of Botany, to which post Queen Anne in 1708 granted an annual salary of £30. Until the beginning of the 19th. century, Glasgow University continued to possess a Botanic Garden within its own grounds. Dr. Thomas Brisbane was appointed in 1720 to a newly established Chair of Botany⁽²⁾ and Anatomy and on his death in 1742 he was succeeded by Dr. Robert Hamilton. A new Physic Garden was laid out in 1753 on the ground purchased by the College at the head of Castlepens Close. Dr. Cullen lectured on Botany and Materia Medica, as well as on Chemistry, from the summer of 1748. He delivered his botanical lectures in Latin, perhaps owing to the formidable array of technical terms used in that subject. "In his course on Botany, he gave an account of the

(1) J.Coutts. pp. 162 & 185

(2) D.Murray. Memories of the Old College of Glasgow. p.248

principles on which the different systems of Botany had been founded, sketched the system of Tournefort, then proceeded to explain that of Linnaeus, first published in 1735." In 1754, Hamilton and Cullen recommended that means should be taken to render the great garden more useful for the study of Botany, and that a good gardener should be procured. Hamilton died in 1755, and Dr. Joseph Black was appointed Professor of Anatomy and Botany in 1756, then Professor of Medicine in 1757, a post which he held until his resignation in 1773. Black was succeeded in the Chair of Anatomy and Botany by Thomas Hamilton in 1757.⁽¹⁾ Hamilton retired in 1781 and his son William who was appointed in his place and appears to have given a considerable share of his attention to botany. On his death in 1790, he was succeeded by James Jeffray, who later separated the teaching of anatomy and botany, so that in Glasgow, Dr. Thomas Brown began lecturing in Botany in 1799.⁽²⁾ "He had a collection of plants for the use of his students in a garden adjoining the former manse of the Rector of Carnwath."

In 1780 at Aberdeen, Rev. Robt. Memis, an Episcopal clergyman was given £20 to enable him to cultivate about $\frac{1}{4}$ acre as a botanical garden,⁽³⁾ but it was soon abandoned. He had taught botanical classes in Aberdeen during the previous two years. Later a class was taught by Alex. Smith. At

(1) J.Coutts. p.498.

(2) D.Murray. p.249.

(3) P.J.Anderson. pp. 196, 161 & 157.

Marischal College, Aberdeen, James Beattie, Professor of Civil and Natural History, (1788-1810) carried on a botanical class for about ten years, (1801-10). It was held during the College Vacation and he "accompanied his scholars to the fields." From 10 to 20 students attended this class.

NATURAL HISTORY.

A new Chair was created in 1767⁽¹⁾ at Edinburgh University when the King appointed Dr. Robert Ramsay as Regius Professor of Natural History and Keeper of the Museum of the University. He treated the post as a sinecure, and scarcely ever lectured. In 1779 he was succeeded by the minister of Moffat, Dr. John Walker, who was outstanding as a naturalist. He continued his parochial duties at Moffat, and later at Colinton, although his residence was in the Canongate. He gave lectures regularly and these were well attended, not only by students, but by lovers of nature of more mature age. His syllabus included Meteorology, Hydrography, Geology, Mineralogy, Botany and Zoology.

At Marischal College, Aberdeen, in 1752, it was decreed⁽²⁾ "that the second year of the course shall be spent in teaching geography, chronology, and an introduction to natural history,

(1) A. Grant. I. p.319-20.
II. 401

(2) P.J. Anderson. p.155 et seq.

commonly called 'special physics' and at the same time that the whole students of this year shall attend the lessons of the professor of mathematics." When regents were abolished in 1753, one of the new professorships was that of "Civil and Natural History", and Francis Skene was appointed.

Prof. Wm. Ogilvie, of the Chair of Humanity at King's College, who had been a student of Dr. Black at Glasgow appears to have taught ⁽¹⁾ Zoology from 1790 to 1805 and to have formed a collection of specimens. Among the changes at Marischal College in 1755, mentioned in the Statistical Account we find ⁽²⁾ that "Natural History - - - is comprehended under six heads: viz., meteorology, hydrology, geology, mineralogy, vegetation, zoology, the last whereof is introduced by a brief view of comparative anatomy and physiology." At King's College in the semi class, in mathematics, "the professor gives occasional lectures on geology and the meteorological branches of natural history." George Skene, son of Francis Skene, who had been Professor of Natural Philosophy since 1760 occupied the Chair of Civil and Natural History from 1775, and resigned in 1788 owing to his medical practice increasing. He was succeeded by James Beattie, Junr. Wm. Morgan, D.D. had been appointed, but died before occupying the Chair.

(1) His printed "Synopsis of Zoology" is preserved in the Public Library, Aberdeen.

(2) Stat.Acc. XXI. Append. p.119.

AGRICULTURE.

During this century, there was an awakened interest in agriculture in Scotland. A General Enclosure Act, passed by the Scots Parliament in 1695 had affected conditions. John Cockburn of Ormiston (died 1758) introduced the cultivation of turnips, rape and clover into Scotland. His letters to his gardener (1727-44), which were published in 1904 by the Scottish Historical Society contain evidence of the good work which he did. James Small, a young Scottish carpenter, who had worked in England, set up at Blackadder Mount in Berwickshire as a maker of ploughs. In 1780 he went to Carron and had plates cast, and the resulting Small's plough replaced the heavy Scots plough. Andrew Meikle of Houston Mill, East Lothian, built the first completely successful threshing machine. The Board of Agriculture was founded in 1793 by Sir John Sinclair. Excellent work was done by the Society of Improvers in the knowledge of Agriculture in Scotland in publishing advice on agricultural matters. This society was founded in 1723 and its Proceedings were published in 1743.

Dr. Cullen, Professor of Chemistry at Edinburgh, owned the estate of Ormiston-hill near East Calder and was ⁽¹⁾ "a great master in the scientific branches of husbandry; a consummate botanist. - - - - In the year 1758, ⁽²⁾ the Doctor

(1) Stat. Acc. IX. p.416.

(2) In J.Thomson - Life of Cullen, the date given is 1768.

after finishing his course of chymistry, delivered to a number of his particular friends and favourite pupils, nine lectures on the subject of agriculture. In these few lectures, he, for the first time, laid open the true principle concerning the nature of soils, and the operation of manures. These are discoveries entirely his own, and which have since been made known to the world by a variety of channels, though without any notification of the source from which they proceeded. The justness of these principles he demonstrated by his practice on the lands of Ormiston-hill, which, though naturally of an ungrateful soil, rendered worse by unmemorial bad management, he raised in a few years to a surprising degree of culture and fertility."

Dr.Cullen had had previous practical experience, ⁽¹⁾ for in 1752, he managed and improved the farm of Parkhead near Glasgow. His biographer, Dr.Thomson, states that, prior to 1749, he had introduced a few lectures on agriculture into his course of chemistry at Glasgow.

In 1788, an enlarged course of lectures on agriculture was delivered by Dr.Walker, Professor of Natural History at Edinburgh. ⁽²⁾ The teaching of agriculture, however, was put on a regular footing by the foundation in 1790 of a Chair in this subject, by Sir Wm. Johnstone Pulteney of Solway Bank. The

(1) J.Thomson. Life of Cullen. pp. 67 & 62.

(2) A.Grant. I. 346. II. 456.

Professor appointed was Andrew Coventry, M.D., who was recognised as an authority on agriculture. According to the foundation, he had to give "a set of Instructions or Lectures on the subject of Agriculture, respecting the nature of soils and manures; the modes of cultivation; the succession of crops; the construction of implements of husbandry; the manner of instituting experiments to ascertain the effect of any proposed practice in any soil or climate; and the best manner of introducing or training skilful labourers and country artificers, where these may be wanting". The new foundation was not popular with the Professor of Natural History, who had a somewhat wide scope in his subject, and now made a formal protest. In the new course were 140 lectures, and the roll of the class between 1790 and 1820 ranged from 30 to 78.

Towards the end of the century, Sir Wm. Fordyce endowed a lectureship at Aberdeen ⁽¹⁾, "on subjects tending to improve the agriculture and manufactures of Scotland, but the salary being life-rented by one of his relations, it has not as yet been carried into effect."

It is interesting to notice that the parish minister of Bothwell, in 1795, suggesting a course of education for schools includes "the principles of agriculture; the rudiments of which may be reduced to as simple a scale and be as easily

(1) Stat. Acc. XXI. Append. p.109. XVI. p.333.

taught as book-keeping." It was some fifty years, however, until this subject reached the schools.

The Professor of Natural Philosophy at St. Andrews from 1759 to 1772 was William Wilkie, ⁽¹⁾ who had previously been minister of the parish of Ratho. He gave attention to agriculture "as part of the subject of his Chair."

PROGRESS. 1701 - 1800. Universities.

1. Natural Philosophy compulsory for Arts degrees.
2. Chemistry and Botany compulsory for Medical students 1767.
3. System of Regenting abolished.
4. "Experimental school" of Natural Philosophy at Aberdeen,
1721 - 1756.
5. Evening demonstration class at Glasgow, 1730.
6. Chair of Practical Astronomy founded at Glasgow, 1760, and
at Edinburgh 1785.
7. Observatory built at Aberdeen, 1781.
8. Chemistry begun at Edinburgh, 1713, and at Glasgow 1747.
9. Chemistry established as a separate branch of science by
Cullen.
10. Improvement in teaching of chemistry by Black.
11. Establishment of better physic or botanic gardens.
12. Materia medica separated from botany. 1768.
13. Chair of Natural History founded at Edinburgh, 1767, and
Civil and Natural History at Aberdeen, 1753.
14. Lectures on agriculture by Cullen, 1758.
15. Chair of Agriculture founded at Edinburgh, 1790.

(1) *Votiva Tabella.* p.267
v

SCHOOLS BEFORE 1800

Education immediately prior to 1800 was carried on principally in two types of school, the burgh school and the parish school. As early as the 12th. century, the parish had definitely emerged, though it was not till 1696 that the "Parish School" in its full sense was established.⁽¹⁾ Education was completely under the care of the Church until 1496, when occurred the first intrusion of the State, by making education compulsory for the eldest sons of barons and freeholders of substance. From this date until 1696⁽²⁾ unsuccessful attempts were made to impose a "stent" on heritors for the support of the schools,⁽³⁾ e.g. in 1616, 1633 and 1646. The standard of instruction and the subjects of instruction varied from school to school, and we shall study how the new subjects were introduced gradually, and spread slowly throughout the country. In the grammar or burgh schools the teaching of geography was introduced in the beginning of the 18th. century and the elements of mathematical science began to be taught about the middle of that century. "In the latter half of the 18th. century in Glasgow,⁽⁴⁾ the children were usually sent to the English school at 5 or 6 years of age, at 7 or 8 they were sent to learn Latin in the Grammar School, and at 11 or 12 they were enrolled at the College". In the schools of other towns the age at which children entered was about the

(1) Acts of Parliament of Scotland. Vol.X p.63-4. II p.238

(2) Register of Privy Council of Scotland. X. p.671

(3) Acts of Parliament of Scotland. V. p.21 and VI. Part I. p.554

(4) McGregor. Hist. of Glasgow. p.361

same as that quoted.

It is interesting to notice that these burgh schools were in many cases the lineal descendants of the cathedral schools, abbey schools and collegiate schools.

The scientific subject which first found a place in Scottish school education was navigation. Towards the end of the seventeenth century there appears to have been a lack of instruction in navigation despite a certain demand for it, and considering the general state of education in Scotland this is not surprising.

(1) David Gregory, the gifted professor of Astronomy at Oxford, a friend of Sir Isaac Newton, and formerly Professor of Mathematics at Edinburgh, expressed great concern in a letter entitled "A Prospect for a Navigation and Writing School by the East India Company of Scotland", dated 10th. April, 1696, and outlined a scheme for a Navigation and Writing School, which, he suggested, might be established by the master and directors of the East India Company in Heriot's Hospital, Edinburgh, (2) which had been opened in 1659, after being commandeered by Oliver Cromwell as quarters for his sick and wounded soldiers after the Battle of Dunbar.

Professor Gregory wrote thus, "That by some contract to be made with the overseers of Heriot's hospital in Edinburgh, the Master and Directors of the said company doe procure rooms in the said Hospital for two schools, and

(1) Edin. Univ. Gregory Manuscripts Folio C. No.217

(2) A.Grant. Endowed Hospitals of Scotland.

lodgings for two masters - - - - 'twill be no hard matter to procure, considering the largeness of the edifice, the great quantity of empty room.

That there be seven of the most capable boys of that house yearly taken into the forementioned schools wher they are to continue three years to sixteen, to learn fair writing, drawing, arithmetick, and the mathematicall sciences, in so far as they are necessary for sea affairs; according to a scheme of education to be drawn up by skilfull persons.'

Seven boys were to be examined every year by the 'professor of Mathematicks of the colledge of Edinburgh,' and, if found suitable, to be "bound apprentices to the masters of the company's ships".

Unfortunately this scheme did not materialise, but at the end of the century, in Edinburgh and Glasgow were established Commercial Schools or Academies in which navigation was taught. ⁽¹⁾

In the Minutes of Ayr Town Council we find that on 17th. June 1721, Mr. Wm. Stewart, late master of the Grammar School of Kirkmichael was admitted Doctor of the Grammar School of Ayr, and it was decided "to Recommend to him to accomplish himself with all diligence in book-keeping and in arithmetic navigation geometry and other parts of the mathematical sciences that he may be in a capacity to teach and instruct the youth in the Town therein". In 1727, Wm. Stewart resigned this post,

(1) D.K.Wilson. Hist. of Mathl. Teaching in Scotland. p.27.

in order "to officiate as an ordinary officer of the Excise"; and on 14th. February, 1727 "the Magistrates and Council - - - - resolved and agree that for the better instruction of the Youth of the Burgh some person be elected to officiate as Doctor who is not only skilfull in the Greek and Latine tongues but also who write a fair hand and is able to teach writing arithmetick navigation and book-keeping." It was decided at the next meeting on 20th. February to increase the salary for this post by 50 merks, as payment for the teaching of these four additional subjects.

At Glasgow in 1695 the Town Council had appointed ⁽¹⁾ a teacher of navigation, and the minutes of the council for 1st. October, 1739 state that "Mr. James Stirling, since the decease of Mr. John Watt, has taught Arithmetic in its several branches, Book-keeping, Navigation, and the parts of practical Mathematics, useful and necessary to be taught in this city."

On the death of Bailie John Paterson in 1722, a legacy ⁽²⁾ of 7000 merks was left to Dumfries to pay "for teaching the children of burgesses - - - - in the arts of writing, arithmetic, book-keeping and navigation."

In the Foundation Statutes and Rules of Robert Gordon's ⁽³⁾ Hospital in Aberdeen, printed 1784, we find that such of the

(1) Town Council Minutes. 7th. Dec. 1695. Vol. XV. p. 84 and James Clelland. Hist. of High School of Glasgow. p. 8.
(2) Wm. McDowall. Hist. of Burgh of Dumfries. p. 505.
(3) Foundation Statutes. p. 67.

boys "as discover a Genius for it" shall be taught navigation. This Hospital, founded in 1731 by Robert Gordon's will, on the pattern of George Heriot's Hospital, resembles it also in this respect that its first occupants were not scholars but soldiers, those of the Duke of Cumberland on their way to and from Culloden, and the Hospital was not utilised for its proper purpose until 1750.

"Navigation, the science of sailing, was zealously taught in the grammar schools in the principal seaport towns from the beginning of the 18th. century," as Grant remarks in his History of the Burgh Schools, ⁽¹⁾ and it was one of the subjects taught at Dunbar 1721, Dundee 1735, Banff 1762, Rothesay 1762, Kinghorn 1763, Kirkcudbright 1765 and Wigtown 1781. The teaching of navigation seems to have been partly vocational, to judge from the information concerning the fees charged at Dunbar in 1727:-

"Mercator's sailing, to apprentices sailing from the burgh £1.1.-; navigation to sons of burgesses or apprentices having already a knowledge of arithmetic, vulgar and decimal fractions, use of the globes and maps 10/-; to boy from the grammar school 5/-; to such as attend the school otherwise, free." At the same time the quarterly fee for mathematics was 10/6.

The various stages of instruction at Kinghorn are shown by the following scale of fees:-

(1) J. Grant. pp. 401. 542.

"Navigation, first part, consisting of the Gregorian or new calendar constitution of lines 15/-, second part consisting of Mercator's middle latitude, parallel and current sailings 30/-, third part consisting of the projection of the sphere, etc. 40/-". English, at 1/6, was a less expensive subject of study.

The relative expense of various subjects can be judged from the table of fees charged at Elgin in 1793, Latin 5/-, Geography 10/6, Arithmetic 3/-, Euclid 10/6, Drawing, Fortification, Navigation 10/6, English 2/-. In 1826 the fees were, Latin 7/6, Arithmetic 4/-, Geography £1.1.-, Mathematics 10/-"

Navigation decreased in popularity as time went on and its value apparently decreased, as is instanced by the fees charged at Fortrose, viz. £1.1.- per session in 1791, 6/- in 1852 and 3/- in 1864. The usual fee charged in the days of the popularity of navigation was £1.1.- per course or per annum.

Scotland was not the only country in which navigation was a subject of instruction at this time. By means of ordinances, Louis XIV had encouraged the instruction of youths in navigation,⁽¹⁾ and this had been used as an argument in England, with its large merchant service, for the training of boys in navigation, and is "typical of the close and direct relations which may be traced between national life and new

(1) Foster Watson. Beginnings of the Teaching of Modern Subjects in England. pp. XXXIV and IV.

suggestions in education."

The cause of the teaching of navigation in Scottish schools appears to have been the rapid development of shipping, so it will be advantageous to study this briefly.

By a "Proclamation anent the Act for encouragement of navigation", ⁽¹⁾ the Privy Council, on 2nd. January 1662, and again on 4th. March 1662, ordered that all foreign commodities must be imported in native vessels and that all Scottish ships must be navigated and manned by Scotsmen.

In 1656, Mr. Thomas Tucker, a Commissioner for Customs and Excise, issued a report ⁽²⁾ on the ships belonging to the various Scottish ports. This shows that there were approxi-

(1) Register of Privy Council. Third Series. Vol.I. 1661-4 pp. 127 & 180

(2) Miscellany of Scottish Historical Society, 1881.

Port.	Ships	Tonnage	<u>100 Tons or over.</u>
Brunt Isle	7	164	
Kinghorne	1	50	
Kircaldy	12	300	100 (1)
Disert	4	84	
Wems	6	64	
<u>Leven</u>	<u>2</u>	<u>38</u>	
Ely	2	90	
St.Minas	1	36	
Petten Wems	2	180	100 (1)
<u>Ainster</u>	<u>10</u>	<u>207</u>	
Craill	1	90	
St.Androes	1	20	
<u>Southferry</u>	<u>1</u>	<u>18</u>	
Dundee	10	470	120 (1)
<u>Montrosse</u>	<u>12</u>	<u>90 Lasts</u>	
<u>Aberdeen</u>	<u>9</u>	<u>310</u>	
Frazerburgh	4	20	
<u>Peterhead</u>	<u>1</u>	<u>20</u>	
Inverness	1	10	
Garmouth	1	12	
Cromarty	1	16	
<u>Thursoe</u>	<u>2</u>	<u>30</u>	
<u>Glasgowe</u>	<u>12</u>	<u>497</u>	150, 140, 100 (3)
Renfrew	3-4	-	
Irwin	3-4	-	

mately 110 ships with a total tonnage of 2726 tons, and that only six ships were of 100 tons or over.

The Convention of Burghs drew up a "Register containeing the state and condition of every burgh within the kingdom of Scotland in the year 1692" and this ⁽¹⁾ shows for these burghs a total of 112 ships and barks with a tonnage of 5895 tons, including 17 ships of 100 tons and over.

The Articles of Union in 1707 included:-

"IV. That all the subjects of the United Kingdom of Great Britain shall, from and after the Union, have full Freedom and Intercourse of Trade and Navigation, to and from any Port or Place within the said United Kingdom, and the Dominions and Plantations thereunto belonging, and that there be a Communication of all other Rights, Privileges and Advantages, which do, or may belong to the Subjects of either Kingdom, except where it is otherwise agreed in these Articles".

This gave to Scotland the benefits of open trade, which with good government she had enjoyed under the Protectorate prior to the intolerance which prevailed during the reigns of Charles II and James VII, and caused her to wish "to participate in the extended commerce and colonial privileges of England or to have a separate commercial dominion of her own". ⁽²⁾ The

Union appears to have been followed by a period of depression

(1) <u>Burgh</u>	<u>Vessels</u>	<u>Tonnage</u>	<u>100 Tons or over.</u>
Leith	29	1702	150, 140, 130, 120, 100, 100 (6)
Dundee	33	1091	200, 100 (2)
Glasgow	15	1182	160, 150, 150 (3)
Kirkcaldy	14	1215	140, 140, 120, 110, 110, 100 (6)
Montrose	18	629	
Dumfries	3	76	

(2) Sir J.D. Marwick. The R. Clyde and Clyde Burghs. pp.126 & 158

and to have been ruinous to the seaport towns on the east coast of Scotland. Glasgow, however, commenced the American trade with "Whitehaven battons", but gradually from 1718 the Glasgow merchants became shipowners, and in 1735 the whole shipping of the Clyde consisted of 67 vessels with a tonnage of 5600 tons.

The earliest details of Scottish Customs dues are contained in the port ledgers, dating from 1742, preserved in the Register House, Edinburgh, but unfortunately these give only the customs duty collected and not the value of the exports and imports.

There are, however, preserved in the Public Records Office, London, Customs and Excise ledgers for Scotland, showing the value of exports and imports from 1755. It is believed that these have not hitherto been published, so a summary of these may be useful in showing the development of Scottish trade, which gave rise to the popularity of navigation as a subject of instruction in Scottish schools:-

<u>Year</u>	<u>Value of Imports</u>	<u>Value of Exports</u>
1755	£465,411	£535,576
1756	480,424	626,048
1757	619,835	828,576
1758	659,165	831,257
1759	605,887	940,804
1760	850,792	1,086,205
1761	748,639	1,165,722

<u>Year</u>	<u>Value of Imports</u>	<u>Value of Exports</u>
1762	708,925	998,165
1763	---	---
1764	886,352	1,243,927
1765	922,401	1,180,867
1766	980,989	1,163,704
1767	1,023,197	1,245,490
1768	1,236,648	1,502,149
1769	---	---
1770	1,213,360	1,727,917
1771	1,386,329	1,857,334
1772	1,210,263	1,560,755
1773	1,115,802	1,612,177
1774	1,202,276	1,372,142
1775	1,267,388	1,123,998
1776	746,680	1,025,972
1777	802,253	837,642
1778	740,654	702,820
1789	774,772	837,273
1780	902,724	1,002,039
1781	803,870	763,109
1782	809,021	653,708

James Paterson, Mathematician, as he describes himself, though apparently an instrument maker, published in 1685 a book entitled The Scots Arithmetician, or Arithmetick in all

its parts." Of interest to us is a list of the densities of various substances in Scottish weights, viz:-⁽¹⁾

"A Table shewing the weight of a solid inch of any of these Mettals following in Scottish weight:

	ow.	dr.	gr.	ow.	grts.
Gold	10	00	00	10	'00
Quicksilver	8	01	21	08	'10
Lead	6	04	17	06	'28
Silver	5	09	27	05	'61
Coper (sic)	4	14	08	04	'89."

The units used here are Troy or Dutch weight,⁽²⁾ where 1 stone = 16 pounds, 1 pound = 16 ounces, 1 ounce = 16 drops, 1 drop = 36 grams, and 1 pound = 17.391885 oz. avoirdupois. In the second table, the weights are expressed as ounces and hundredths thereof.⁽³⁾

Included in the book is the following advertisement by the author, and it shows the instruments then in use:-

"Those who desire any Mathematical Instruments, as Cross-staffs, Quadrants, Scales, Spiral lines, Dials, Uncels for weighing money, or the like, portable Ink, Sea Compasses made or drest, or any Mathemetical or Sea Books, Edinburgh, 13 May, 1685, at the head of the Cowgate, in the sign of the Cross-staff and Quadrant. James Paterson."

(1) p.141.

(2) J.M.Henderson. Scottish Reckonings of Time, Money, Weights and Measures.

(3) D.K.Wilson. Hist. of Mathematical Teaching. p.28.

Mr. Andrew Cornfute, Rector of Perth Grammar School, in 1752 taught "the knowledge of the celestial and terrestrial globes" which with maps were supplied by the Town Council. Some years later a telescope costing three guineas was purchased for the school.

In 1740, Alexander Wright, M.A., Writing Master and Accomptant at Aberdeen published "A Treatise of Practical Arithmetic both Integral and Fractional with The Mensuration of all sorts of Bodies both Superficially and Solidly. The whole after a new method Accommodated to the Capacity of Beginners." (1)

The following shows the treatment of the subject:-

"Of Mensuration of Superficies and Solids.

Sect.I. Of Superficies.

Prop.L. Having the Diameter of a Circle, to find the Circumference.

RULE. The Diameter of a Circle, being 1, the Circumference is 3.1416 fere, and all Circles being to one another as their Diameters, therefore, as 1:3.1416 so is the Diameter of any Circle to its Circumference.

Exa. What is the Periphery or Circumference of a Circle, whose Diameter is 15 (Inches, Feet, Yards, etc.)

1 : 3.1416 :: 15 : 47.124 Circumference."

The introduction of navigation marked a step in the real broadening of the curriculum in grammar schools. The subjects had usually been limited to the classics,⁽¹⁾ though in some cases English was included, and arithmetic was now finding a place, accompanied by mathematics and navigation.

In a number of burghs, the portals of the grammar school still remained closed to such new subjects, and these were taught in a new Commercial, Writing, or Arithmetic School, as in Dumfries (1723), Aberdeen (1747), Banff (1762), and Paisley (1781). Where English was not included in the curriculum of the Grammar School, it was frequently the principal subject of a third type of school,⁽²⁾ the English School, as in Elgin (where it was a relic of the old Sang School), and in Stirling⁽³⁾ (1740).

There was a general desire for an extension of the school curriculum, and the inclusion of various practical subjects. The Industrial Revolution in Scotland had commenced, and its influence was being felt in education. The pioneer in this progress in education was John Mair, Master of the Grammar School at Ayr. From the Town Council Minutes of Ayr, we find that in 1727, there were two candidates for the post of Doctor of the burgh school. Usually the term Doctor was

(1) H.F.Morland Simpson. Bon Accord. p.255.

(2) J.Strong. Hist. of Secondary Educn. in Scotland. p.165

(3) J.Lascelles Graham. Old Boys. p.33

applied to the master's assistant, but evidently there was only one teacher in the school at Ayr. John Mair⁽¹⁾ and John Hall were the two candidates, and they were students at St. Andrews and Edinburgh respectively. On 20th. June, after an examination lasting three days, Mr. Hall was preferred for the post. On 20th. November, it was intimated that Hall had become "Governor to Mr. Charles Cathcart, son to the Honourable Collonell Charles Cathcart" and had not taken up the post of Doctor. In consequence application was made by Mair, who stated that his writing had improved since his examination in June. A week later Mair's request was granted and he was appointed Doctor of the grammar school, at a salary of 200 merks, to teach arithmetic, book-keeping and navigation, in addition to the classics.

The decision to broaden the course at Ayr was due to Mair, and as this was one of the most important steps in the teaching of science in Scotland, we shall study Mair's own words, as they are recorded in that old leather bound minute book, preserved in the Town House at Ayr, one of a long row of such books which trace the history of the burgh throughout the centuries. When the Town Council met on 18th. November, 1746,

"Mr. John Mair gave in a representation shewing that whereas the magrats. for some time past had the Settlement of

(1) Mair matriculated as a student at St. Salvator's College, St. Andrews, in February 1723, and graduated as Master of Arts in May 1726.

the Schools of this Burgh under Consideration and have had severall Conferences with him on the Subject he now at their desire gives this brief representation of the result of their deliberations on that head and of the method that appears to them most proper for promoting the purposes of Education, that is, for Training up Youth to the Knowledge of Literature and preparing them for Business in the most Expedition and Effectual way possible which is as follows. It is proposed that for this purpose there be three Masters who are to be employed in the following manner Vizt. One of them is wholly to be taken up in Teaching to read English and that According to the newest and most Approved method The Business of another is to Teach Arithmetic, Bookkeeping, Geography, Navigation, Surveying, Euclids, Elements, Algebra with other Mathematicall Sciences and some parts of Natural Phylosophy - - - - -
The School being Settled on this footing will be attended with Severall advantages which otherways it Could not possibly have had. It will now be Converted into a Sort of Academy where Almost Every Sort of the more Usefull kinds of Literature will be taught and the want of College Education will in a great measure be Supplied to Boys whose parents Cannot well afford to maintain them at Universitys - - - - -

Signed. John Mair."

Which being read in presence of the Magrats and Council and Considered by them They Unanimously Resolve and Agree that

the said Mr. John Mair be and is hereby Elected and Chosen Rector and First Master of the Grammar School of Ayr and teacher of Arithmetick, Bookeeping and other Sciences."

His salary was 400 merks, while Archibald Wallace was appointed master of Latin at a salary of 200 merks.

To Ayr therefore belongs the credit of having the first school in which was taught one of the present-day school science subjects - physics, or natural philosophy as it was then called, and as it is still termed in the Scottish universities.

That this subject was actually taught at Ayr is shown by the following minute of 6th. June, 1750:-

"The Magistrates report that at visiting the schools the Thirty-first of May last when there were severall gentlemen both in Town and Country with some ministers when the schollars both in Latine and English Schools with the students of Mathematicks Geography and natural Philosophy were examined and performed very well to the satisfaction of all present."

The next stage in the progress of extending the curriculum was reached at Perth, when the Town Council, on 24th. September 1760:-

"considering that it would be of great utility to the youth to have an academy for literature and science established in Perth, recommend an inquiry to be made on the footing of academies in other places."

A memorial was prepared by Rev. James Bonnar, minister of St. John's Church, Perth, and presented to the Town Council.

In this memorial he stated:-

"In times not long past, all learning was made to consist in the grammatical knowledge of dead languages and skill in metaphysical subtilities, while what had an immediate reference to life and practice was despised.

But Providence has cast our lot in happier times, when things begin to be valued according to their use, - - - - - although our different universities are at this time filled with men of distinguished abilities, yet both the time necessary for completing a course of education there, and the vast expense of such attendance, must prove an insurmountable bar in the way of the greater part who have inclination and capacity for these studies. The people of England have been so fully convinced of this, that we find private academies established almost in every town, where not only the languages, but these sciences which are of the greatest use in life, are taught in a compendious and practical manner.

The example has not been sufficiently attended to in Scotland, where scarce any institution of that kind is to be found, although the advantage of it must appear from the following scheme of education, which is imagined might be easily executed in the space of two years.

First Year.

- I. A short view of natural history in its different parts, viz. the constitution of the material world, the nature

and property of the elements, and vegetable, mineral and animal economy, as a proper introduction is well calculated to fix the attention and awaken the curiosity of young people, being all illustrated by experiments.

- - - - -

V. Practical geometry in its different parts, such as mensuration, surveying, dialing etc. in theory and practice.

Second Year.

I. The business of this year might be very properly introduced with some lectures upon the history of philosophy and the rise and progress of the arts and sciences.

II. A course of natural philosophy should follow, or practical mathematics, illustrated by experiments on the mechanic powers, and their applications and uses in life.

- - - - -

N.B. All the teaching in the Academy, and exercises ought to be in the English language."

This scheme was adopted ⁽¹⁾ with only slight alterations and by April 1762, accommodation suitable for the purpose had been provided in the "two storeys above the Corn Mercatt". Two masters were appointed, Dr. Tait and Mr. John Mair, who was experienced in similar work at Ayr Grammar School, as we have already seen. The Town Council specified the subject matter to be taught by each master.

(1) E.Smart. Hist. of Perth Academy. p.80.

Mr. Mair's scheme included "a course of Natural Philosophy, illustrated by experiment" and mathematics. Dr. Tait was to include, "1. A short history of Philosophy and the rise and progress of Arts and Sciences; 2. A course of Natural History, in which he will give an idea of Botany and the Animal Economy."

The cost of providing instruments for illustrating Natural History and Natural Philosophy was met by public subscription, and instruction in these subjects was commenced.

(1)
At Ayr, John Mair was succeeded in 1761 by Alexander Paterson as "teacher of Mathematics and Rector of the Grammar School". The Town Council also fixed the various fees, including "for teaching navigation, one guinea, for course of Natural Philosophy comprehending the Doctrine of Attraction, Gravitation, Congress of Bodies, Mechanick powers, Pendulums, &c., Hydrostaticks, Pneumaticks, Opticks and Astronomy, with the several Experiments, Two guineas." This is the first syllabus of the physics taught in a Scottish school. Unfortunately none of the note books used at Ayr in these early days of the subject have been preserved. Evidently there were instruments used in the teaching at Ayr, for in the Town Council Minutes of 11th. June, 1766 we find:- "Magistrates and Council resolve and agree Statue and Ordain that the Schools of this Burgh be visited and publickly examined annually on the

(1) Town Council Minutes. 7th. July, 1761.

Second Thursday of June, and that the magistrates and Dean of Gild inspect yearly on that Day the publick Library and Mathematical Instruments."

At Perth, Dr. Tait resigned after two sessions, and in 1769, John Mair died. His successor, Robert Hamilton, worthily maintained the scientific reputation of the school, and in 1775 received the degree of LL.D. from the University of Edinburgh. In 1779 he left Perth to become Professor of Natural Philosophy in Marischal College, Aberdeen. During his rectorship, some expensive apparatus was purchased, including an air pump and a set of globes.

At Ayr, in 1773, ⁽¹⁾ payment was made of an account given in by Mr. Geo. Douglas, teacher of Mathematics in Ayr, for $18/10\frac{3}{4}$, the cost of "a crystal receiver to the air pump and tubes for mathematical demonstrations," and in 1776 an electorising machine was purchased.

Mr. Alex. Gibson, teacher of Mathematics at Dunbar was elected Rector at Perth in 1779, ⁽²⁾ and he purchased scientific apparatus including an orrery at a cost of £26.5., an electrical machine, a set of models of the mechanical powers, a universal microscope, a solar microscope, concave and convex mirrors, and new globes. He retired in 1809.

(1) Town Council Minutes. 22nd. Sept. 1773.

(2) E. Smart. Hist. of Perth Academy. p.85.

(1)

The next burgh to establish an academy was Banff, where in 1786 the public schools were converted into an academy, at which, in 1797, there were 180 scholars.

In 1786, it was decided ⁽²⁾ to establish an academy in Dundee, and the somewhat ambitious course which was advertised, consisted of:-

- 1st. Class - Arithmetic.
- 2nd. " - Book-keeping.
- 3rd. -" - 1st. Mathematics class, comprehending the Elements of Euclid, Plain Trigonometry, Practical Geometry, containing the Elements of Mensuration, Surveying and Gauging.
- 4th. " 2nd. Mathematics class, comprehending Algebra, Conic sections, Spherical Trigonometry, Fluxions and Geography.
- 5th. " Navigation.
- 6th. " Natural Philosophy and Astronomy.
- 7th. " Drawing, Perspective.
- 8th. " French.

In the following year, a meeting was held at Inverness, ⁽³⁾ to consider proposals for an academy there. The funds and property of the existing Grammar School were transferred to the new academy. The masters were to teach the following

(1) Stat. Acc. XX. p.361.

(2) J.Grant. Hist. of Burgh Schools of Scotland. p.119.

(3) Transactions Inverness Scientific Socy. Vol.IX. E.M.Barron. p.258. & p.299. and Stat.Acc. IX. p.619

subjects:-

4th. Class - Euclid's' Plane and Spherical Trigonometry, Mensuration of Solids and Surfaces in all its parts; Geography, with the use of the Globes; Navigation, with Lunar Observations; Architecture, Naval, Civil and Military; Practical Gunnery; Fortification; Perspective and Drawing.

5th. Class - Being the Rector's class - Natural and Civil History, Natural Philosophy, Chemistry and Astronomy.

The hours were 7-9 a.m., 10-12, 3-6 p.m. from April 1 to October 1.
and 9-12 and 2-4 " October 1 to April 1.
for the first four classes, while in the fifth class the work was from 11-1 and 3-4 in winter, with an additional hour 8-9 a.m. in summer.

Academies were established in smaller burghs also, and in 1791 an academy was established at Fortrose.⁽¹⁾ Here, the rector did not teach the scientific subjects, as was done in most academies, but languages, geography and history, while the second master taught mathematics, arithmetic, drawing and book-keeping, the elements of Euclid, algebra, navigation, land surveying and the elements of chemistry and natural philosophy. The third master taught the more elementary work.

At Salton, about this time,⁽²⁾ Mr. Andrew Fletcher had

(1) J. Grant. p.121.

(2) Stat. Acc. X. p.256. XII. p.385

founded two academies, one for boys and the other for girls, with accommodation for boarders. The instruction included "music, mathematics, natural philosophy and astronomy, for which proper apparatus was procured." Unfortunately, after several very successful sessions, these academies fell into disuse.

It is interesting to learn the opinion expressed concerning the grammar school at Nairn. "Every branch of education, which now makes such a noise at the academies, is taught at Nairn, in perfection." This was one of the many burgh schools where boarders were received.

In most cases, subscriptions were necessary before academies could be established, and in 1794 this method was adopted at Ayr.⁽¹⁾ It was decided by the subscribers in 1795, "that the business of the Rector should be to teach Arithmetic, Book-keeping, Mathematics, and all the various practical branches of Science depending thereon, Natural Philosophy and Astronomy." In 1796, the Rector appointed was Mr. Wm. Meikleham, who had lately had the charge of Professor Anderson's class at Glasgow. There is an interesting point in a letter concerning his duties - "To do the same as Mr. Mair had taught." Mr. Mair must have been very highly respected in Ayr to be remembered after so many years, because he had left Ayr to become the first Rector of Perth Academy in 1761, over thirty

(1) D.Patrick. Air Academy and Burgh Schule. pp.51 et seq. & 103

years prior to this. Mr. Meikleham was authorised to purchase instruments in London, including an orrery and a sphere, and in consequence £300 was remitted to him for his purpose. In 1797 was made the following statement, "The value of the Mathematical and Philosophical Apparatus of the best and most useful kinds, already procured amounts to at least Six Hundred Pounds". In 1798, the school hours were 7-1, 2-4, 5-6, "whilst Natural Philosophy, which as we saw by the Prospectus included Astronomy, was pursued by its votaries in the evening, no more precise time being mentioned." During Mr. Meikleham's rectorship, a small tower on the building was utilised as an observatory when the telescope was used. Capt. Vint's chronometer was later presented to the Academy.

Unfortunately none of the apparatus has survived to this day, and the reason for this is contained in the following statement:-

"As long as the Rector prelected on subjects which he could illustrate by the different kinds of apparatus, they were well cared for. But when a change in this respect took place, or they had become antiquated, they were allowed to lie neglected in a small room in the top flat of the Academy. At some time when discipline was less strict than usual, the boys managed to get access to this room at their pleasure, where, amusing themselves with its contents, they soon destroyed what neglect had spared; and when the late Rector came, the

octagonal mahogany stand of the Orrery was about all that remained. Dr. Macdonald had it brought down to the Hall and placed beside his desk."

As at Perth, Ayr Academy had to pay the penalty of selecting good men for its staff, as Dr. Meikleham left in 1799 to become Professor of Astronomy in Glasgow University. He was succeeded by Mr. Thomas Jackson, Lecturer in Natural Philosophy at Glasgow. In those days, there was a decidedly scientific staff in the leading academies and a prominent bias was given towards science in the curriculum.

In 1774, Mr. James Brander of Pitgavenie presented a terrestrial and a celestial globe "for the benefit of the rising generation at the publick schools of Elgin."⁽¹⁾

An azimuth compass was gifted to the mathematical school under the town of Greenock in 1776,⁽²⁾ and a theodolite was ordered in 1790.

A text book published in 1757 was entitled The First Elements of Geography by way of Question and Answer, adapted to the Capacities of Children for the Use of the Grammar School of Montrose, by Hugh Christie, M.A. It contained only 68 pages, and was published at Dundee for the modest sum of sixpence. In the preface the author states that "the following Epitome ----- appears in Print for the Sake of the young Gentlemen under his Care ----- It presents the learner with a general

(1) Records of Elgin. Wm.Cramond. Vol.II. 425.

(2) J.Grant. Burgh Schools. p.399

view of the Terrestrial Globe, in as narrow a Compass as possible."

The various chapters deal with Axis, Poles, Zenith, Nadir, The Equator and Parallels, The Tropics and Polar Circles, The Horizon, The Meridian, The Ecliptic and Zodiac, Zones and Climates. The next chapters are entitled The Inhabitants of the Earth distinguished by (a) their several Meridians and Parallels, (b) by their Shadows at Noonday, then the remaining chapters deal with Spheres defined, The Hour Circle, Quadrant of Altitude and Semi Circle of Position, Problems, Oceans, Seas, and Land.

The following selection of extracts will illustrate the scope and method of the book:-

"Q. What is the Nadir?

A. Another Point directly opposite to the Zenith under our feet.

Q. Into how many Degrees is the Equinoctial divided?

A. Into Three hundred and sixty.

Q. What is the Horizon on the Globe?

A. A broad wooden Circle encompassing an artificial Globe.

Q. What is the Meridian?

A. A Great Circle passing thro' the Poles of the World and the Zenith and Nadir.

Q. What is the Grand Meridian?

A. The Brazen Circle, whereon are marked 360 Degrees.

Meridians at that time were not with reference to Greenwich as is shown by these questions:-

- Q. Thro' what Place is the First Meridian drawn?
- A. Most commonly thro' London by our British Geographers.
- Q. How is it drawn by foreign Geographers?
- A. Generally thro' the Capital of their own nation.

Much of the geography taught then is no longer of interest to schools, as is evident from these questions?

- Q. What are the Equinoctial Signs?
- A. Aries and Libra.
- Q. What are the Solstitial Signs?
- A. Cancer and Capricorn.
- Q. What do you mean by these that are called Periaeci?
- A. The Periaeci ly (sic) under the same Parallel but opposite Meridians.
- Q. What do you observe as to their Days and Nights?
- A. When it is Noon with the one it is Midnight with the other.
- Q. What do you mean by these that are called Amphiscii?
- A. They have their Shadow one part of the Year North of them and the other part South.
- Q. How are they situated?
- A. In the Torrid Zone, between the two Tropics.
- Q. How are the various Positions of the Globe commonly termed?
- A. Spheres; viz., Right, Parallel and Oblique.
- Q. What is a Parallel Sphere?
- A. When the Poles are in the Zenith and Nadir.
- Q. What is the Horary or Hour Circle?

A. A small brazen Circle fixed upon the Meridian.

Q. What is the use of the Hour Circle?

A. To show how long before or after us any Place has the Sun.

Problems were set and could be solved by the Globe,
such as:-

To find the Extent of the Globe's Surface in Square Miles
and its Solidity in Cubic Measure.

To rectify the Globe.

To find the length of the Day in any particular Place.

To find at what point of the Compass the Sun rises and
sets.

A definition which is strange to us today is:-

Q. What is a Climate?

A. A broad Tract on the Globe, between the supposed Parallels
of Latitude.

Q. How do we reckon the Climates?

A. By the longest Day increasing Half an Hour.

The longest chapter is that dealing with Land, and
it contains the following questions:-

Q. How is that land towards the North Pole called?

A. Terra Incognita Septentrionalis.

Q. How is Scotland situated?

A. Between 1 and 6 Degrees W. London and 54 and 59 Degrees
N. Lat.

A list is given of shires and their chief towns,
including Fife (St.Andrews), Bamf (Bamf), Clackmannan, (Culross),

Sterling^g, Lanerk (Glasgow) and Aire (Aire). One is compelled to recall the period when this book was in use, when reading passages such as:-

- Q. What remarkable Towns belong to the Austrians and French in Flanders?
- A. Ghent, Bruges, Ostend, Oudenard, Tournay to Austria and Lisle, Dunkirk and Doway to France.
- Q. What are the British Settlements in America?
- A. New Scotland - chief town Annapolis or Port Royal.
New England - " " Boston.
New York - " " York.

In the Library of Perth Academy is preserved a manuscript copy of the lectures given by the Rector, Robert Hamilton on "Arithmetic, Gunter's Scale, Practical Geometry, Land Surveying, Geography, Navigation, Trigonometry, and Part of a Course of Natural Philosophy", in session 1777-78 and written by Patrick Mitchell. This is presumably the oldest Scottish science note book extant, and is beautifully written with neat little water colour paintings illustrating some of the problems and including various local buildings, also gentlemen with red jackets and three cornered hats.

The geography consists principally of lists of names of counties and their capitals, followed by "General Geography" mainly about the Terrestrial and Celestial Globes.

Only eleven pages are devoted to Navigation, which consists for the most part of calculations on Latitude, Longitude, Departure, Course and Distance, then 218 pages are occupied by Natural Philosophy, and we shall discover here what constituted a school course of Natural Philosophy in 1777.

Laws of Motion, Collision, Mechanical Powers, (Lever, Wheel and Axle, Pulley, Inclined Plane, Wedge and Screw) are all defined or briefly described, each item being in a separately numbered section, then these are followed by sections dealing with Falling Bodies, Pendulums, Projectiles, Central Forces. All these branches have been quickly disposed of in 38 pages.

Astronomy is next studied with a coloured illustration of the phases of the moon and another of the formation of eclipses. There is a brief description of the various heavenly bodies, without any calculations, and this occupies 36 pages. It is followed by Physical Astronomy (mainly about Gravitation), The Figure of the Earth, The Tides, Densities of the Planets, Perpetual Almanac, and Hydrostatics (Hydraulics and Resistance of Fluids), for all of which another 63 pages are required. Some typical extracts from the notes will throw light on the treatment of the subject in those days. The book has not been corrected, so the spelling, it may be noted, is not always correct. Specific Gravity is treated thus:-

"CXVIII. This specific gravity of Bodies is their weight consider'd with respect to their Bulk and is proportioned to their density. Water is the stander'd to which all others

are referr'd. River water, Spring water, Rain and Melted Snow and all other kinds have the same Specific Gravity when free from salt and Minerals. Fluids may be compared in respect of specific gravity by pouring them into the opposite legs of a bent Tube or by observing how far a Ball prepar'd for that purpose (called a Hydrometer) sinks or by a case of Balls but most accurate by the Hydrostatic Ballance. - - - - -

This Specific gravity of solid Bodies havier than water is determined by weighing them first in Air then in water; as the part of the weight lost in water: the whole weight :: this specific gravity of water : that of the Body. Bodies lighter than water may be connected with heavier Bodies and their specific gravities determined. Of these three, magnitude, weight, and specific gravity any two being given the third may be found.

weight		magnitude		specific gravity
w	=	m	x	s ."

In the section dealing with Pneumatics appears the following curious passage:-

" CXL. Miscellaneous Experiments with the Air Pump.

1. Animals cannot (sic) die.
2. Insects cannot fly.
3. Fishes swimming if their air Bladder breaks they sink and they can never swim afterwards.
4. A Candel goes out.

5. Gun Powder has no explosion.
6. Shribble Apples swell.
7. Bear Foms ⁽¹⁾
8. Water Boils.
9. Sound is not heard.
10. Writing with Phosphorous shines."

After the section dealing with Motions of the Air come the sections "Of Sound" and "Of Fire," e.g.

"CXLIX Of Fire.

The Nature of this principle, the cause of light and heat, so varies in its operations, so Beneficial in a moderate degree, and so destructive in Excess, is unknown. We are certain (sic) if fire be a separate Element or only a motion of a peculiar kind how light and heat are connected or whence they proceed. We have instances of light without heat in the Rays of the Moon, Aurora Borealis, light imitted by Glow-Worms and of heat in Boiling water &c. without light. Yet they are generally suppos'd to be some subtile matter which light and heat are effects and modifications.

CL Origin of Fire

- - - - -

Bodies of animals are warmer than the outward air. This is attributed by some to the Friction which attend the animal motions; by others by a heat arising from the dissolution of the food or to other causes. The process of vegetation is not attended with any warmth." - - - - -

(1) Beer Foams.

CLVIII. Fire has no sensible weight. A Red Hott Barr is no havier than when cold. If a Body be exposed to Flame it becomes havier and retains this additional when cool it is owing to subtile particles dissipated by the Flame and lodged in the Pores of the Body to which the Flame is applied."

CLIX. Violent Effects of Fire.

The Effects of Fire are various according to the Nature of the Body on which it acts, Fusion, Evaporation, Inflammation, Ignition (or burning without Flame), Calcination, Vitrification - -

Most Bodies we meet with arround us are compos'd of Heterogeneous parts. A certain number of simple substances (or principles) variously combin'd gives to the variety which nature exhibits. The nature of these principles and their combinations cannot be properly traced by Human art, but it may to a certain degree and this is the Subject of the Science of Chymistry. To Analyse Bodies is to reduce their Hetroginus parts to their original principles or at least to simpler combination. This Annalysis is chiefly affected by the means of Fire or Elective attractions. Fire separates the principles by acting on them in a different manner or by acting on them in the same manner in different degrees. In the division of Substances used by Chymists the different effects of Fire are chiefly regarded. Elective attractions decompose Bodies by disuniting their principles when others are added to which some of the former ones have a greater affinity than to those with which they were before combined."

In the section dealing with "Electricity", we learn that, "Substances are divided into electrates per-se which may be excited by friction and non-electrates which cannot. Non electrates always conduct electricity for which reason they are likewise called conductors. - - - -

CLXIII. There is a subtile matter diffused thro' all matter called the Electrate fluid and is generally diffused in equal measure thro' different Bodies tho' they are capable of having their usual quantity increased or diminished. In the former case they are said to be Electrified Plus and in the latter Minus.

Magnetism is disposed of in four pages, after which the next topic is Optics, e.g. "CLXXVI. The Nature of Light is unknown. When we speak of the rays of light and their direction we only mean the line on which Luminous Bodies diffuse their effects and vision is performed. Light is usually communicated in right lines."

In the section entitled Dioptrics, or Refraction of Light, there is mention of the "Magic Lanthorn" which seems an unfamiliar guise for a very familiar instrument, then, after a description of the Human Eye there is a section dealing with Vision thro' Lenses and the course concludes with a description of "Mieresopes" and Telescopes.

One can almost imagine the relief with which Patrick Mitchell, in his beautiful writing, wrote in large letters

Finis at the end of this course of lectures, for, by this time he had even ceased to append his interesting little illustrations which brighten the earlier part of his session's work.

George Chapman L.L.D., who was Latin Master and Rector of the Grammar School, Dumfries, from 1747 to 1774⁽¹⁾ and later occupied a similar position at Banff, published, in 1773, "A Treatise on Education" which reached a fifth edition in 1792, so it must have been a popular publication.⁽²⁾ In this, he states "those who are destined for agriculture should be instructed in the simplest principles of mechanics, the nature of the different soils in the parish or county where they reside, the culture adapted to them and the methods of the best farmers in this island."

"There should be in every considerable town, teachers of Book-keeping, Geometry, Drawing, Algebra, Navigation and Mechanics."

Chapman expounds his ideas as to what a boy should be taught, and states that in his twelfth year "may be added an explanation of the Five Mechanical Powers, and of models or drawings of the simplest and most useful machines - - - - - Boys who are taught according to this plan may enter the University at the age of 14 years complete."

He gives a description of his Method of Instruction

(1) Dumfries Academy Prospectus.

(2) Treatise on Eduon. pp.74. 80, 167, 211.

"while he taught the School of Dumfries," but the only mention of anything scientific is in the fifth year, "Mair's Survey of the Terraqueous Globe being used as a text book, they are carried through a course of Practical Geography - - - - and directions are given them how to improve themselves farther in this entertaining study from Salmon, Guthrie, Varenius and other Geographies."

In 1762 was published A Brief Survey of the Terraqueous Globe, written by John Mair, A.M., The maps in this volume were engraved by Thomas Kitchin. The author had been rector at Ayr and at Perth, and was one of the outstanding teachers of the time. At least two other editions of this book were published later.

The author deals first with the description and use of the globes, then the construction and use of maps, e.g. "Rivers are described in Maps by black lines, which are always wider or broader near the mouth than towards the head or source. Mountains are represented by a sort of cloud; forests or woods by a kind of shrub; bogs or morasses by shades; sounds or shallows by small dots; roads by double lines; and towns by O, or by the shape of a little house."

Next is a section on "Geography or a short view of the Antient and Modern State of the several Kingdoms of the World." The descriptions are all very brief, and typical of them is the following:-

"Scotland has Edinburgh for its capital; and is situated between 54 and 59 degrees north latitude, and between 1 and 6 degrees west longitude, being 300 miles in length, and from 50 to 150 in breadth, and bounded, on the north by the Caledonian or North sea; on the east by the German sea; on the south, by the river Esk, which divide it from England; and on the west, by the Irish sea, and the Atlantic Ocean. Scotland is divided into two parts, viz., south the frith (sic) of Forth, and north the frith of Forth; and each of these is subdivided into several districts, dales, glens, straths, stewartries, baileries, or baronies."

Mair was the author of various other books, Arithmetic 1766, Book-keeping modernised or Merchant Accounts by double entry 1773, Introduction to Latin syntax, to which is subscribed an epitome of ancient history. This last book reached a 9th. edition in 1786 and a 15th. edition in 1853.

"Arithmetic, Rational and Practical" by John Mair A.M., was published in 1766 in three parts. Part III deals with Practical Arithmetic. Typical of the contents is the following extract ⁽¹⁾ dealing with the mensuration of solids:-
"XXXVI. Any irregular body, such as, the bones in a horse's head, a thorn or whin bush, &c. Rule. Take any vessel of a regular form, such as that of a prism or cylinder, and therein put the irregular solid; then pour in as much water as will cover the solid; this being done, take out the solid, and

observe how far the water sinks or falls on the side of the vessel, and compute the solidity by Problem 24 or 25.

Or, Take any sort of vessel, fill it with water to the brim; then immerse the irregular body; receive the water that runs over, and pour it into some vessel of a regular form; and then proceed as above."

Thus is described the method of finding the volume of a solid by displacement of water, as the process is termed now, but fortunately, no science master today keeps a stock of horse bones, or whin bushes in his laboratory.

This book reached a third edition in 1777 and a sixth edition in 1799.

The first Rector of Royal Academy, Inverness from 1792 to 1794 was James Weir⁽¹⁾ who had been Rector of the Academy, Dundee, 1786-92. He was succeeded 1794-1803 by John McOmie or McComie who had taught in Perth and returned there in 1803. He was awarded the L.L.D. of Marischal College in 1793.

The Statistical Account of Scotland drawn up from the communications of the ministers of the different parishes by Sir John Sinclair during the years 1791 to 1799 gives us an indication of the localities where various subjects were taught.

(1) P.J.Anderson. The Grammar School & Royal Academy of Inverness p.10.

The most popular scientific subject was navigation, and it was taught principally in seaboard parishes, such as Kirkmaiden, Portsoy, Anstruther Wester (where the schoolmaster was esteemed the best teacher of navigation on the coast), Lochgoil-head, Lerwick, Dunse, Scoonie (Fife) and Fraserburgh. At Ardrossan, where the present incumbent had accepted this office 42 years ago the teacher had been very successful in the teaching of navigation. It was taught also at Arbroath, Oldhamstocks (near Dunbar), Torryburn, Ruthwell, Inverness (with lunar observations), and Inverkeithing, where Mr. Robert Duncan, "a very good scholar" taught it with other parts of mathematics. At Rosemarkie the Academy was nearing completion and the Rector taught languages while the second master included navigation among the subjects he taught. At Dalkeith it was taught in 1794 by the principal English master. In 1795, Navigation was a subject taught at Benholme (Johnshaven) where in 1756 every fifth man had been taken by the press gang, and which in 1768 had been harrassed by press gangs so that the exactions made on the fishers during the last war had given a decisive blow to the fishery at Johnshaven. Navigation appeared among the subjects taught at Dysart, Borrowstouness (modern Bo'ness), Peterhead, where in 1788 a "kind of academy" had been formed, Aberdeen (Robert Gordon's College), Ayr and Banff. It seems strange that navigation was taught in inland schools such as Careston (Angus) and Callander (Perthshire), and it must have been merely as a practical application of

mathematics.

Astronomy was studied in only a few schools, at Careston (Angus), where there were 20 to 30 pupils, Inverness Academy, Salton Academy, Perth Academy, and at Callander, where about 80 boys attended from different parts of Britain and from abroad.

Geography was less popular than navigation, and was taught at Tain, Arbroath, Inverness, Rosemarkie, Callander, Closeburn, North Uist, Robert Gordon's Hospital, Aberdeen, and at Stornoway, where a course of geography was charged 10/6 per quarter. It was also studied at Montrose, where a public library began in 1785, and at Irvine, where, "before our connection with America was dissolved, many young men from that country and the West Indies were sent here for their education. Mr. Cunningham was then rector and had always a doctor under him, while he had frequently from 20 to 26 boarders in his house."

At Inverness Academy, philosophical apparatus was used in the teaching of natural philosophy, which was also a subject at Salton. There were over 200 pupils at Inverness, where civil and natural history, practical gunnery, fortification and "chymistry" were also taught.

An idea of the poverty of the parochial schoolmaster at this time is conveyed by the account of Ecclefechan⁽¹⁾ where his salary amounted to 100 merks (£8.6.8 sterling), his school

(1) Stat. Acc. II. p.370. III 61, IV 433, VIII 587, XVI 54.

fees and perquisites not more than £1 and his salary as session clerk and precentor another £1, i.e. a total income of just over £10, while a "plowman" made £15 a year. At Portsoy the income was £17, but at Glenholm (Peebles-shire) the schoolmaster had had to supplement his income by keeping a shop.

There is a worthy tribute given at Symington, where the salary was £8.6.8. "He has taught for these 50 years with such fidelity and unwearied perseverance, as, in some lines of life, would have loaded him with riches and honour." At Heriot, the schoolmaster, over 70 years of age, was also precentor, session clerk, beadle and grave digger, yet his whole income did not exceed £8 sterling per annum.

It is stated ⁽¹⁾ that, "once upon a time a schoolmaster in Bute had been glad to resign his office on being promoted to the more lucrative office of beadle."

The conditions of teaching were such that the parish minister of Urr wrote, ⁽²⁾ "A ~~parish~~ school is now a temporary employment for some necessitous person of ability, or a perpetual employment for some languid insignificant mortal hardly deserving the shelter of a charity workhouse." In the burgh schools, conditions were slightly better than in the parish schools, as they were better endowed, and "had the services of not a few men of admirable skill and learning."

(1) Henry G.Graham. Social Life in Scotland in the Eighteenth Century. p.433.

(2) Stat.Acc. XI p.81. IV 252, XVI 293, IV 298, XVIII 303, V 391.

Economic changes had been taking place since 1750 when there was no wheat, no hay or clover and rye grass, no potatoes, and no turnips grown, little butcher's meat consumed, most farms were run-rig, and no wheat bread, sugar or tea were used except by the wealthy. By 1790 conditions had improved. Even in those days there was depopulation of the country, and it was owing to "inclosing". The heavy Scottish plough, drawn by oxen or four horses, had been replaced by the English or Small's plough with its two horses. Tenants were burdened by thirlage to a certain mill and smithy and by a "grassum" when they took possession of a farm. Ware or sea-weed was used either as manure or for kelp manufacture. A window duty had caused a diminution in the number of windows in houses, and other taxation was equally burdensome. The duty on English salt was 5/- per bushel weighing 56 lb., there was a tax on saddle horses, and another on coal landed north of the Red Head of Angus, while statute labour on roads was imposed, though often commuted. The Turnpike Road Act of 1777 was causing a much needed revolution in transport. At Inverary, ^(H) iron imported from the West of England was smelted by wood charcoal, at Prestonpans the manufacture of oil of vitriol, aqua fortis, spirit of salt, and Glauber salts was carried on, and in 1759 had been established the famous Carron iron works. Perhaps not least among the changes was the fact that not only the farmers, but many of the tradesmen now read the newspapers.

In 1793 and 1794 there was a great stagnation of trade

and an unfortunate dearth of employment.

In 1785, Scotland saw aerial transport for the first time, when a Florentine, Lunardi, ascended in an air balloon from Edinburgh at 3 p.m., and landed a mile away from Ceres, Fife at 4.20 p.m.

During the Eighteenth Century there had been considerable progress in education in Scotland, but it was by no means wide spread. The commencement of science teaching was due mainly to the establishment of academies, and by 1800, the scientific subjects which had been introduced into the schools were navigation, astronomy, geography, natural philosophy, chemistry and natural history. It is interesting to note that most of these subjects were taught by mathematical teachers, and were, in fact, treated as branches of mathematics, whereas in the first part of the following century there was a tendency for much of the teaching to be attempted by teachers of English. Great praise must be given to the pioneer work of John Mair, first at Ayr then at Perth, and he may rightly be considered the first real science master in Scotland.

Progress.

Schools - to 1800.

1. Navigation introduced into schools.
2. Study of celestial and terrestrial globes.
3. Introduction of natural philosophy at Ayr, 1746.
4. Pioneer work by John Mair.
5. First academy established at Perth, 1760.
6. Natural history introduced at Perth.
7. Study of geography.
8. Extended curriculum of academies.
9. Introduction of astronomy into schools.
10. Introduction of chemistry at Inverness, 1787.
11. Wider study of scientific subjects in schools.

CHAPTER IV.

UNIVERSITIES. 1801-50.

At Edinburgh, in 1829, it was proposed that there should be an entrance examination to the University, but the Arts Faculty protested against this. ⁽¹⁾ In 1842 the Senatus established a B.A. degree, as suggested by the Royal Commission of 1826, but, during the time that this degree existed the number of such degrees varied each year from 6 to 12 only, and in 1858 it was abolished by the Royal Commission of that date.

The number of students in various classes during 1821-2 was as follows:-

Latin 417, Greek 376, Mathematics 192, Chemistry 497, Natural Philosophy 160, Botany (Summer 1821) 201.

The Disruption of the Church of Scotland in 1843 had also a disruptive effect on society throughout Scotland, and the Town Council of Edinburgh did not escape this, consequently neither did Edinburgh University which it controlled.

The Statute of 1833 replaced Latin by English as the language in which written and oral tests in Medicine were to be carried out, and for Medicine prescribed a First or Scientific Examination, which included Chemistry, Botany, and Zoology.

(1) A. Grant. Univ. of Edinburgh. II pp. 50, 113, 74, 333 v

The Commission for all Scottish Universities under Rosebery in 1826 showed ⁽¹⁾ in its report that at Aberdeen in 1826-7, the course was:-

Bajan Year - Latin and Greek.

Semi Year - Mathematics, Latin, Greek with Chemistry at King's College and Civil and Natural History at Marischal College.

Tertian Year - Natural Philosophy, Mathematics, Latin and Greek.

Magistrand Year - Moral Philosophy, Logic, Rhetoric, Latin, Greek.

Students entered King's College at an age of 14 and Marischal at 12 years. It is interesting to notice that in 1857 these ages were 18 and 17 respectively.

The Commission drew up for Aberdeen ⁽²⁾ a course consisting of:-

Bajan Year - Greek, Latin, English.

Semi " - Mathematics, Greek, Latin.

Tertian " - Natural Philosophy, Mathematics, Logic.

Magistrand - Moral Philosophy, Natural History.

The last subject is of interest in being unique among the Scottish Universities as it was due to the Natural History

(1) J.M.Bulloch. Hist. of Univ. of Aberdeen. p.183

(2) P.J.Anderson. Hist. of Univ. of Aberdeen. p.199

course at Marischal College.

In 1831, the Report of the Parliamentary Commission (1) contained a course for King's College as follows:-

- First Session - 1st. Greek, 1st. Humanity.
- Second " - 2nd. Greek, 2nd. Humanity, Mathematics, Chemistry, Natural History.
- Third " - Natural Philosophy, 2nd. Greek, 2nd. Humanity.
- Fourth " - Logic and Moral Philosophy, 2nd. Greek, 2nd. Humanity.

A Commission met in 1837. In its Evidence, the curriculum for Marischal College is given as:-

- First Year - (Greek - 15 hours per week.
(Latin - 6 " " "
- Second Year - (Greek - 3 " " "
(Latin - 3 " " "
(Civil and Natural History - 15
(Mathematics - 6 hours per week.
- Third Year - (Mathematics - 6 " " "
(Natural Philosophy - 15 hours per week.
- Fourth Year - (Moral Philosophy and Logic - 15 hrs. per wk.

This curriculum continued to be in force until the provisions of the Act of 1858 came into operation.

(1) R.S.Reit. Universities of Aberdeen. pp.218. 311.

(1) In 1845, at Marischal College, Aberdeen the course with the number of meetings per week in each class, is shown as follows:-

First Year	-	(1st. Greek	14
		(
		(1st. Humanity	8
Second Year	-	(2nd. Greek	3
		(
		(2nd. Latin	3
		((
		(1st. Mathematics	6
		(
		(Natural History	12
Third Year	-	(2nd. Mathematics	6
		(
		(Natural Philosophy	12
Fourth Year	-	Moral Philosophy and Logic	- 12.

The Chemical Class was attended by many during the third and fourth years.

Included in the medical curriculum were Botany, Chemistry and Practical Chemistry, the courses lasting three, six and three months respectively.

By this time there was a spacious chemical laboratory and two rooms for chemical apparatus.

(1) New Statistical Account. XII. p.1172. et seq.

NATURAL PHILOSOPHY.

The Professor of Natural Philosophy at Edinburgh from 1805 to 1819 was John Playfair, whose demonstrations are said to have been extremely clear.⁽¹⁾ He had previously been Professor of Mathematics, as was also his successor, John Leslie, who occupied the Chair from 1819 to 1833. Leslie invented the Differential Air Thermometer which, at that time, was far more sensitive than any other form of thermoscope. In 1804 was his "Experimental Inquiry into the Nature and Propagation of Heat", and his name is remembered today by the apparatus called Leslie's Cube. During the summer session in 1826, he conducted popular classes, in the university for mixed classes of ladies and gentlemen, but these classes were not repeated. James David Forbes, Professor of Natural Philosophy from 1833 to 1860 was noted for his "well chosen and invariably successful experiments", as well as for his work on heat and on the motion of glaciers. He used the word "seismometer" for the first time.

At Glasgow, Wm. Meikleham (Rector of Ayr Academy, 1796-9) was Professor of Natural Philosophy from 1803 to 1846, and it is thought⁽²⁾ that it was at his request that the ceiling of the Natural Philosophy Class-room "was decorated with a representation of the vault of the heavens in bright blue with

(1) A. Grant. II. p.353.

(2) D. Murray. p.109.

the stars in white". In 1838-9 Meikleham's health broke down and his lectures were shared by Professors Thos. Thomson (of the Chair of Chemistry) and John P. Nichol (of the Chair of Astronomy) then in the following year Nichol took over all the work in Natural Philosophy. He was keen and enthusiastic, and as Kelvin stated in 1904, Nichol largely promoted scientific study and thorough appreciation of science in the University of Glasgow. From 1842 to 1845 David Thomson carried on all Meikleham's work. He has been described as "inoculated with Faraday fire". When Meikleham died in 1846, the Faculty at Glasgow⁽¹⁾ knew that the spirit of advancing science required not only modern appliances but a reform of methods. In Scotland, as in Germany at that date, the physical sciences were not yet emancipated from the shadow of the scholastics, who in the Middle Ages "rather wore away knowledge, by their numerous treatises than increased its weight", and deductive methods largely overshadowed the value and importance of direct experiment". As Professor of Natural Philosophy, was elected Wm. Thomson, B.A., who had been a student at Glasgow for six sessions, after matriculating at the early age of 10 years 3 months, had entered Cambridge in 1841, and was now only 22 years of age. He soon got rid of out of date useless apparatus and procured modern apparatus, among the first of which was apparatus for research in electro-magnetism.⁽²⁾

(1) Silvanus P. Thompson. Life of Wm. Thomson. p.183

(2) D. Murray. pp. 119 & 108

Throughout a session of six months, his class met two hours daily on five days of the week. In his class room, "on the south wall, beside the Professor's table, there was a large board on which Newton's Laws of Motion were painted in white letters on a black ground, and judging from its appearance, it must have been looked upon by many generations of students. These laws were often quoted by Professor Thomson."

At St. Andrews, in 1809, James McDonald succeeded George Rotheram as Professor of Natural Philosophy. According to evidence before the Royal Commission of 1826 to 1830, the University at this period ⁽¹⁾ "was reduced to the direst straits". It was poorly dowered and has been described by Andrew Lang as "a tocherless lass wi' a lang pedigree", but in Scotland, lack of resources has never prevented education, though it has frequently hindered it. During this period, at St. Andrews, were many students, such as John Playfair and John Leslie, who later achieved fame in the scientific world. In 1837 Adam Anderson, Rector of Perth Academy, became Professor of Natural Philosophy and he was succeeded in 1847 by Wm.L.F.Fischers. As Principal of United College in St.Andrews from 1838 to 1859 was David Brewster, ⁽²⁾ who had invented the kaleidoscope in 1816 and whose efforts had led to the British Association being established in 1831. He

(1) Votiva Tabella. p.172.

(2) A.Grant. II. p.275.

had become a student at Edinburgh University when only twelve years of age.

At King's College, Aberdeen,⁽¹⁾ in 1831 the Professor of Natural Philosophy lectured upon General Physics, Dynamics, Mechanics, Hydrostatics, Pneumatics, Acoustics, Optics, Electricity, and Magnetism, while Galvanism was treated by the Professor of Chemistry. In 1834, Rev. John Fleming, D.D., was Professor of Natural Philosophy, and the text book used was Playfair's Outlines, while at Marischal College in 1843 were two rooms for apparatus for Natural Philosophy, and the apparatus for teaching this subject was said to be extensive.⁽²⁾

In 1840, at Glasgow, the Crown appointed as Professor of Civil Engineering and Mechanics, Mr. Lewis Dunbar Brodie.

The Outlines of Natural Philosophy, being heads of lectures delivered in the University of Edinburgh by Professor John Playfair was published in Edinburgh in 1812. Various sections deal with dynamics, mechanics, hydrostatics, hydraulics, aerostatics (heat and equilibrium of elastic fluids) and pneumatics. When the lever is discussed,⁽³⁾ the Principle of Virtual Velocities is introduced, as we have found it also in the lectures at Perth Academy in 1838. Playfair states that "Heat or caloric may be regarded as a substance that penetrates

(1) R.S.Rait. p.219 et seq.

(2) New Stat. Acc. XII. p.1176.

(3) pp. 66. 215, 217, 309

and expands all bodies and that produces in us the sensations of heat and cold. Though we conceive heat to be a substance, it is never found in an independent state, or existing otherwise than as a property of body."

A table is given of expansion of different bodies for 180° of Fahrenheit, and reference is made to Dalton's "New System of Chemical Philosophy". A description is given of the Sucking Pump and the piston called the Sucker.

Dew is described as "a precipitation of humidity from the lower strata of the atmosphere, which does not disturb the transparency of the air, and to which the mixture of different streams of air does not seem necessary."

CHEMISTRY.

A Chair of Chemistry was founded at Glasgow in 1818,⁽¹⁾ and its first occupant was Dr. Thomas Thomson, who had invented the oxy-hydrogen blow pipe in 1802. The class to which he lectured numbered 140 to 150, and as the subject developed and the number of students increased, more accommodation was required, so that, in 1830-31, were built new buildings for Chemistry in Shuttle Street⁽²⁾ at a cost of £5000. In addition to his lectures, Professor Thomson found time to carry on research in a very enthusiastic manner. "He was a

(1) J.Coutts. p.538

(2) D.Murray. pp. 194 254.

scientific chemist, eager in research and anxious to establish a practical class - - - - A laboratory was fitted up but the room was too small and only ten students at a time" could work there. Thomson claimed that this Experimental Class, as he named it, was the first of its kind in Britain. He had been a student of Black in 1795-6 at Edinburgh, and lectured in chemistry for several years at Edinburgh where he established a chemical laboratory for the training of students. On the death of Cleghorn, he became lecturer in chemistry at Glasgow University, and the following year he was appointed first Professor of Chemistry, and continued as such until his death in 1852. The standard work in chemistry at this time was his "System of Chemistry", first published in 1802, and many editions of it were published. He raised the standard of the teaching of Chemistry in Glasgow University and aroused the interest in this subject of the industrial section of Glasgow.

In Edinburgh the chemistry class of Professor Charles Hope was extremely popular, ⁽¹⁾ as is shown by the number of students in 1823 being 575, so it was necessary that his experiments should be carried out on a very large scale, in order to render them visible to the whole class. It was only in 1823 that the teaching of practical chemistry was commenced, and this was undertaken by Hope's assistant, Dr. Anderson. In 1826 Hope delivered a course of popular

(1) A. Grant. II. p.398

lectures on chemistry to both ladies and gentlemen.

Hope was succeeded in 1844 by Wm. Gregory (from King's College, Aberdeen), who had taught previously at Edinburgh, Glasgow and Dublin, after having studied under Baron Liebig.

(1)

At King's College in 1816, Rev. Wm. Jack, M.A., M.D.

taught both chemistry and moral philosophy. The Humanist in

King's College, Rev. Patrick Forbes, (2) assistant and successor

to Prof. Wm. Ogilvie, commenced a class in chemistry and natural history in 1817, in addition to his own work.

In 1818 it was proposed to set up a medical school which was to include lectures on botany during summer, and in 1825, to candidates for the degree of M.D. it was compulsory to include classes in chemistry and botany among those which they attend-

ed. Forbes delivered his chemistry lectures five days per week, and during one session, one of his daughters attended this class with the male students. She was the first woman student in the University. It was stated that, in 1834,

King's College taught the leading doctrines in chemistry and geology. Professor Forbes, in addition to being Professor of Humanity was one of the ministers of the Parish of Old

Machar. With respect to the lectures on chemistry and

natural history, it is stated in the New Statistical Account (3)

that "attendance on those lectures was rendered imperative,

(1) J.M. Bulloch. p.169-170

(2) R.S. Rait. pp.209 et seq. 222

(3) New Stat. Acc. XII. p.1145.

as it now continues, on candidates for degree of A.M., a circumstance without a parallel in any other British University. - - - - At the commencement of the session 1840-41, Dr. Forbes relinquished this part of his duties - - - and since that time chemistry has been taught by the present Professor of Medicine," Dr. Wm. Gregory. He had been appointed in 1839, and was the author of "Handbooks of Organic and Inorganic Chemistry" and of "Outlines of Chemistry". About 1840, King's College possessed a Chemistry room, and around 1845 the Chemistry Class consisted of 40 to 70 students. ⁽¹⁾ This included a certain number of medical students. There was "a moderate stock of apparatus, the property of the College, and an excellent lecture room. The Professor has a considerable amount of apparatus of his own - - - - in summer he gives a course of Practical Chemistry - - - the average number of students is 10." In 1844, Gregory left Aberdeen on being elected Professor of Chemistry at Edinburgh. At Marischal College, Thomas Clark became Professor of Chemistry in 1833.

At St.Andrews, Dr. Robert Briggs who was appointed to the Chair of Medicine in 1811, ⁽²⁾ had to teach both Chemistry and Pharmacy. Even in that first session there were 32 students, and although there was no laboratory, chemistry was taught regularly, and it has been a subject in the United

(1) New Stat. Acc. XII. pp.1148 & 1160

(2) *Votiva Tabella*. p.173 and J.M.Anderson. Matriculation Roll of Univ. of St.Andrews. 1747-1897. p.XXX et seq.

College ever since. In 1827 it was made obligatory for candidates for an Arts degree. Dr. Briggs died in 1841, and in the previous year a Chair of Chemistry was founded, the first occupant being Mr. Arthur Connell, who lectured on both Organic and Inorganic Chemistry, with experimental illustrations, as far as the scanty apparatus at his disposal permitted. There was no fund to replace apparatus broken. Despite these disadvantages, Professor Connell carried on research over the whole field of chemistry.

BOTANY.

In Glasgow, the teaching of the Botany class by Dr. Thomas Brown appears to have ceased about 1808.⁽¹⁾ The College Botanic Garden was feued in 1813 and 1814, having apparently been disused for teaching purposes some years earlier. Professor Jeffray seems to have taken over the class until 1816, when Dr. Robert Graham carried on the lectures and received an annual allowance of £20 for the purchase of plants as illustrations of his lectures, then in 1818 he was appointed Regius Professor of Botany.⁽²⁾ It had been decided to construct by private subscription a new Botanic Garden of nearly 8 acres, which would be public and not merely university property. It lay between Dumbarton Road and Sandyford Road (now Sauchiehall Street) and Graham was

(1) J. Coutts. pp. 531. 359.

(2) A. Grant. II. p. 384

busily occupied with the construction of the garden, which would take the place of an insufficient one near the Old College. This experience served him in good stead, for in 1820 he was appointed Professor of Botany at Edinburgh University, in succession to Rutherford, and one of his first duties there was to transfer the Botanic Gardens from Leith Walk to Inverleith Row,⁽²⁾ and this task was completed in 1823. In 1832, at Edinburgh, it was ordered⁽³⁾ that every student in Botany should pay a fee of 5/- for the use of the garden.

Graham removed successfully all the trees and plants, even a splendid yew tree grown by Sutherland in the old Physic Garden. His lectures at first were "according to Linnaean principles but he gradually adopted more and more the Natural system". He extended the teaching of botany by introducing a winter course as well as the summer one. One of the outstanding features of the latter was the series of botany excursions on Saturdays. He was succeeded in 1845 by John Hutton Balfour, who had been Professor of Botany in Glasgow since 1841, the same year as the gardens laid out by Graham had been replaced by a large garden of 22 acres on the banks of the Kelvin.

Balfour's predecessor, and Graham's successor at Glasgow was Wm. Jackson Hooker,⁽⁴⁾ who occupied the Chair from 1820 to 1841. He was a very successful and enthusiastic

(2) Royal Botanic Garden. p.IX.

(3) A.Grant. II. pp.58 & 384

(4) J.Coutts. pp. 532-3.

professor. The number of students attending his class up to 1833 was about 65, but subsequently this number was about doubled. He left Glasgow to become Director of the Botanic Gardens at Kew. In 1840,⁽¹⁾ the Royal Botanic Institution which owned the Botanic Gardens (established in 1817) that were stated to be only 25 minutes' walk from George Square "by a good footpath", purchased 22 acres on the north side of the newly made Great Western Road, and to this site the Botanic Garden was transferred in 1842. In 1845, George Arnott Walker Arnott was appointed Professor of Botany.

At Marischal College, Aberdeen in 1825,⁽²⁾ Professor Knight, who occupied the Chair of Natural Philosophy, began a class in Botany, in addition to his other work, and taught the subject "in a manner strictly scientific, to render it useful to the medical profession." He issued in 1813, and again in 1828, a pamphlet entitled "Outlines of Botany intended to accompany a series of practical demonstrations in that Science given in Marischal College and University". This course included morphology and physiology of plants, but was concerned principally with the characters of the Linnaean orders and classes.

The lectures in Natural History delivered at St. Andrews by Mr. John G. MacVicar between 1825 and 1827 contained some elementary instruction in Botany.

(1) D.Murray. p.252

(2) P.J.Anderson. p.164.

NATURAL HISTORY.

The Chair of Natural History at Edinburgh was held from 1804 to 1854 by Robert Jameson, ⁽¹⁾ who founded a great school of Natural History, and, with his collections, created a splendid museum. He gave lectures also on Meteorology, Hydrography, Botany and Zoology. In 1820 ⁽²⁾ had been completed the Chemistry and Natural History class rooms in the south west corner of the "New College of Edinburgh", of which the foundation stone had been laid in 1789, also all the west side of the quadrangle was completed and fitted up as the Natural History Museum, which was to be open to the general public at a fee of 2/6. In 1834 the Town Council reduced the fee to 1/- and opened the Museum at all times to the public. This decision provoked a rather bitter dispute.

At St.Andrews, a lectureship in Natural History comprising Meteorology, Hydrography, Mineralogy, Geology, Zoology and Botany was commenced in 1825-6 by Mr. John McVicar ⁽³⁾ with a class of 45 students, but this lectureship ceased after two years, and the subject did not reappear for the next 25 years.

Owing to the death of James Beattie, Jun., in 1810, Professor Knight was, in 1810-11, at Marischal College, Aberdeen, acting Professor of Civil and Natural History, ⁽⁴⁾ which

(1) A.Grant. II. pp. 433, 205, 197. I. 60.

(2) Votiva Tabella. p.176

(4) R.S.Rait. p.306.

seems to have been rather a medley, to judge by the syllabus:-

4 lectures on Poetry

10 " " Chronology and Geography

Introduction to General History - British Constitution, etc.

History of more Ancient Nations, Egypt, etc.

" " Ancient Greece and of Rome.

Natural History.

Lecture on Chemistry, introductory to Mineralogy.

Mineralogy.

Geology and Meteorology.

Botany and Vegetable Physiology.

Zoology - Anatomy and Animal Physiology.

History of Man and of Animal Kingdom.

He did not, however, receive the permanent appointment, which was given to James Davidson.

In Kennedy's Annals of Aberdeen, ii, pages 95-6, published in 1818, it is stated re Marischal College:-

"Second Class. James Davidson, M.D., Professor of Civil and Natural History."

In the Scottish Universities perhaps there is no class correspondent to the second year at this class. It is denominated the Natural and Civil History Class. - - - - In the first branch is given a short view of the celestial system - - - - nature and effects of light - - - - electricity and galvanism, magnetism and their various causes and effects. - - - - a brief view of the affinities which unite

minute atoms of matter of the same kind forming aggregation; and of dissimilar kinds producing chemical union. History of the atmosphere; of the phenomena connected with it, rain, wind, hail, snow, meteors, thunder, etc., with the origin of springs, the nature of rivers, etc. Geology, phenomena of volcanoes, earthquakes etc.

In the second branch, an explanation of the three kingdoms of nature. Minerals. Vegetables. Physiology of plants. Linnaean classification, animal chemistry and physiology of animals. Natural and civil history of man."

John Shier was assistant to Professor Davidson. ⁽¹⁾

Wm. MacGillivray succeeded Davidson at Marischal, and from 1841 to 1852, as Professor of Natural History, taught Zoology and Geology in winter, and Botany in summer.

In the 1826 Report of the University Commissioners, ⁽²⁾ it is stated that Mineralogy, Geology, and Chemistry are taught in King's College, Aberdeen, by Rev. Patrick Forbes.

At Glasgow in 1807, a Chair of Natural History was founded and Lockhart Muirhead, who had been lecturer in this subject since 1803, and librarian since 1795, was appointed Professor. He supervised the transfer from London to Glasgow of the splendid museum collection formed by Wm. Hunter.

(1) P.J.Anderson. pp. 165 et seq.

(2) R.S.Rait. p.324.

ASTRONOMY.

At Edinburgh, after the death in 1828 of Professor Robert Blair, who, as we have seen, treated the Chair of Practical Astronomy as a sinecure, it was arranged that the university should have the use of the observatory (on Calton Hill) owned by a private society called "The Astronomical Association", and in 1834, Thomas Henderson was appointed Professor, also Astronomer Royal for Scotland, the duties of which office were "to make Observations for the extension and improvement of Astronomy, Geography and Navigation." This observational work kept him steadily occupied and he gave no lectures. On the death of Henderson in 1846, the successor appointed was Charles Piazzi Smith, who improved matters by giving a six months' course of lectures to some dozen students. The Commissioners of 1829 had recommended that the Chair of Practical Astronomy be abolished as the Professor did no teaching.

After Wm. Meikleham transferred from the Chair of Practical Astronomy at Glasgow in 1803, ⁽¹⁾ Rev. James Couper, minister of Baldernock, was appointed. An observatory was built and equipped by "The Glasgow Society for promoting Astronomical Observation", a private association formed in 1807 with a capital of £5,000. Interest declined, and, after some time it was sold. Couper "taught no class in

(1) D.Murray. p.263.

Astronomy except for a few years at the beginning, and by and by he gave up observing too. It was alleged that the smoke of the town rendered observing impracticable,⁽¹⁾ and St. John's Church, built about 1819, obstructed the view." Professor Couper died in 1836, and an unsuccessful candidate for the Chair was Thomas Carlyle. The successful candidate was John Pringle Nichol, who began afresh the making of observations, enlarged the stock of instruments, and revived the class for students. This was a scientific class on four days per week for those who wished to study the subject for navigation, engineering, and other professions.⁽²⁾ In addition, he conducted a popular class which met twice a week, and it was for the benefit of those who wished a general knowledge of astronomy without the use of mathematics.⁽³⁾ Sometimes the audience exceeded 1,000 in number and this is a proof of the enthusiasm which he aroused. He helped to form, in 1839, the Astronomical Institution of Glasgow, which erected an observatory at Horselethill.

In King's College, Aberdeen in 1843, according to the New Statistical Account,⁽⁴⁾ "there are a few astronomical instruments belonging to the College, but no regular observatory," and a list is given of astronomical apparatus in Marischal College.

(1) J. Coutts. p.353.

(2) D. Murray. p.266.

(3) J. Coutts. p.388

(4) New Stat. Acc. XII. pp. 1160 & 1186.

AGRICULTURE.

At Edinburgh, David Low, in 1831 succeeded Coventry as Professor of Agriculture. ⁽¹⁾ He had assisted his father, a land agent, and, during the first years of his professorship 70 to 90 students attended his class. The Commissioners in 1829 recommended that the Chair of Agriculture should be abolished unless a class could be obtained and taught regularly, as the teaching had been only intermittent.

A Lectureship in Agriculture was established in 1840 ⁽²⁾ at Aberdeen and the first lecturer was John Shier.

The period under consideration was marked by slow progress in the universities. Astronomy was in the worst plight, for the occupants of the Chairs either treated the office as a sinecure or were absorbed in their observations. Natural history was a medley of various subjects, none of which received adequate treatment. The Professors of Botany in some cases were aided in their work by the provision of new botanic gardens, and practical experience was provided at Edinburgh in excursions. In Natural Philosophy there were many distinguished physicists among the Professors and progress was made steadily, while in Chemistry an important step was the introduction of the teaching of practical chemistry.

(1) A. Grant. II. pp. 456 & 43.

(2) P. J. Anderson. p. 186.

Progress. Universities 1801-1850.

1. New botanic gardens at Glasgow and at Edinburgh. 1818-23.
2. Natural history museum established at Edinburgh, 1820.
3. Teaching of practical chemistry introduced at Edinburgh, 1823.
4. "Experimental class" in chemistry established at Glasgow.
5. Natural Philosophy compulsory for Arts degrees. 1826.
6. Natural History compulsory for Arts degree at Aberdeen, 1826.
7. Chemistry compulsory for Arts degree at St. Andrews, 1827.
8. Galvanism treated by Professor of Chemistry at Aberdeen, 1831.
9. Latin replaced by English in written and oral tests in
Medicine at Edinburgh, 1833.
10. Class of astronomy revived at Glasgow, 1836.
11. Botany excursions introduced by Graham at Edinburgh.
12. Chair of astronomy ceased to be sinecure at Edinburgh, 1846.

CHAPTER V.

SCHOOLS 1801-50

In this half-century there were numerous educational developments, and among these was the establishment of academies in many burghs. In 1791 an academy had been proposed at Elgin,⁽¹⁾ and in 1801 this was opened to teach languages, with "the elements of mathematics including geometry, trigonometry, algebra, navigation, surveying, perspective and drawing." In addition, fortification, gunnery and architecture were taught. The curriculum here was not as scientific as in most academies and a somewhat similar curriculum was that at Tain Academy, founded in 1810.⁽²⁾ In 1801, Annan Academy was established "for the "education of youth upon a liberal plan."

Sometimes an academy was formed by the union of existing schools. This happened in 1802 in Dumfries,⁽³⁾ when the Commercial School (where, as we have seen, navigation was taught) amalgamated with the Grammar School. A similar union took place at Cupar, Fife, in 1822, when the Grammar School and the English School combined, then

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- (1) Wm. Cramond Records of Elgin, Vol. II p. 428. J. Grant, Burgh Schools, p. 120.
(2) Report on Endowed Schools. ii p. 569 & 344.
(3) J. Grant, Burgh Schools, p. 122.

later this academy was merged into the Madras Academy, which like the Madras College, St. Andrews had benefited by Dr. Bell's Trust. Kirkcudbright Academy was the result of the amalgamation of the Grammar School, a separate English Department, and a Commercial School.

Some of the other academies formed were Kilmarnock 1811, Irvine 1818, Peterhead 1846, Greenock 1855, and Dumbarton 1865.

It must be remembered that this was a period of progress in many ways, ⁽¹⁾ e.g. "The first public railway in Scotland was constructed between Kilmarnock and Troon, $9\frac{1}{2}$ miles long, which was opened for traffic in 1812. The rails of the tramway were of cast iron and fixed in stone blocks and the carriages were drawn by horses. Before the year 1830, the sanction of Parliament had been obtained for the construction of upwards of a hundred miles of railways." "Progress was such that, when the Newcastle and Berwick Railway was opened in 1847, the journey from London to Edinburgh was announced to occupy $19\frac{1}{4}$ hours, and to Glasgow 21 hours.

Preserved in the library of the Mathematical Department of Glasgow University with five similar books,

(1) J. Mackintosh, Hist. of Civilisation in Scotland.

is a manuscript book of lessons given at Perth Academy, apparently in 1801, by Mr. Gibson, Rector of the Academy. After lessons on The Stereographic Projection of the Sphere and Spherical Trigonometry, the remainder of the book deals with Astronomy. This is divided into four parts. The first part contains explanations of "the phenomena of the heavens depending or arising from the diurnal motion of the starry heavens and the annual motion of the sun." Some of the problems in this part are:-

3. "To make a planis sphere or chart of the position of the fixed stars.
4. Required the latitude and longitude of the star Regulus, its right ascension being $9^{\circ}56'$ and declination $13^{\circ}4'$.
21. To explain the phenomena of the Perioeci, Antoeci, and Antipodes."

The second part is concerned with Refraction and Parallax, and the third part with the Solar System. In the latter are described the Copernican, Ptolemaic and Tycho^mic Systems. Among the problems given are to find the sun's place on 9th February, 1801 at noon, and the places of all the planets for 1st March, 1801 at noon. Eclipses of the sun and the moon are described. The subject of the fourth part is Nautical Astronomy, of which "the problems

of principal and indispensable use are the three following, to determine the latitude a ship is in, to determine her longitude, to correct the variation of the compass."

Other notebooks written by pupils at Perth Academy are preserved in Glasgow, in the library of Perth Academy, and in Perth Museum. The dates range from 1777 to 1838, and the subjects include Geometry, Algebra, Arithmetic, Astronomy, Natural Philosophy and Book-keeping, so that it is possible to obtain an insight into the studies of pupils at an academy then. Unfortunately there do not appear to be any similar books preserved in other Scottish academies.

Many of the schools were conducted by kirk sessions, and the Edinburgh Sessional School, founded in 1813, enjoyed a considerable reputation. Special text books were printed for the pupils there, and the necessity for this was thus stated:-

(1) "It became desirable to furnish the scholars with an additional book, which might afford them more interest and information..... This desideratum has now been supplied by the publication of "Instructive Extracts, comprising Religious and Moral Instruction, Natural History,

(1) Account of the Edinburgh Sessional School by the Compiler of the Edinburgh Sessional School Books.

6th edtn. 1854, p. 226.

"Elementary Science, Accounts of Remarkable Persons, Places, Manners, Arts and Incidents with a selection of Passages from the British Poets." No articles have been studied with greater avidity, have been more thoroughly understood, or, we trust, will be found more beneficial than those which treat of the mechanical powers, and other elementary science."

The method of instruction was purely theoretical, and the method of questioning is illustrated thus:-

"What is necessary to put a body in motion?

What property of the body is it which renders force necessary in such a case?

Will a body go quicker of itself? or slower? or stop?

Why then does a marble rolled along the floor first go slower, and at length stop altogether?

What is a lever? How many kinds of lever are there?

What is the first kind? Can you give me any examples of its application?

What is a pulley? Is any power gained by employing a fixed pulley? What is the use of it? Is any power gained by the use of a moveable pulley?"

The general state of education in Scotland in 1820 is shown by statistics published in that year, viz.

(1)
viz.

	<u>Number of schools</u>	<u>Children</u>
Parochial Schools	942	54,161
Endowed "	212	10,177
Dames' " (unendowed)	257	5,560
Ordinary " (")	<u>2,222</u>	<u>106,627</u>
	<u>3,633</u>	<u>176,525</u>
 Sunday Schools	 807	 53,449

The population of Scotland at the previous census (1811) was 1,805,688.

The corresponding figures for England with a population of 9,543,610 were:-

Endowed Schools	4,167	165,433
Unendowed "	<u>14,282</u>	<u>478,849</u>
	<u>18,449</u>	<u>644,282</u>
Sunday "	5,162	452,817

One of the most interesting experiments of this period was that of Robert Owen at New Lanark. ⁽²⁾ He provided "a useful and genteel education" to 300 day scholars (under

(1) General Table showing state of Educn. in Scotland, 1820
(1820, xii 349)

Outline of
(2) /the System of Education at New Lanark by Robt. Dale Owen.

(ten years of age) and 300 evening scholars (aged ten to twenty years) and at one time he even clothed all the children "in a beautiful dress of tartan cloth, fashioned "in it's make after the form of the Roman toga," and described elsewhere as being of strong white cotton cloth, reaching to the knees of the boys and to the ankles of the girls.

Here, even the youngest scholars were taught Natural History, but it was evidently merely from diagrams which were as far as possible on the same scale, so as to give the children correctly the relative size of the objects represented. Robert Dale Owen's description in 1824 is as follows:-

"These drawings may be either hung round the room, "or painted, as the botanical representatives at New Lanark "are, on glazed canvass, which is rolled from one cylinder "to another, both cylinders being fixed on an upright frame, "at about six or eight feet distance from each other, so "as to show only that length of canvass at once. These "cylinders are turned by means of a handle, which may be "applied to the one, or to the other, as the canvass is to "be rolled up or down."

The children were at school for 5 hours per day,

except the infant classes, aged 18 months to 5 years, who attended only half the regular hours. Most children entered Owen's factory at the age of ten. The schools which measured 100 ft. by 50 ft. and cost £6,000 was open in the evening but after 10½ hours of labour, only a small portion of the workers attended then. (1)

The state of science teaching in 1826 can be seen from the "Return from the Sheriffs of the Several Counties of Scotland relating to the parochial Schools of nine hundred and five parishes."

Navigation was still by far the most common scientific subject and though it was taught principally in sea board towns, strange to relate, it appeared also in a number of schools inland. It was taught at Colinton, but that school was probably at least within sight of the sea. It does however appear rather a strange subject to be taught at Kirkmichael (Perthshire), Kirktown and Wilton (Roxburghshire) In these schools it was associated with "trigonometry and its application to heights and distances, land surveying and mensuration." At Saline was taught arithmetic (including mensuration book-keeping, navigation and land surveying), while at Gladsmuir, (Haddington) were taught trigonometry,

(1) R. Owen at New Lanark by one formerly a teacher at New Lanark, 1829.

mensuration, conic sections, gunnery, navigation, architecture, geography and logarithms.

The master at Monifieth taught "a complete course of navigation, including necessary previous preparation and trigonometry, logarithms, the sailings, the construction and use of Mercator's chart, several journals, nautical astronomy and the lunars etc: etc.," and for this course he charged three guineas and a half, which appears to have been the dearest fee. The next in regard to cost was £2: 2: charged at Cross Burness, Orkney, for navigation including preliminary branches and lunar observations." The usual fee was £1: 1 per course, but pupils at Colvend (Kirkeudbright) were the most fortunate in being able to receive this instruction at 2/6 per quarter. The schoolmaster at South Ronaldshay, who was also sub-deputy-postmaster at a salary of £4 per annum, charged 20/- per course in navigation.

Astronomy was taught at Annan, Crail and Lecroft.

At Ayr Academy was taught natural philosophy, also at Edinkillie (Elgin), Cupar Academy, Inverness Academy and Lecroft. At Elgin, "a small apparatus" had been obtained by public subscription, and the mathematical master was to commence a class in natural philosophy.

As yet chemistry was not widely taught, the only schools in which it was mentioned as a subject being Ayr and Cupar Academies. Eight years later a similar return

was made, entitled "Abstract of Education Returns (Scotland)
"1834."

Navigation was as popular as before, being taught in coastal schools, and even at Crieff and Jedburgh, where it could not have been capable of practical application, but must have been taught only as an application of mathematics.

At Ayr Academy (a large school of 460 pupils), and at Dundee, natural philosophy was taught, while lectures on this subject were given at The Scottish Naval and Military Academy, Edinburgh, and at George Watson's Hospital, Edinburgh. The elements of natural philosophy formed part of the course at Tough, Aberdeenshire and the principles of natural philosophy and physical geography at Selkirk. The subjects taught at Abbotshall, Fife, included practical mechanics, at Crail, natural and mechanical philosophy, and at Sorby, Wigtownshire, the elements of mechanism and philosophy.

Astronomy was taught at Alloa, Dumfries, St. Andrews, Kirkpatrick - Durham, Kelso and at St. Andrews school, Lanbride, "the problems of the terrestrial globe and astronomy, "so far as without instruments, it can be managed."

Chemistry was obtaining an entry as a subject of education and was taught at Ayr Academy, Crail, Kinghorn,

Dundee, Sorby, Wigtown, and the Scottish Naval and Military Acedemy, Edinburgh.

New scientific subjects were appearing, such as natural history at Tain Academy and Wigtown, botany at Kinghorn and Kirkpatrick - Durham, mineralogy at Crail, animal physiology at Falkirk and the elements of zoology at Kinghorn. At Philips' Institution, Kirkcaldy a subject taught was entitled "the elements of useful knowledge" and at the infant school, Kirkcaldy of which the pupils were aged 3 to 6 years, a subject was zoology, which must have comprised merely what we now term nature study.

The difficulties of teaching in those days are reflected in the return from Renfrew: "the great thing wanted in teaching is division of labour: the teachers generally have too many branches to do justice to any; and are withal miserably paid," and that from Towie: "The present school room is only 16 feet by 14 and is therefore very inadequate to the wants of the parish, not only proving a drawback upon the teacher's usefulness, but a source of much discomfort to those taught."

This is not surprising as the roll consisted of 36 males and 30 females, yet in this crowded room, John Fyfe, the schoolmaster taught English, reading, writing, arithmetic, Latin, book-keeping, geography and mathematics,

and was prepared to teach chemistry in the evening.

There was a drop in attendance during the summer months in country districts, as instanced at Strathdon where "the elder children are engaged as herds during the "summer, and the younger ones are kept at home to herd the "family cow." In some ways the Industrial Revolution did not aid education. At Kilwinning, children 8 or 9 years old assisted handloom weavers in making shawls, at Dundee in winding yarn, and at Loudoun, children aged 7 to 10 years assisted cotton handloom weavers, while at East Kilpatrick, children aged 7 years worked at a calico print work.

What prospect could there be of much science being taught when we learn that at Cavers, Roxburgh, "almost all "the girls learn to write before they finally leave school, "and not unfrequently to calculate also?" At Dalserf, "young people often acquire a large portion of their educa- "tion after they have become weavers and tambourers in the "Evening Schools of the parish."

Science was not viewed with favour by John Wylie, "the minister of Carluke:-

"Some of the native parishioners also forgetting what chiefly formed, under the blessing of God, the holy,

"wise, and strong character of their forefathers, have
"begun, in their desire for their children to be infected
"with "the spirit of the age" to evince a taste for a
"paltry, flimsy, and most inflating respect for what is
"called Science in their school exercises, to the nec-
"essary neglect, where it is yielded to, of what is far
"more precious and enduring."

At Perth Academy, the assistant, Gilbert Wright, informed the Town Council in 1806 that he wished to commence a class in chemistry and that assistance would be required for the purchase of material and apparatus. ⁽¹⁾ A sum of £21 was voted for the purpose. There was still no practical work performed by the pupils. Adam Anderson, elected Rector in 1809, persuaded the Town Council in 1810 to purchase scientific apparatus costing £240:18:8.

An advertisement ⁽²⁾ of the re-opening of Perth Academy for the session, in 1811, included the following:-

"The following branches of Science will be taught
"by Mr. Anderson:-

Mechanical Philosophy - comprehending Dynamics;

(1) E. Smart, Hist. of Perth Academy, pp. 86 and 111.

(2) Perthshire Courier 9th Sept. 1811.

"descriptive physical and practical Astronomy; Projectiles,
"with their application to Gunnery; Mechanics; Hydrostatics;
"levelling; Hydraulics; Aerostatics; Pneumatics; Acoustics;
"Electricity; Galvanism; Magnetism; Optics.

Chemistry and its application to the Arts."

The purchase of chemical agents to the extent of £15 was
authorised in 1810, and chemistry was to be "a permanent
"branch of education connected with the Academy."

A similar advertisement in 1830⁽¹⁾ intimated that
teaching would be resumed:-

"By A. Anderson, L.L.D., F.R.S.E. etc. Algebra
"and the Higher Branches of Geometry, the more abstruse
"parts of Arithmetic and Accounts, Natural Philosophy,
"Astronomy and Chemistry."

An Appendix to "View of the System of Education
at present pursued in the Schools and Universities of
Scotland," by Rev. M. Russell, appears over the initials A.A.,
presumably Mr. Anderson, and gives information regarding
Perth Academy.

"The teaching rooms are large and commodious.
"They consist of five apartments, two for mathematics,
"natural philosophy and chemistry, one for languages, one

(1) Perthshire Advertiser 1830.

"for writing, one for painting and drawing, with an
"apparatus room.

"Physics or Natural Philosophy. The apparatus
"is extensive; it already embraces all the more common
"philosophical instruments for the illustration of practical
"mathematics, physics and chemistry; and by the liberal
"donations of the noblemen and gentlemen of the county of
"Perth, who have always patronised the institution, it is
"yearly increasing. Among other valuable instruments it
"contains the powerful air pump, constructed by Millar and
"Adie, with which Mr. Leslie first succeeded in freezing
"mercury by the evaporation of ice."

Popular scientific lectures delivered by the Rector
provided another source of income for the provision of
apparatus, ⁽¹⁾ including an air pump, a theodolite, a sextant,
an electric machine, a galvanic battery, and a mountain
barometer.

In 1837 Dr. Anderson resigned owing to his having
received the appointment of Professor of Natural Philosophy
at St. Andrews University. To his successor, Mr. Thomas
Miller, the Town Council in 1839, granted £30, "to put in
"proper condition the apparatus for illustrating the theory

(1) E. Smart, pp. 118 et seq.

"in the various departments of Electricity and Astronomy."
In requesting an annual grant for the upkeep of apparatus, Miller in 1842 mentioned various pieces of apparatus which he had been obliged to buy, and stated their cost, an Electro Magnetic Apparatus £3:6, a Bennet Gold Leaf Electrometer 7/6, two Globes etc., for chemical and other experiments 10/6, a High Pressure Steam Engine £3, a model of a Locomotive Engine £3. A model of a Watt's Double-Acting Engine had been obtained on loan.

At Paisley, in February 1826, it was intimated
(1) that at the Town's Commercial and Mathematical School,
"on the first Monday of March, Mr. Macome will commence his
"summer course of Geography, embracing, according to the
"approved practice of the late Mr. Denholm of Glasgow, an
"experimental illustration of such principles of Natural
"Philosophy as are referred to in geographical works."
In 1833 at Paisley Commercial School, a prize was awarded to Peter Kerr for trigonometry and astronomical calculations.

(1) R. Brown, Hist. of the Paisley Grammar School, p.320.

At Ayr Academy in 1804, additional apparatus amounting to £507. 16. 10 was purchased. (1) In the account it is described as "New apparatus, consisting of Orrery, Globes, Telescope, Etc., exclusive of what belonged to the Old Schools." In 1806, the Rector, Mr. Jackson, extended the curriculum (2) to include chemistry. "The Directors have also the greatest satisfaction in seeing that the Class of Chemistry has been revived, and taught by Mr. Jackson, the Rector, with the utmost ability and success." In this same year a prize for natural philosophy was awarded to John Gairdner, and the following year, Alex Robertson received a silver medal for natural philosophy, one of the seven medals received by Provost Dunlop from Mr. James Johnston. The fees for natural philosophy in 1804 were 10/6 per quarter and for chemistry 10/6, while the fee for navigation was 1 guinea for a whole course. Mr. Jackson's term of office as Rector was brief, as he became Professor of Natural Philosophy at St. Andrews in 1809, and on his departure, he presented to Ayr Academy his chemical apparatus and theodolite.

(1) D. Patrick, Air Academy and Burgh Schule p. 145.

(2) Ibidem pp 70 et seq.

In, 1826, when there were 502 pupils (347 boys and 155 girls) in the school, Dr. Memes, the Rector, reported the introduction into the school of botany, a subject not previously taught there. Later, a botanic garden was laid out. On 21st March, 1827 he drew the attention of the Directors to the state of apparatus generally and especially in the Chemical Department, and in his letter (1) states,

"In Natural Philosophy - to the subjects of which Mathematical reasoning is applied when studied as it ought to be in such a Seminary as ours - the use of apparatus is not indispensable because Experiment is employed more for the purpose of illustration than demonstration. But in Chemistry the case is different. Experiment then constitutes the very essence of proof and often the truth of an instructive and important fact can be exhibited only by means of good apparatus. Hence the present difficulties under which this class in particular now labours. Notwithstanding every care on my part, and the considerable expense already incurred, the class must be discontinued, and in so far the reputation of the establishment be compromised, unless something effectual be accomplished and that immediately."

(1) Letter from Dr. Memes in possession of Dr. Ritchie the present Rector.

He continues that he is aware that the Directors have no funds at their disposal so he requests permission to spend £30 to £35 on chemical apparatus immediately and to recoup himself by delivering in the Academy a series of public lectures on "Chemistry with its application to the useful Arts."

Dr. Memes in 1844, relinquished the Rectorship, when he was inducted to the second charge of the parish of Hamilton.

Peter McDougal, who was master of the Writing and Mathematical School at Stirling from 1791 to 1846⁽¹⁾ "taught mathematics, including surveying, land measuring, dialing, gauging and navigation." It has been shown by his class registers that, in navigation, a number of his pupils were sailors.

In these days of keen interest in Nursery Schools it may be of advantage to study the methods suggested as a result of experience with young children over a century ago. These methods are described in a book printed in Aberdeen in 1829 and entitled Infant Play School for the Development of Five Senses, evidently translated from the German by W.L. Schonberg.

(1) A.F. Hutchison, Hist. of the High School of Stirling p.161

The keynote of the system was Personal Observation of Nature, as is shown in this passage:-

"At another time I conducted my children before a tree in order to consider it. After a few minutes we turned our backs to it, and I commenced as usual to ask, Was the tree as large as the fir tree at our house?, Were its leaves broad or needle shaped? Was there any fruit on it? Was the bark burst? In the same way I went on with the flower-beds, which furnished more queries."

Another part of the training of the children was to instruct them to distinguish strong smelling flowers and shrubs by their scent.

"For that purpose, pull them, and give them, wrapped up in thin linen or the like, to the child to smell and guess at. In the garden and walks, this is a very entertaining and useful game. Children learn in this way not only properly to know which are hyacinths, roses, violets, geraniums, gillyflower, but they also learn to endure the smells of wormwood, garden-cypress, rue, coriander, and other medical plants."

The measurement of volumes of liquids and solids and the measurement of lengths was also included in the training of the children. We are told, however, that, "the surest

best means of curing in children the fault of trifling, so generally complained of, is to introduce them early to an acquaintance with natural history. Collecting pebbles is the first and easiest occupation for them; here they may be always shown something new, which they may be made to wrap up and preserve. Above all others, the study of botany is adapted to awaken in children habits of attention, activity and order. Let them at first collect single leaves, which may be different in their forms - as heart shaped, oval, kidney-shaped, feathered and so on; in their edges - as serrated, teathed, sinuated; in their surface - as ribbed, hairy, smooth. After this follows the collecting of differently shaped flowers; and finally, the arranging of whole plants after they have been examined and named.

----- In this way, the development of the senses in children is its own reward, leading to a spirit of observation which we may repeat, is the basis of all learning and science."

Dollar Institution or John McNabb's School had been founded in 1818, and the Statutes and Rules published in 1828 detailed the duties of the various teachers:-

" 12. Teacher of Mathematics and Natural Philosophy.

He shall teach the following branches, viz:-

1. Elements of Geometry, Plane Trigonometry, Practical Land-Surveying and drawing Plans.

2. The Higher branches of Arithmetic, Algebra and higher Mathematics.
 3. Astronomy and Navigation, Ship-building, Gunnery and Fortification.
 4. A Course of Mechanics and other branches of Natural Philosophy applicable to the Arts, to be taught at an evening hour, and to be open to every person who shall obtain permission from the Trustees.
- 14 Teacher of Chemistry as connected with the Arts, etc.

The Trustees have it in view, as soon as circumstances will permit, to institute a regular Class for giving instruction in the following Branches of Knowledge, viz.

1. Chemistry, as connected with the Arts.
2. Natural History and Practical Mineralogy.
3. Gardening and Husbandry.

And in the meantime, if any properly recommended Scientific man can be found, who is willing to Lecture on any of these Branches free of expense to the Institution, and to take his chance of remuneration from the fees of admission to be fixed by the Trustees and him, a Class-Room will be appropriated in the Institution Building for his use, and every other facility at present in the power of the Trustees will be given to him."

In addition to the academical Teachers, a school of Industry was to be established and a Master for Rustic Manufactures, who, in addition to teaching basket making, wire working, best modes of making door mats, brooms and beehives was to be employed occasionally, "in making models and apparatus for the Classes of Mechanics, Chemistry, etc., under the direction of the Teachers of these classes when they shall be established, and will of course exhibit and explain them to such of the Pupils as can understand them."

In the Gardener's Magazine of October 1832, Mr. J.S. Menteth of Closeburn Hall, Dumfriesshire, wrote an article suggesting the teaching of gardening in the parochial schools, and at his request, James Rennie M.A., Professor of Zoology King's College, London published in 1834 a Handbook of Gardening for the Use of Schools and Self Instruction. Rennie was also the author of an Alphabet of Botany for the use of Beginners, which was the text book used by the botany class at Dollar. This book was published in 1833, was only 6 inches by $3\frac{1}{2}$ inches in size, and contained 123 pages. The various chapters deal with the plan of work, the word plant, skin or bark of plants, coloured rind, inner and special vessels, organs of plants, sponglets or suckers and finally

systemic^{at} arrangement of plants. An extract shows the scope. of the book:-

"The pulp vessels (in Latin cambium) were proved to be different from the sap vessels by Dr. Darwin who immersed plants of spurge in red fluid which he saw rise through the leaf stalk into the leaf and return white from the edges of the leaf. From chemical analysis and experiment, it appears that the chief matters taken up by plants besides water, consist of carbonic acid gas and azote, together with a few salts, such as potass, and out of these and the hydrogen and oxygen of the water, all vegetable products seem to be wholly or chiefly elaborated."

An arithmetic note-book written by a pupil at Perth Academy about 1835 is preserved in Glasgow University Library. It is somewhat similar to a book which was written in 1837 and which will be described later. There are examples dealing with lineal, superficial and solidity measures, and the pupil had to understand old Scottish measures and weights such as Trone, Dutch and French Troy, the first being used for butter, cheese, wool and hay. The Winchester bushel of 2150.42 cubic inches was also considered, and the French weights such as the "Chiliogramme or as it is sometimes written Killiogramme. There is a list of specific gravities including those of

gases or aerial substances" including atmospheric air (barometer 29.75 in., thermometer 32°) .00122, oxygen .001355 and hydrogen .000085 .

Some of the scientific calculations are of interest:-

"If 1572 grams of lead be suspended from one arm of a balance and an equal weight of marble of the specific gravity 2.7 from the other, what weight must be put in the scale from which the marble is suspended to restore the equilibrium when both the substances are immersed in pure water?

If a hollow brass ball 5 ft. in the inside diameter and $\frac{1}{2}$ inch thick were immersed in pure water, what weight placed in the inside would make it just float?

According to Mr. Boyle, 50 sq. ins. of gold leaf weighed only a single grain, what is its thickness?

If a spherical balloon 100 ft. in diameter were made of sheet Copper and filled with Hydrogen of sp. gr. .0001, what must be the thickness of the Copper that the balloon might just float in the atmosphere."

There is no sign of this work in physics being carried

out in practice, but the accompanying trigonometry is practical, such as determining the height of the chimney of Perth water works, and of Bellwood House above the level of the South Inch, and the distance between the steeples of St. John's and St. Paul's Churches.

Included in another manuscript note book written by a pupil of Perth Academy, apparently in 1835, and preserved in Glasgow also, ^{are} calculations on the mensuration of solids such as "to find the solidity of a cube." An important part of this book is concerned with Fortification. This was a subject mentioned frequently in the syllabus of the early academies, but as far as is known, this is the only example preserved of the work done. Fortification is defined as "the art of inclosing towns or other places with such works as may enable a small number of men to resist for some time a considerable army." Over thirty pages are devoted to this subject and there are numerous excellent coloured sketches. The teacher dealt in succession with outworks, ravelins, covert ways, glacis, tenailles, crown works, detached redoubts profiles and orillions. To exemplify these, the fortification of Hunningen on the Rhine was treated in detail with accompanying sketches. The dimensions are given in toises, where 1 toise = 6 feet. The book was surely not inspected

by the teacher as there is one, but only one schoolboy outburst, "Fig. 1 now comes Huzza! Huzza! "

This rather military subject is followed by the more peaceful one of Book-keeping by Single Entry. Such was the mathematical training of a pupil in 1835.

"The Examination Papers given at the visitation of the public Commercial and Mathematical School of Aberdeen in October 1835" were printed, and a study of these indicates the content of the subject matter. The paper given to the Geographical Class on Saturday 17th October 1835 consisted of the following:-

- I. Find the latitude and longitude of Dublin, Lima, Bergen, Okotsk and Quebec.
- II. What place has Lat. 39°N and long. 113°E ?
- III. What place has Lat. $22\frac{1}{4}^{\circ}\text{N}$. and long. 28°W ?
- IV. Find the Right Ascension and Declination of the Sun on December 1.
- V. When it is 3h.9' p.m. at Aberdeen what o'clock is it at Quebec, Berlin, Pekin and Astracan?
- VI. Find the length of the longest and of the shortest day at Petersburgh.
- VII. Find the length of the day and of the night at Aberdeen on October 31.
- VIII. Find the Right Ascensions and Declinations of Capella, Bellatrix and Markat.

6. Find the times of Rising, Setting and Culminating of Rigel at Aberdeen on Oct. 20."

On the following Monday, a paper of twenty five questions was given in descriptive or topographical geography then on the Tuesday another paper was given. This contained seventeen questions on descriptive geography, then the following questions.

- XVIII. Name the signs of the ecliptic and give the characters which represent them.
- XIX. What is meant by the terms lat. and long. of a star?
- XX. What is the prime vertical?
- XXI. What is meant by the term amplitude?
- XXII. What is the obliquity of the ecliptic?
- XXIII. When it is 2h. 3m A.M. at Aberdeen, long. $2^{\circ}5'$ W, what o'clock is it at a place in long. $40^{\circ}5'$ W?
- XXIV. Find how many feet there are in a second of space, allowing 70 English miles to a degree.
- XXV. A ship having on board a chronometer regulated to mean time at Aberdeen, $2^{\circ}5'$ W sails to a port, where, by an observation of the sun, the time of the day is found to be 1h. 2m. p.m. when it was 1h. 9m. A.M. by the chronometer. Required the long. of the port arrived at."

On Wednesday 21st October, 1835, the examination paper given to the Natural Philosophy class included the following typical questions:-

- I. If two bodies weighing 2lb and 5lb move with velocities of 12ft. per sec. and 8 miles per hour what is the ratio of their momenta?
- IV. If two bodies move over equal spaces uniformly, the one in 3" and the other in 4", what is the ratio of their velocities?
- VI. What space must a body fall through so as to acquire a velocity of 300ft per sec, and what is the time occupied?
- VIII. A body is projected upwards with a velocity of 200 ft. how far will it ascend in 3", and when will it fall to the ground?
- XI. Required the time of a body's descent down an inclined plane, whose length is 120 ft. and height 6 ft.
- XII. A cylindrical beam, 20 ft long weighs 30 lb. and is balanced on a fulcrum, after two weights of 5lb. and 7lb. are placed at its extremities. Required the situation of the fulcrum.
- XIII. What weight will be raised by a power of 5lb. by means of a wheel and axle; the radius of the former being 20ft. and that of the latter 5ft?
- XIV. What power will be necessary to raise a weight of 1000lb.

by means of a system of 5 moveable pulleys , where each pulley hangs by a separate string attached to the weight?

XVII. If two perfectly elastic bodies weighing 3lb. and 5lb. meet one another with velocities ^{of 20ft. and 25ft. per sec., what are velocities} after impact?

The Prize List is appended to the copies of the papers and in the Geographical Class one boy obtained full marks, 385. His name was Wm. Garden Blaikie. The other prize winners were Geo. Smith 366, Robt. Smith 313, Farquhar Milne 301, David Dunn 289. The answers to the questions are also given. In Natural Philosophy, Blaikie was again first, with 114 marks out of a possible 142, Barclay was second with 108 and Robt. Smith third.

Evidently the Natural Philosophy which was taught consisted merely of Statics and Dynamics and so differed from the broader treatment given at Perth Academy, as will be shown by examining a note book of a pupil there.

In 1837, some physical calculations which in later times were included in science teaching formed part of the instruction in arithmetic. This is shown in an old arithmetic note book written by James Blair at Perth Academy and preserved in Perth Museum. After work concerning weights is an "Appendix to the Weights" which begins thus:-

"The specific gravities of bodies denote the relative weights of equal bulks of the various kind of substances. It is usual to assume pure water as the standard of reference and to call its Sp. Gravity 1. The weights of a cubic inch of pure water, at the temp. of 62° is 252.458 Grains and therefore a cubic foot of ordinary running water weighs almost exactly 1000 ounces or $62\frac{1}{2}$ lbs. Avoir."

This is followed by a table of specific gravity,

- I. of Metals, e.g. Silver (pure) 10.500, Copper 8.508, Zinc 7.191.
- II. Earthy or Stony Bodies, e.g. Barytes 8.508, Zinc 7.191.
- III. Solid Substances of a Miscellaneous Nature, e.g. Amber 1.082, Beech .852, Wax (Bee's) .956.
- IV. Liquids, e.g. Acid Muriatic 1.184, Blood, (Human) 1.045. Oil (Whale) .923, Aether Sulphuric .7396.
- V. Gaseous Substances, e.g. Hydrogen .000099.

Various examples are worked, such as:-

"How many cubic inches of Sulphuric Acid of the Specific Gravity 1.925 would there be in 3 lbs. of it?"

A cask which when empty weighed 15 lbs. 5oz. weighed 106 lbs. 12 oz. when full of rum and when full of pure water weighed 111 lbs. 6oz. How many gallons did the cask hold; what was the specific gravity of the Rum; and what the proportion of water and spirit?

If a balloon in the form of a prolate spheroid,
"longer diameter of which is 30 feet and the shorter 20 feet
"weigh 100 pounds, what additional weight will it carry up in
"the atmosphere, when it is filled with coal gas of the sp:
"Gr: .456, that of the common air unity?"

These examples included in arithmetic teaching in 1837,
are somewhat similar to those included in science up to about
1922.

Other examples of a scientific nature included later
are:-

"If the human pulse make 70 pulsations in a minute
"and the velocity of sound be at the rate of 1142 ft. per
"sec. how far distant was a ship, the flash of whose guns
"was seen 35 pulsations before the sound reached the ear?

The distance of the planet Jupiter from the sun is
"490 millions of miles and that of the earth 95 millions: in
"what time will an immersion of one of Jupiter's satellites
"be perceived, after the actual occurrence of the phenomenon
"when Jupiter and the Earth are in conjunction, what is the
velocity?"

The method used in tackling problems may be studied
from the two examples which follow:-

"If the expansion of Iron be .00000678 for each degree
 "of Fahrenheit thermometer what would be the apparent length
 "of a line on being measured with an Imperial chain if it was
 "found to be 75 chains when the thermometer was at 80° supposing
 "it was again measured in winter when the thermometer is at 10°?

The difference of temperator (sic) being 70° the
 "subtraction is .00000678x70" .004746. Hence unity would
 "become 1-0004746=9995254. And since the number of chains
 "must be inversely as the length we have.

$$\begin{array}{r}
 \text{ch.} \quad \text{ch.} \\
 \cdot 9995254 : 1 = 75 : 75 \cdot 0056 \\
 \text{ch} \quad \text{L} \\
 = 75 : 0 \frac{56}{100} . \quad \text{Hence the line would be}
 \end{array}$$

apparently a little more than half a link longer.

What is the velocity mean, of the Earth in its orbit
 round the sun, its mean distance from that luminary being
 95000000 and the period for its syderial 365 D "6 H."11 M."53
 Sec?

$$\begin{array}{l}
 \text{Earth's orbit miles } 2 \times 59,000,000 \times 3.1415926 \\
 = 596902494 \text{ miles.}
 \end{array}$$

$$\text{Syderial year in seconds} = 31558313$$

$$\begin{array}{l}
 \text{Velocity per second} = \underline{596902494} \\
 31558313.
 \end{array}$$

19 miles nearly being about 100 times the velocity of
 a cannon ball."

It should be noticed that π is taken to seven decimal places.

At this time natural philosophy, except in mechanics was principally descriptive and calculations in this subject appeared in arithmetic.

Another book, also written in 1837 by James Blair at Perth Academy, and preserved in Perth Museum, deals with geometry. In it are trigonometry, calculations on heights and distances, then follows a section on The Measurement of Heights by the Barometer. It is explained that as mercury is about $13\frac{1}{2}$ times as heavy as an equal bulk of water which in turn is about 790 times as heavy as air, and consequently for which every inch the barometer falls as one ascends, there must be an ascent of 10664 inches or about 900 feet. "Example. If the pressure of a Barometer at the lower station be 28.772 and that at the top 27.855 how much is the the upper station above the lower?"

It is pointed out that this method is merely approximate and neglects the influence of temperature on both mercury and air and the elasticity of air, therefore each of these is then considered, and an example is given :-

"To determine the height of the top of Cairn-Ghour one of the Ben Gloc hills (and the highest) above the Manse

"of Mouline, the barometer readings being 26.403 and 29.708
"respectively. The temperature were 48° and 64° respectively
"for the barometer and 45° and 62½° for air."

It was worked out according to the formulae given,
the difference in height was found to be 3192.012 feet, and
"as the ground floor of the Manse Mouline is 498 feet above
"medium level of the German Ocean, it follows that the top
"of Cairn Ghour is 3690 feet above the level of the sea."

Much of the science, so-called, that was taught in
schools consisted of reading lessons on scientific subjects.
The reading books used were almost exclusively those written
by the Rev. H.M. McCulloch, A.M, Headmaster of Circus Place
School, Edinburgh, and later Minister of Kelso. They were
first published in 1837, and in 1895 they were still in use,
the First Reading Book having reached its 50th edition, and
the Second Reading Book its 49th edition. The miscellaneous
nature of the contents is shown by the index of the Third
Reading Book which included some doleful moral poetry for the
children, viz:-.

The Glow Worm.

Lucy Gray.

The Sin and Danger of Deceit.

The Senses.

Buds.

Cabbages.

Steam and Smoke.

Clouds, Rain and Snow.

The Swallow.

Meddlesome Matty.

The Child's First Grief.

The Dead who die in the Lord.

In 1827, Mr. McCulloch had published a Course of Elementary Reading in Science and Literature, which included Geography, Religious and Moral Pieces, Poetry, Natural Science and Natural History. Many of these lessons are extracts from writers of good standing e.g. "On the pleasures of Science" by Lord Brougham, but others were not. The subjects included in Natural Science are:-

General properties of bodies.

Attraction of Cohesion and of Gravity.

Pressure of watery fluids.

Capillary Attraction.

Atmospheric Air.

Properties of True Caloric.

Effects of Caloric.

The Winds.

Aqueous Vapour.

Light.

The Eye.

Simplicity of Nature - Simple Bodies.

Causes of Celestial Motions.

In Natural History the following are considered:-

The three Kingdoms of Nature.

The Malleable Metals.

Vegetation.

Floral Emblems.

Vegetable Clothing.

Adaptation of Plants to their respective places of growth

Structure and functions of mammiferous animals,

birds, amphibious animals, fishes, insects.

Circulation of blood.

The treatment of the subjects is shown by the following extracts:-

"Oxygen is a very subtile and elastic substance, generally diffused throughout nature, although never found unless in combination with other substances. There is scarcely a process whether natural or artificial, in which it has not some important share. When combined with caloric, it is called oxygen gas, which forms one of the constituent parts of the atmosphere."

"The phenomena which accompany the passage of caloric into substances, are expansions, liquefaction, vaporization,

"incandescence and combustion. These may be considered as all its effects, for the phenomena, that attend its escape from them, viz. contraction, solidification of fluids, and condensation of vapour are merely the converse of these."

Our survey of this period is continued from "Answers made by Schoolmasters in Scotland to Queries circulated in 1838 by order of the Select Committee on Education in Scotland," which show both the subjects taught and the text books used in each school.

Navigation is usually stated as a branch of the mathematics taught. Again it appears in inland schools, such as Kingussie, Castle Douglas, Moffat, Paisley Commercial and Mathematical School, Edinburgh Mathematical School, South Bridge (under Walter Nichol, A.M.) and Mathematical School, Infirmary Street (to pupils aged 14 to 20, under George Murray). In Beattie's Seminary, Ship Row, Aberdeen, nautical astronomy and navigation were taught.

Many of the schools mentioned as teaching navigation are now long forgotten, such as Brown's Academy, Queensberry Square, Dumfries, in addition to the Mathematical Department of Dumfries Academy. Of course, in those days, ships sailed up the Nith as far as Dumfries. Navigation was taught in Dundee by Andrew Greig in Bucklemaker Wynd School

and in R. Wighton's School in St. Clement's Parish, also in the Seamen's Fraternity School, Greyfriars, where 30 of the 50 pupils were seamen, aged 15 to 40. At Eärtsferry, there was "navigation for seamen", and at Tangovich School, Northmairne, Shetlands, "some grown up men attend in the winter session" to learn this subject, while at Perth, Thomas McIntosh, who had been educated in Kent, taught "at times navigation" in South Street School.

At Fortrose Academy, it was taught in addition to spherical trigonometry, land surveying and book-keeping, and at Mr. Fraser's School, Lennoxton, Campsie, where the pupils were aged 4 to 20 years, spherical trigonometry was also taught. At Longforgan, where the ages varied from 5 to 13 years, some pupils were taught navigation, and at Airth Parish Stirlingshire, where pupils were even 30 years of age, navigation was taught with nautical astronomy and the use of instruments.

The most popular text-books in use were Kiddle's, Norrie's, Hamilton Moore's, and Mackay's books on Navigation, with the addition in some schools of Norrie's Lunars, and Thomson's Lunar Tables. We shall examine these presently.

The navigation taught appears to have been of two varieties, in the burgh and other higher schools as a branch

of mathematics, (in the same way as dynamics is now taught), and in seaboard towns as a vocational training. Other vocational training in the schools at this time appears in land surveying e.g. at Fortrose, stenography e. g. at Ayton, book-keeping e.g. at Carmylie (5/6 per quarter by single entry and 7/6 by double entry), Dalbeattie and Airth, and architecture e.g. at D. Graham's School, Comrie, "taught to masons and carpenters."

Natural Philosophy was taught in Robert Gordon's Hospital, in Jules Legendre's School, Dundee (where the teacher had been educated in the College of Chartres), in J. Connell's department of Glasgow High School, in Andrew Robertson's class at Kelso (pupils aged 7 to 16 years), at Banff, and at Kinglassie, Fife, while at Elgin lectures on this subject were given by the teacher. At Cardross, Kenton Academy, it was treated under English, and at Paisley, Maxwelltown School, it was taught to pupils aged 4 to 10 years.

Mechanics was a subject in the Mathematical School, Infirmary Street, Edinburgh, at Holm, Orkney, at Glen-street Academy, Paisley, in Elgin, in Kinglassie, Fife and in Carnbee, Fife.

In some schools the instruction took the form of reading lessons under the teacher of English, and in these cases

the usual text book was Chamber's Natural Philosophy and Introduction to the Sciences, as at Cardross and at Borrowstowness (i.e. modern Bo'ness), but if dealt with by a mathematical master, the books used were Bland's Mechanics Bridge's Mechanics, or as at Elgin, Lee's Catechism, or the Introduction to Mechanics by the Society for Diffusion of Useful Knowledge or Bridge's Natural Philosophy as at the High School, Glasgow.

Elementary Science was taught in the Lancasterian School, Davie Street, Edinburgh, where there were 627 pupils, and Outlines of Science at Balmullo Subscription School, Leuchars.

Astronomy was a subject of instruction in Lochside School, Montrose, in R. Wallace's School, Blythwood Hill, Glasgow, where the text book was Laplace's *Mechanique Celeste* which had been preceded by Francoeur's *Cours des Mathematiques* at least such is the official report. It was taught also at Kilbarchan, Renfrewshire, as were the outlines of astronomy at Maxwelltown School, Paisley, (where the pupils were aged 4 to 10). Ewing's *Astronomy* was the text book used at Longforgan, (where the pupils' ages varied between 5 and 13), while at Lecropt the text book was Delambre's *Astronomy*, which had been preceded by Bonnycastle's *Plane and Spherical Trigonometry*.

Chemistry was taught at Jules Legendre's School, Dundee, and at Kinglassie, Fife. When the various Dundee schools were amalgamated to form The Seminaries, Legendre became teacher of French.

At Loanhead Subscription School, Lasswade, where there were 82 pupils, aged 4 to 13 years, "instruction is afforded in all the sciences but no practical instruction."

Gardening was a comparatively new subject, and it was professed at Dornoch, at McNab's School, Dollar (now Dollar Academy), at Path-head School, St. Mungo, Dumfriesshire, and in the same county at Good Hope School, Johnstone, "in the spring and summer months", while at Dumfries Grammar School, "the boys of their own accord have formed themselves into a horticultural and agricultural society and relish these pursuits." In the 2280 schools which were not parochial, mathematics was a subject in 683 schools, Latin in 501, geography in 1,141 and gardening, agriculture or any mechanical operation in 51 schools.

Out of 924 parochial schools, 36 taught gardening and while in only 689 was the subject of mathematics taught and Latin in 664, geography was in 761 schools, the usual text book being Keith's, "On the Globes". At Ayton (Alex. Moffat's school), "the pupils may have instruction in gardening, designs for gardens, etc."

Preserved in Perth Museum is a book of notes on Natural Philosophy transcribed by James Blair, a pupil at Perth Academy in 1838. This would be the first year of the teaching of Rector Millar, who had previously been Mathematical Master of Madras College, St. Andrews. The notes are beautifully written in ink, with the headings of sections extremely neatly printed. To maintain the neatness of his book, Blair had ruled lines in pencil.

The book begins, "That science which treats of the composition of, and the changes which bodies undergo without producing sensible motion is called Chemistry; that science which treats of all the other properties of bodies is called Natural Philosophy."

The section on Statics is treated mathematically, being a series of twenty eight propositions, e.g.

"Prop. XI. Find the centre of gravity of a pyramid.

Prop. XV. To find the position of equilibrium of a lever whose weight, dimensions, the weight in each scale and of course the preponderating are given."

The various matters dealt with are the lever, parallelogram of forces (with the triangle of forces as a corollary), resolution of forces, centre of gravity, equilibrium, "pulleys," wheel and axle, inclined plane, wedge,

screw, compound machines (compound lever, steelyard). He uses the word "momentum", instead of the modern word "moment", and the definition is given thus, "The momentum of a body estimated in reference to a point, line, or plane is the product of the body and its distance from the same." Prop. XII states, "If any number of bodies be placed in a straight line the sum of their momenta estimated in reference to any point in that line is equal to the momenta of the bodies collected at their common centre of gravity referred to the same point."

In many examples Blair makes use of proportion where we should use moments, e.g. in levers.

There are thirty seven propositions in the section on Dynamics and they deal with impact of bodies, motion, accelerated motion, motion on inclined plane, cycloidal motion simple pendulum, Harrison's or the gridiron pendulum, Graham's pendulum. Last came the section on motion of projectiles, which the lecturer completed by saying, "You may read Robin's new subject of gunnery or a short abridgment of it in Dr. Jackson's treatise on Machanics (sic) We cannot devote more time to Statics and Dynamics, but I beg to refer you to Bridge's Machanics, Gregory's Machanics, Hivel's Machanics, Playfaire's treatise on Natural

Philosophy." Teachers of science in 1838 evidently did not correct the note books of their pupils, hence the spelling in the passages quoted. This might even explain the term "momenta" mentioned already.

Hydrostatics composed the next branch studied, the subjects treated being communicating vessels, Bramah's hydrostatical press, pressure in fluids, floating bodies, specific gravity. The treatment of this section is by propositions also:-

"Prop. V. If a body float in a fluid and is in equilibrium the weight of the fluid displaced is equal to the weight of the whole floating body.

Cor. 3. This proposition indicates a way of raising sunk in deep water.

Let ABCD be vessel filled with sand until it sinks to the level MN let PR be a heavy body as a piece of ordinance sunk in the bottom of the ocean a person having descended in a diving bell attaches the chain QP to PR and then the sand in ABCD is thrown out and of course PR is thereby raised."

This corollary is illustrated by a very fanciful ink sketch showing a diving bell resting on the bed of the ocean where cannon, kegs and other articles and scattered around. From the diving bell a pipe is led to a small bell or helmet resting on the shoulders of a man who is to attach the chain.

The definition of specific gravity of a body is given as "the weight of a cubic unit of that body-----but "it will be more convenient to find the ratio between the "specific gravity of the body and some standard fluid such as "water, taken as a standard." The instructions for finding the specific gravity of fluids begin as follows:-

"Fill a phial with the fluid to be weighed up to a certain mark."

The hydrostatic balance is in use for many of these experiments, but mention is made also of the use of areometres and hydrometers, including Nicholson's hydrometer.

"The Expansion of bodies by Heat" is next studied, including the behaviour of water at 39° . The scale then in Common use for teaching purposes was Fahrenheit.

"Of the Thermometer" is the section dealing with the Air Thermometer then the advantages of the use of mercury and spirit of wine, followed by "On the Graduation of Theremometers". It almost reconciles a teacher to this error in spelling by pupils, when one discovers that the same mistake was common a hundred years ago. "The use of "spirit of wine in the thermometers was introduced by the "Florentine Academicians about the middle of the 17th century. Sir Isaac Newton made use of Linseed Oil instead

"of spirit of wine; but this, on account of its viscosity
"is not used, Dr. Halley suggested that mercury would be
"preferable to either and accordingly it is now universally
"used except for low temperatures."

"The one now used in France is called the Centigrade
thermometer." Next is considered "the capacities of bodies
for caloric," then Wedgewood's pyrometer, Sir John Leslie's
Differential Thermometer and the Expansion of Solids by
Heat, accompanied by a "table of lineal expansions answering
to 1° of Fahrenheit."

"The science which treats of the phenomena of
compressible fluids is called Pneumatics". First the
atmosphere is considered; "the predominant constituents
of atmospheric air are Oxygen, Nitrogen, formerly called
Vital Air and Azote;" then Elasticity of Air is discussed
and the explanation of certain Pneumatical Instruments,
the condensing syringe, the exhausting syringe, the air
pump (consisting of one or two exhausting syringes),
Syphon gauge, Smeaton's Pear Gauge, Smeaton's improvement
on the air pump, Cuthbertson's Air Pump, the common
sucking pump, the forcing pump, the syphon, Tantalus's Cup,
intermitting springs. Explanations follow of various

instruments and natural phenomena, the common bellows, sucking water up with the mouth, respiration, the action of chimneys, circulation of air in mines, nature of land and sea breezes in warm countries, trade winds and a ventilator. In the section "Of Latent Heat" is stated "by mixing 1 lb. of ice at 32° with water at 172° the result will be 2lbs. of water at 32° the water has lost 140° of heat." The value obtained with steam is 1049.4. Dalton's Table of the Tension of Vapour is given, then various laws ~~are~~ in relation to aqueous vapour at a given temperature and description of Sansure's Hygrometer (with hair) Anderson's Hygrometer (wet and dry bulb) and Daniel's Hygrometer.

Rain and Dew are next discussed then the Measurement of Altitudes by the Barometer, and examples given included sea level, Belmont Castle, Ben Lawers, Ben More, Leith Pier, Arthur's Seat.

Typical of the teaching of the time is the prominence given to the Steam Engine. Its history is traced from the suggestions by the Marquis of Worcester in 1663 and the engine of Captain Savoury in 1698, by Newcomen's Steam Engine to Watt's improvements. All of these are described in detail and illustrated with diagrams. The Throttle Valve, the Governor, the Self regulating Damper, and the Wind Mill are all described in a similar manner.

Hydraulics or Hydrodynamics is next treated in a few pages.

In Electricity the various phenomena are based upon possession or otherwise of "the electric fluid." "All bodies which cannot be excited are called nonelectrics."

"There are two kinds of electricity, each of which kinds is repulsive in itself but they mutually attract each other. They have been called the vitreous and resinous in reference to the non-conductors."

Cavallo's Electroscope (pithballs), Bennet's Electroscope (gold leaf), and Coulomb's Electrometer (torsion balance) are all described, then follow Fundamental Experiments, the Condenser, the Electrophorus, Cavallo's Multiplier, Bennet's Doubler, the Electric Fly, and the Electrical Bells, Mention is made of a Leyden Phial and of charges on glass, then there is consideration "Of the identity of the electric fluid and lightning, "Dr. Franklin's analogies, e.g.

- I Lightning dissolves metals, and so does electricity.
- VI Lightning dissolves or rends bodies (imperfect conductors) and the electrical spark will strike a hole through a card, or even through a quire of paper.
- VII Lightning often strikes animals dead, so does electricity. Dr. Franklin killed a turkey weighing

10 lbs.

Finally there is a note about the "Thunder Rod" then the conclusion states "when two plates, one of copper and another of zinc are united together, electricity is produced, and the two plates are in different states, the one positive and the other negative. This is the foundation of the Galvanic Trough." Evidently all the electricity which was taught consisted of Electrostatics.

The lectures on Natural Philosophy occupy 396, pages, of which 66 deal with Statics, 76 Dynamics, 71 Hydrostatics, and Hydrodynamics, 135 Pneumatics, and 48 Electricity. There are no notes on Magnetism, Optics or Astronomy, the remainder of the book being devoted to Differential Calculus and Mensuration of Surfaces.

The Academy in Dundee had been established in 1785 and closed in 1797, but it was revived in 1802 on receipt of the Webster bequest of £6000. The Public Seminaries were formed in 1829 (1) by the incorporation of the several Burgh Schools, the Grammar School, the English School and the Academy. In the Report on the Dundee Seminaries by a Committee of the Town Council in

(1) Burgh of Dundee Charters and Writs, 1880 p. 195.

September 1827, it is stated that natural philosophy is to be taught with the highest class 9 to 10 a.m. daily, and natural history and Chemistry with the 6th class from 10 to 11 a.m. while it is suggested that the elements of physical science contained in Mr. Brougham's Library of Useful Knowledge may be taught.

In an "Address to the Inhabitants of Dundee on the Unfinished State of the New Buildings and on the System of Education in the Public Seminaries," the Directors state the plan of education in 1834, and this contains natural philosophy and chemistry taught in the senior class of the Academy by Rev. Mr. McLaren. In the second session is a course of mechanics including statics and dynamics, with their application to machinery, etc., also hydrostatics, pneumatics and optics. "These subjects to be followed up by an outline of the principal facts in magnetism, electricity, galvanism, astronomy and chemistry."

Merchiston Castle was leased in 1833 by Charles Chalmers⁽¹⁾ as a boarding school and instruction was provided in science. This attracted boys who had intentions of entering the technical branches of the services and of industry. Wyville Thomson, the naturalist was one of the

(1) Scot. Ed. Jnl. 1936 p. 63. Charles Chalmers, by

first pupils.

When Forres Academical Institution was founded in 1829, ⁽¹⁾ navigation and natural philosophy were taught.

This school developed into Forres Academy in 1848.

The Scottish Naval and Military Academy was founded in 1825 ⁽²⁾ in James' Square, but was transferred to George Square, then to Royal Academy Buildings, Lothian Road. In 1832, there were 105 students under Capt. Orr as superintendent, while the chairman of the directors was Right. Hon. Lord Robert Kerr. The Mathematical Master was George Lees, A.M., whose duties included the teaching of natural philosophy and navigation. There was a wide range of subjects, from Classics, Italian and Portuguese, Arabic, Persian, Hindostanee to Book-keeping, Fortification and Military Exercises with the Firelock and Broad Sword.

Chemistry was taught in George Heriot's Hospital, Edinburgh, by means of a course of lectures in the winter of 1835. ⁽³⁾ In 1840, Alexander Jameson became teacher of practical mechanics, which was taught in the sessions

(1) J.B. Ritchie, Forres, it's schools and Schoolmasters.

(2) Report of Scot. Naval and Mil. Acady. 1832. p. 7.

(3) Wm. Steven, Hist. of Geo. Heriot's Hospital, pp. 157 & 310.

following that date. In George Combes' Lectures on Popular Education (1833), he states with regard to George Heriot's Hosiptal. "On 1st November, 1833, it was enacted "that the branches of education for the senior boys "shall be such as may be interesting to all these boys, "whatever may be their destination in after life,' and "among the branches enumerated are the first principles "of Natural History and Mechanical Philosophy."

At The Scottish Institution for the Education of Young Ladies, Moray Place, Edinburgh, lectures were given in chemistry by Dr. Reid, in 1835, ⁽¹⁾ and "the young ladies practiced many useful experiments." Lectures in natural philosophy were given by Mr. Lees whose "lectures were illustrated by experiments, in geology by Dr. Murray, whose "specimens were inspected," and in botany by Mr. Macgillivray.

This school had been commenced in 1834 by several teachers who had been carrying on their profession individually, and who decided then to co-operate in forming a school for young ladies, especially as there was at the time a demand for a wider education for girls, ⁽²⁾ "little attention having been devoted to the instruction of ladies

(1) Report of Scot. Institn. for Educn. of Young Ladies, (1835.

(2) Report, 1837.

in the many highly useful and now popular branches of science." The education now provided consisted of the "ordinary and the or^aamental branches of education with such a liberal course of instruction in the Physical Sciences as had not previously been attempted in schools." The fees charged were 20 guineas per annum and boarders were accepted at a charge of 40 guineas.

Dr. D. B. Reid, F.R.S.E., who delivered the lectures on chemistry was similarly employed in various Edinburgh educational institutions, so the following syllabus of his course (1) is of interest:-

Attraction - Chemical Action.

Heat - Liquefaction, etc. Electricity. Galvanism.

Chemical History of Elementary Substances.

Oxygen , Hydrogen, Water, Sulphur, Carbon, Chlorine,
Iodine, Alkalis, Potassium, Nitre, Soda, Salt, Ammonia.
Earths, Lime, Chalk, Baryta.

Common Metals.

Vegetable Chemistry - Gum, Sugar, Starch, Bleaching,
Dyeing, Oils, Soap.

(1) 1835 Report p. 20.

Animal Chemistry - Animal Substances - Albumen, Fibrine, Gelatine, Respiration.

Later, Dr. Reid reported (1) that he had introduced successfully the history of the Atomic Theory and several other parts of the subject, which had previously been considered rather difficult for elementary classes. Another innovation was a course of "select experiments," described in his own text book, "Rudiments of Chemistry with Illustrations of the Chemical Phenomena of Daily Life," and conducted principally with Tube and Flat Glass Apparatus.

The lecturer in natural philosophy, George Lees A.M., was another of the peripatetic science lecturers of Edinburgh and has been encountered by us elsewhere. The text book used was Lee's Catechism of Natural Philosophy. His syllabus (1) consisted of:-

"Properties of Matter, Elements of Mechanics, Pendulums, Central Forces, Movements of Heavenly Bodies, Motion and Pressure of Air, Acoustics, Theory of Music."

(1) 1837 Report p. 11 and 30.

The science lectures were given on Saturdays from noon till 3 p.m. and the course extended over a period of two years.

The 1850 report shows that Natural History, Physical Science, Astronomy and the Use of Globes were subjects taught by Mr. Anderson and a lecture course extending over four years consisted of Natural Philosophy, Chemistry (by Dr. Murray), Botany and Physiology (by Dr. Dubic), also Geology and Mineralogy (by Mr. Alex. Rose).

According to an advertisement in The Edinburgh Advertiser of 6th October, 1840 a rival school, "The Edinburgh Institution for Education of Young Ladies" in Charlotte Square provided lessons in Elementary Science including Astronomy taught by Rev. Mr. Graham, and at another institution in Great Stuart Street, West, Mr. Lees taught Popular Science on Wednesdays from 11 a.m. until noon.

The Annual Report of Edinburgh Academy for 1840 shows that in the seventh class, which was the highest class, the mathematics syllabus includes Surveying and Navigation, but apparently ^{no} ~~as~~ other scientific subjects.

(1)

A class in chemistry was begun at The High School of Glasgow in 1834, when a room was provided for instruction in this subject by Mr. Hugo Reid.

The prospectus for 1837-38 shows that there were seven departments in the school, Classical, Mathematical, English, Modern Languages, Writing Drawing, and Chemical. The Chemical Department, however, did not survive many years. The work of the Mathematical Department included the teaching of geography and natural philosophy. Mr. D'Orsey, the English Master, introduced the teaching of physiology into the school under the official title of "Reading in Morals and Physiology." In 1836 there were 13 pupils studying mathematics and 27 geography, while in 1841 these numbers had risen to 48 and 112 respectively. Over nine years, the average number of pupils studying in the second or advanced mathematics class was $3\frac{9}{10}$. In consequence, this class was discontinued in 1844.

Considerable detail of the teaching is obtained from "Proceedings at the Annual Distribution of Prizes given by Lord Provost, Magistrates and Council of the City of Glasgow to pupils attending the High School, September 25, 1840." In the English Department, the first class in

(1) Thos. Muir, Hist. of High School of Glasgow, p. 59.

the Junior Division, aged 7 to 9 years and containing 56 boys, studied natural history on Tuesday and Thursday, 10 to 11 a.m., the book used being Parley's Natural History. The second class, aged 8 to 10 years, from 11 a.m. to 12 noon studied elementary science from Chambers' Introduction. "The popular and instructive parts of geology, zoology and botany were made perfectly intelligible by means of the black-board coloured drawings, specimens, etc." The third class, aged 9 to 11 years, from 1 to 2 p.m. on Monday and Wednesday carried on reading in elementary science, then towards the end of the session they used Dr. Hamilton's book on Animal Physiology, "which, when properly explained and illustrated, was found to afford the combined advantages of interesting lessons in technical language and valuable information as to the conditions of bodily health." The Prospectus for session 1841-2 states that this subject was commenced in 1839-40. Prizes were awarded for Introduction to the sciences to Andrew Maxwell and John Fleming, and for Collection of Minerals to James Wilkie.

Two classes were held, junior and senior, by Mr. Connell in Physical Geography and Astronomy, also Use of Globes. In the senior class, the work embraced Climate, Winds, Clouds, Volcanoes, Earthquakes, Currents, Universal

Gravitation, Motions and Appearances of the Bodies, composing the Solar System, The Seasons, Tides, Eclipses, and Fixed Stars.

The class in Natural Philosophy was conducted by Mr. W.M. Buchanan and contained 14 pupils, out of a school roll of 865. The text books used were Wood's Mechanics and Bridges' Natural Philosophy, and the course covered Composition and Resolution of Forces, the Mechanical Powers, Centre of Gravity, Pendulum, Rectilinear and Rotary Motion of Bodies, Theory of Projectiles. In Hydrostatics were studied the Laws of Fluid Pressure, Floating Bodies and Specific Gravity. A gold medal was awarded to the best scholar in the class, John Elder. An examination paper is appended, and it contains the following questions:-

"How far will a stone descend in 5 secs., and through
"how many feet will it pass during the last second of it's
"fall?

"A weight of 8 lb. is sustained on the face of a
"plane inclined to the horizon at an angle of 30° by means
"of a force acting parallel to it's base, required the mag-
"nitude of the force.

"A cannon being fired at the enemy from the shore,
"the ball just grazed the top of a mast 90 ft. high, belonging

"to a ship 600 ft. from the piece; continuing its course
"it struck the admiral's ship the instant he heard the
"report. Required the distance between the ships.

"A cylindrical vessel whose base contains 90 sq. ins.,
"and whose altitude is 4 ft., is filled with mercury, what
"is the difference in pounds between the pressure on the base,
"on the curve surface, and to what distance would the fluid
"spout on a horizontal plane from an aperture 10 ins. from
"the ground."

The method of instruction in the Philosophical
Department is explained. "The mode of teaching is strictly
"inductive. The subject of the lesson is illustrated at
"every step by appropriate experiment, and reference to
"fundamental knowledge. The pupils is thus taught to
"reason on the phenomena before him, and to draw his con-
"clusions from data evolved under his own observation, and
"in many cases by his own manipulations. He is led to
"acquire a knowledge of facts and principles adapted to his
"capacity and progress, and being accustomed to take nothing
"for granted that should be proved, he learns the art of
"analysing evidence, and lays a solid foundation for future
"acquirements."

The Natural Philosophy class was held from 12 noon
to 1 p.m., and the work included Acoustics, Optics,

Electricity and Magnetism. Prizes were awarded to James Simpson and to Andrew Melville. We are told that, "the behaviour of the pupils of this class was very satisfactory."

The class in Chemistry was held from 9 to 10 a.m., and dealt with the second part of Dr. D.B. Reid's Text Book for Students. "The mode of teaching was, as far as possible practical. The subject of the lesson was invariably illustrated by experiments, of which the pupils commonly performed the manipulations. They were thereby not only rendered familiar with the distinctive characteristics of numerous chemical products but also with the phenomena attending their chemical actions."

Later in the session, organic chemistry and qualitative analysis were studied, and the tests and antidotes for various common poisons were "pointed out and detailed." Prizes in this class were awarded to James Simpson and Robert Thom.

The Government began to give "annual grants in aid of education in 1834. The first grant amounted to £20,000, which was continued till 1839 when the Committee of Privy Council on Education was instituted." (1)

Minutes of the Committee of Council on Education were issued first in 1839-40, and the first mention of science

(1) J.Mackintosh, Hist.of Civilisation in Scotland, IV p.325.

is contained in the reports of 1842-3 by Mr. John Gibson,
X one of the first two H.M.I.S. in Scotland. He mentioned
(1) that several teachers, out of their own limited income,
had spent a considerable sum of money on supplying apparatus
and "had exercised no small share of mechanical skill and
"dexterity in the construction of apparatus suited to ill-
"ustrate the lessons on natural philosophy and chemistry.
"The schoolmaster of Greenlaw deserves special commendation
"for this. He has constructed a complete set of electrical
"apparatus; he has made very admirable models of several
"useful machines, he has collected a large assortment of
"interesting natural objects, and has arranged them in
"beautiful order in the school room to which they impart
"somewhat of the air of a museum. The parochial teacher
"of Dunse, also has a tolerably complete set of chemical
"apparatus, with which he illustrates the various lessons
"on chemistry." There was also a large supply of apparatus
in the school at Gordon.

We receive an idea of the education of that time
when we learn that of the 120 pupils at Greenlaw, 13 studied
grammar, 14 geography, 107 writing, 41 arithmetic, 5

(1) Minutes 1842-3, pp, 689. et seq.

X Mr. Gibson's services were dispensed with when he left
the Established Church at the Disruption of 1843, but he
was appointed Superintendent of the Free Church Education
Committee. Soon after this he was appointed H.M.
Inspector of Free Church Schools.

mathematics and 3 Latin. At Dunse, in a room measuring 36 feet by 19½ feet, there were 80 pupils, taught by a Mr. Mercer, who, with the older pupils had carried out a series of experiments, "in illustration of the principles "and more imported parts of natural philosophy and "chemistry."

An outstanding school at Edinburgh at this time was the Lancasterian School, ~~Dalry~~ ⁽¹⁾ Street, where there were 600 children under a headmaster, Mr. Dun, who had himself bought "a considerable assortment of philosophical "apparatus, with which he performs before his pupils the "more useful and interesting experiments in chemistry and "natural philosophy." No teacher of the present day would care to exchange places with his son, Mr. Robert Dun, who with only one assistant, taught the 200 older boys. Natural Philosophy was one of the subjects taught to four combined classes of boys and girls from 12.20 to 1.15 p.m. Botany was taught to them, "from a web of cloth painted "with botanical figures."

(1) Ibidem, p. 742.

*

Mr. John Gordon, the other H.M.I., reported
(1) a "remarkable acquaintance with the Principles of
"Natural Philosophy, which is displayed in the well
"conducted parochial school of St.Ninian's."

One of the most advanced schools of this period
was Dollar Academy, (2) which had been opened in 1821.
Various scientific subjects had been taught, but
chemistry was dropped after a short time. In 1839,
however, lectures on botany had been commenced, and
were attended by about 15 pupils each year. The
lectures were given by the gardener, John Westwood,
whose salary of £75 included £15 for these lectures which
took place three hours per week in May, June, July and
part of August. Six of the pupils were apprentices
in the garden.

* John Gordon was in 1825 appointed secretary to Educa-
tion Committee of the General Assembly, (3) and was
secretary of Edinburgh University from 1834 to 1843.
He edited the New Statistical Account of Scotland
which was published in parts from 1834 to 1845.

(1) Minutes 1845, p. 332.

(2) *Ibidem*, pp. 344. et seq.

(3) A.Grant, Story of Univ. of Edinburgh II p.58 and
Scotsman, May 19, 1936.

"The course of instruction comprehends the terms
"applied to all the parts of a plant with their various
"modifications, the systematic arrangement of plants
"and the principles of Linnaean botany in connection
"with the above. The whole course of instruction is
"illustrated by actual examples taken from the garden
"and fields."

The text book for the theoretical part of
botany was Rennie's Alphabet of Botany.

The senior mathematical class in the previous
session had received from the teacher a series of
lectures including "the theory of gravitation; the
position of our globe in space, and its relation to
the other planets; the phenomena of eclipses." The
salary of the janitor included £5 for "keeping the
rain gauge and barometer."

In 1844, grants had been given for schools
apparatus, ⁽¹⁾ and a list is given of apparatus approved
for this purpose. This list is of interest in showing
what had received official approval for the teaching
of science in schools. It includes:-

(1) Minutes 1844, p. 113.

(a) From Thomas Varty, 31 Strand, London.

A set Mechanical Models. 63/-

Simple chemical apparatus used with Johnston's Catechism to find the Qualities of Soils, etc. 31/6

Diagrams in Natural History, set of 20 sheets, 15"x12", coloured, 40/- a set.

(b) From Taylor and Walton, Upper Gower Street.

Set of 15 large plates (Mechanical Diagrams) in sheets - 15/-.

Atwood's Machine for explaining the laws of falling bodies - 42/-.

Set of Mechanical Powers, £1:5 and £2:6 per set.

The Bent Lever convertible into a Bent Lever or Toggle Joint,

Press 10/-.

A Train of Spur Wheels. 21/-

A double Inclined Plane, etc. 10/-

A Sectional Model of the Steam Engine. 42/-

Griffin's Chemical Apparatus for a Student. 46/- in packing case.

(c) From The Society for Promotion of Christian Knowledge.

Mechanical Models, 25/-, 46/-, 92/-.

Diagrams in Natural History mounted on roller and canvas, 4'6" by 3'8", plain 7/- coloured 10/-.

Prints of animals, 1/3 per dozen, in sheets, not mounted.

Glasgow Western Academy was opened in 1842 with Robert J. Nelson, M.A., as Classical and Mathematical Master. In the Prospectus for session 1842-3 included in mathematics are the applications to mechanics, hydrostatics, astronomy and natural philosophy in general. Text books in use were Whewell's Mechanics, Blands Hydrostatics, Thomson's Geography, Keith's Globes, Taylor's Elements of Zoology.

The Disruption of 1843 had a disturbing effect on Scottish education. Many parochial schoolmasters who seceded from the Established Church were deposed because they refused to sign the Confession of Faith and Formula of the Church of Scotland. Among these were ⁽¹⁾ Wm. Scott, Carmyllie, Wm. Mackenzie, Barry, Wm. Steele, Arbroath, Wm. Poole, Borgue Academy and Alex. Paterson, Lauder. By 1844, the sum of £52,000 had been raised for Free Church Schools and 120 schools had been opened. The number increased until in 1860 there were 621 schools. The Free Church maintained grammar schools at Inverness, Oban, Hamilton, Arbroath and Campbeltown.

The next record of the work done in schools is contained in The New Statistical Account of Scotland published in 1845, though the various accounts had been

(1) Government Report. 1844.

drawn up a few years previously. The descriptions in this publication are not as detailed as those in the previous purely educational returns which we have been studying, but it also gives us an insight into the social conditions of the period.

We still find navigation an extremely popular subject in the seaboard towns and in the academics, e.g. Ayr, Perth, Arbroath, Banff, also in both Stirling High School and Stirling Writing School. With regard to Sorbie, Wigtownshire, we are told that "one of the schools of Garlieston has been long famous for navigation and the practical branches of mathematics," and at Greenock, Grammar School, mention is made of Mr. Colin Lamont, teacher of the mathematical class. ⁽¹⁾ "It is believed "that he was the first in Scotland to introduce into public "schools the application of modern astronomy to navigation. "So early as in the year 1785, he gave instructions in "nautical astronomy and the use of the instruments nec- "essary for ascertaining a ship's place at sea, by lunar "observations and chronometers. With this view he had a "place fitted up at his own expense, and provided with "suitable instruments, including a 3½ feet telescope,

(1) VII p. 486.

"astronomical circle, clock, etc., for which, so far as
"we have learned, no remuneration has yet been made to
"him. He retired some years ago, after having for many
"years discharged the duties of his office with great
"credit to himself and advantage to the public."

Very frequent mention is made of practical
mathematics and this is defined at Pitsligo⁽¹⁾ as men-
suration of surfaces and solids, which, after all, has only
comparatively recently ceased to form the first year of
science instruction in schools.

Astronomy was taught at Selkirk, at Perth Academy,
and at Sandwich, Orkney.

At Ayr Academy, Perth Academy and Dundee Academy,
natural philosophy was taught, while at Elgin Academy,
(2) "a course of lectures on natural philosophy is
"occasionally delivered, and illustrated by a neat experimen-
"tal apparatus, partly public and partly the property of
"the mathematical master," and at Inverness Academy, "the
"elements of mathematics and philosophy," were included.
At Midcalder, mechanics was a subject taught and we find
at Alloa Academy, (3) "the various departments of practical

(1) XII p. 404.

(2) XIII p. 21.

(3) VIII p. 61.

"and theoretical mathematics, including the higher departments of analytical geometry, trigonometry and theoretical mechanics."

Chemistry appears among the subjects taught at Perth Academy and Dundee Academy, while at Falkirk we find botany, geography and animal physiology. The elements of mathematical science were taught at Longforgan, and at Sandwich the outlines of natural history.

At the parochial school, Kinghorn,⁽¹⁾ where the number of pupils averaged 120, a museum had been established, "well furnished with good specimens of mineralogy, geology, zoology, conchology, and anatomy. There are also a few good casts from the busts of eminent men, such as Sir Isaac Newton, Franklin, Watt ---. The children are taught the uses of the various specimens which the museum presents to their youthful inquiry, and thus they receive an initiatory knowledge of geology, mineralogy, etc." We have here an indication of the method of teaching in a school other than an academy.

At Dollar Institution,⁽²⁾ classes for geography and botany were taught during the summer months and we find, "Besides an extensive lawn around the public

(1) IX p. 816.

(2) VIII p. 98.

"building, the grounds on the north of the academy park,
"consisting of several acres, have been formed into a
"garden and nursery where every kind of culinary and hor-
"ticultural produce, besides shrubs, trees and flowers are
"raised. A certain number of the pupils of the academy,
"who have finished their general education are allowed
"to enter the garden as apprentices, where, under the
"supervision of an experienced and scientific gardener,
"they are instructed in all the branches of gardening.
"They also attend a class for drawing in the evening, and
"with some other pupils, both male and female, receive
"lessons in botany from the master gardener. In this way
"they become qualified for places in gentlemen's gardens."

In those days when education was not free, it must have been hampered by the want of employment in 1820, when weavers were engaged to make roads, and by the extreme drought of summer 1826, when, just as before in 1799 and 1800, the failure of crops was general.

Communications at that time did not favour daily travelling to school from a distance, as is so common now. In 1799 a stage coach with four horses commenced the journey from Glasgow to Edinburgh, and covered the distance of 42 miles in 6 hours, and in 1833, 61 stage coaches

departed from Glasgow daily, while of Neilston we read: "At present there are neither canals nor railways in the parish; but if the present mania for railways go on, we shall probably have one from Ayr, Troon, Kilmarnock, and Irvine, running through the whole length of the parish." In 1826, a railroad from Dundee to Newtyle began to be constructed, and the Edinburgh, and Glasgow Railway was opened in 1842.

In consequence of the lack of facilities for travelling, pupils boarded at various popular schools in order to obtain higher education, thus at Dalkeith grammar school in 1828, ⁽¹⁾ a house had been built specially for boarders. This provided a welcome addition to the income of the teachers concerned, and one of the most fortunate appears to have been the schoolmaster at Eddlestone ⁽²⁾ near Peebles, who in addition to his salary of £34 and fees of £42 kept 37 boarders at £25 to £30 each, and from this source alone obtained £500 to £600. Others, however, were not so fortunate, especially the schoolmaster of Portpatrick ⁽³⁾ who "was obliged to keep an ale house to help

(1) I p. 523.

(2) III p.152 and Abstract of Educn. Returns (Scot.) 1834.

(3) Return from the Sheriffs 1826, pp. 973, 81 and 450.

"to support his family" at a time when his fees amounted to £7:17:8 for the year plus 100 merks Scots, and the schoolmaster of Rathen, Aberdeenshire, in addition to fees of about £13 had an awkward salary to obtain, namely "one fish from each boat's^t crew every day they are at sea," although he might have preferred an occasional exchange with the teacher at Leuchars, who enjoyed the use of 5 acres of rabbit warren.

In those days there was no "education for leisure" when the employees in the cotton mills at Lochwinnoch (1) worked a 69 hour week, while at Balfour the hours of the handloom weavers were 6 a.m. to 8 p.m. and their earnings, after deducting all expenses, were less than 6/- per week.

Praise of Scottish teaching is made by Horace Mann, Secretary of the Board of Education, Massachusetts, U.S. in his Report of an Educational Tour in Germany and parts of Great Britain and Ireland, which was published in 1846.

(2) "I do not exaggerate when I say that the most "active and lively schools I have ever seen in the U.S. "must be regarded almost as dormitories, if compared with "the fervid life of the Scotch schools; and by the side of

(1) New. Stat. Acc. VII p.104 and VIII p.294.

(2) P. 61.

"theirs, our pupils would seem to be hibernating animals, just emerging from the torpid state, and as yet but half conscious of the possession of life and faculties. It is certainly within bounds to say, that there were six times as many questions put and answers given in the same space of time, as I ever heard put and given in any school in our own country."

For several years there had been a general desire for the teaching of elementary agricultural chemistry in country schools, ⁽¹⁾ "some thinking that, by giving to the young a knowledge of the elements of the science, the practice of agriculture would, in due time profit; others, that education would be improved by taking more of a scientific and practical character; others again, that by the interest of that subject, the school might become more attractive, not only for that, but for other things besides, among those classes by which it is at present so much neglected." It had been successfully tested previously in England and Ireland.

A public meeting to discuss the matter was held in October 1844 at Glasgow, and an "Agricultural Education Committee" was formed, mainly of members of the Highland and Agricultural Society. The parochial schoolmasters

(1) Minutes of Comm. of Council on Educn. 1846. p.477.

of Scotland next held a meeting in Edinburgh, and decided it desirable "to introduce this branch of science into the course of school education," and asked the help of the Agricultural Education Committee in the achievement of their purpose. In order to prepare the schoolmasters for teaching this new subject, Professor F.W. Johnstone compiled a book called "The Catechism of Agricultural Chemistry" and delivered a course of lectures to illustrate the Catechism and the methods of teaching the subject. Over 300 schoolmasters attended the course held at Edinburgh. Similar courses were conducted at Ayr and Dumfries.

This subject met with considerable success, and by 1845, it had been introduced into 74 schools, the majority of which were in Ayrshire, but difficulties were encountered. Some of the masters were not disposed to commence it, many were not acquainted with the subject, and the people were indifferent to it. The popularity of the Catechism, however, can be judged by the fact that in 1845, it had reached the fourteenth edition.

The Catechism of Agricultural Chemistry and Geology by James F.W. Johnston, M.A., F.R.S. was published in Edinburgh in 1844, and dedicated to the Schoolmasters

and Teachers of Great Britain and Ireland. It is stated that any little apparatus the teacher may require will be readily obtained at the cost of a few shillings. As the title indicates the book is written in the form of a catechism, e.g.

"Question - What is Hydrogen?

Answer - "Hydrogen is a kind of air or gas which burns
"in the air as coal gas does, but in which a
"candle will not burn, nor an animal live, and
"and which after being mixed with common air,
"explodes when it is brought near the flame of a
"candle. It is also the lightest of all known
"substances."

This shows the standard of the book, which consisted of only sixty four pages. Other gases such as oxygen and nitrogen were treated similarly, e.g.

"Q. - What is Chlorine?

"A. - Chlorine is a kind of air, which has a greenish
"yellow colour and a strong, suffocating smell. A
"taper burns in it with a dull smoky flame. It
"exists in common salt in like quantity."

Lime, potash, soda, magnesia, iron, oxide of iron and silica were next considered, then acids, after which is a chapter Of the Organic Food of Plants.

"Q. Do plants require food as animals do?

A. Yes, all animals require constant supplies of food in order that they may live and grow."

Q. Do the leaves suck in this carbonic acid at all times?

A. No, only during the day time. During the night they give off a quantity of carbonic acid."

Another chapter is entitled Of the Substance of Plants including woody fibre, starch and gluten, e.g.

"Q Is it not a very extraordinary thing that liquid water, which puts out fire should consist of two gases, one of which (Hydrogen) burns readily, while in the other (Oxygen) bodies burn with great brilliancy?

A. Yes, it is very wonderful but there are many other substances, the composition of which is almost equally extraordinary.

Q. Can you name any such substance?

A. Yes, it is almost equally extraordinary that white starch should consist of black charcoal and water only, and that sugar and gum should consist of the same elements as starch and woody fibre."

The next subjects are the inorganic food of plants, the manuring of the soil, the composition of the crops which the farmer reaps and uses of the crops in feeding.

This book was so popular that it reached a 23rd edition in 1849 that is within the space of five years. In addition a special edition was published in U.S.A. in 1845.

1843. Johnston also published "The Elements of Agricultural Chemistry and Geology" in 1842 and ^d12 th. edition of this book was published in 1881.

In recommending the study of Nature Science as a subject of study at Aberdeen Grammar School, it was stated by Professor Blackie (1) in 1846 that the power of accurate and vivid description would find an interesting subject "on which to assay its first unsteady flights," also, "as the scientific language of Natural History is to this day Latin, a grand storehouse is forthwith opened, from which the young classical scholars can be supplied with a copia verbum, and with easy instructive subjects also for early essays in Latin composition. Of all things , therefore, when the Grammar School is extended and reformed, let Natural History be introduced, not indeed as a principal (for that is not necessary) but, as a subsidiary matter; and the person who should be called on to superintend this branch, can be no one more conveniently than the teacher of English; partly, because the Latin, masters will be otherwise sufficiently employed, partly, because the art of description which is essentially belongs to it, is a most useful and natural element of English composition in its earlier stages; partly,

(1) Report on the Grammar School and other Educational Institutions under the patronage of the Town Council of Aberdeen 1854 p. 21.

because the attainment of a little knowledge of this subject is so easy, that no teacher has a right to complain of its being made subsidiary to his own peculiar qualification"

These benefits would be derived, he stated, in addition to the eye/^{being}trained to observe and discriminate, "besides the smattering of natural science, which is a very secondary consideration."

At Irvine Academy, in 1846, "in the Junior Classes, the science of Zoology is taught by an interesting collection of the pictures of animals and of preserved insects and reptiles"; evidently, only what we should term Nature Study; but at Kilmarnock Academy, in the Commercial and Mathematical Department were taught Geography, Astronomy and Natural Philosophy. The text-books which were used included Reid's Astronomy, Whewell's Mechanics, Wood's Natural Philosophy and Newton's Principia. At Ayr Academy, the books used were:-

Use of the Globes - De Morgan, Keith, Walker, Ferguson, Geography - Angus' Geography, Thomson's Complete System of Modern Geography, and to be got out of the library. - Malte Brun, Bell's, Murray's Geography, also Balmain's Lessons on Chemistry.

An idea of the books in common use may be obtained from a Minute dated 18th December, 1847, (1) which

(1) Minutes 1847-8 pp. XVI XXIX and XXXVIII.

authorised grants for the purchase of lesson and text books and maps for Elementary Schools. Some particulars concerning the books are given, and included in the list are:-

		<u>Pages</u>	<u>No. of Woodcuts.</u>	<u>Price</u>
Rudiments of Animal Physiology-	Chambers' Educnl. Course.	108	39	1/6
" " Vegetable "	Do.	128	88	1/6
Catechism of Agriculture, Chemistry & Geology.	J.F.W. Johnstone	64	17	10d
Laws of Matter & Motion.	Chambers	82	26	10d
Mechanics	Do.	86	87	10d
Principles of Nat.Phil.Part I.	No.7 of Scottish School Book Asscn.	178	90	1/9
Hydrostatics & Hydraulics, Part II.	Do.	186	101	2/-
Introduction to the Sciences.	Chambers	132	50	1/-
Lectures on Astronomy.	Hugo Reid	165	-	2/6
Outlines of Astronomy for Families and Schools.	Rev.J.Hall	80	-	10d

Among the maps etc. are mentioned Illustrations of Natural Philosophy, published by W. & A.K. Johnston, 4'2" x 3'6", coloured and mounted on cloth and rollers, price 10/-

In 1848 were held examinations (1) by which school-masters could obtain certificates entitling them to conditional augmentations of salary, that for a Third Class Certificate being £15 to £20, for a Second Class £20 to £25, and for a First Class £25 to £30. The only scientific subject, apart from Mathematics, required for a Third Class Certificate was General Geography, with the descriptive, physical and historical geography of the British Empire and Palestine. The Second Class examination included Practical Mathematics (a. Mensuration of Planes, b. Land Surveying, c. Levelling), Elements of Mechanics (from Tait's Elements of Mechanics), and Popular Astronomy (from Hugo Reid's book). For a First Class, Elements of Mechanics (from Lardner's Treatise) formed one subject, and Astronomy (from Herschel's Treatise) another.

In the examination in Mechanics, set at Glasgow, occurred the following questions:-

- "1. How many tons of coal will an engine of 3 horse power raise per hour from a pit whose depth is 120 fathoms?
2. A train of 80 tons moves at the uniform speed of 20 miles per hour, on a level rail whose friction is 6 lbs. per ton: required the horse power due to friction."

A "Broad Sheet for Teachers" was issued stating the minimum salary to be paid. The lowest permitted for a master when no house was supplied was £40 per annum, and for a mistress £26. A "Broad Sheet for Apprentices" laid down the annual payment of Pupil Teachers at the end of each year of their five year's apprenticeship to be £10, £12¹⁰, £15, £17 and £20 respectively, and stipulated that they must be at least 13 years of age. Stipendiary monitors served four years, and rose from £5 to £12¹⁰ per annum.

In the General Examination of Schoolmasters (Scotland), held in Autumn, 1849, (1) we find the following questions typical of the examination:-

(2) Geography and Popular Astronomy.

Section 5.

1. Why is the arctic circle drawn where it is? What peculiar phenomena are to be observed within it?
2. What is the density of the sun as compared with that of the earth?
3. State precisely the cause of an eclipse of the sun, and at what times it must necessarily happen.

Mensuration, Trigonometry and Elements of Mechanics.

Section 5.

(1) Minutes 1848-49-50.

(2) Ibidem pp. CCCXXII 742 and 568.

1. What is meant by the resolution of a force; and how may a single force be represented by two or more other forces?

Section 6.

1. What are Newton's laws of motion?
2. A piece of gold weighed 81 grains on one end of a false balance, and 64 grains on the other end; what was the true weight, and the relative lengths of the arms of the lever?
3. Explain the simple pendulum; what is the connection between the length and the time of vibration?

The students in the Free Church Normal Training School, Edinburgh, received instruction in Chemistry from Dr. John Murray, two hours per week. They "proceeded with the subject as laid down in McCulloch's course of reading, Chemical attraction, heat, agricultural chemistry, experiments and diagrams".

In a report on Milne's Free School, Fochabers, Elginshire, a school opened in 1846, Mr. John Gordon, H.M.I., stated that the English master had occasionally given lessons on the principles of agricultural chemistry but there had been a cessation of these for a few years.

It was intended, however, to resume these, and owing to the skill of the teacher and the provision of sufficient apparatus, the lessons were likely to meet with success.

"One cause of the little progress that has been made in this branch of instruction elsewhere is, that it has been given to too young a class of pupils; (1) whereas it had better been reserved for those about to leave school, and for other young persons already occupied in agriculture work. There is reason to expect that this branch will soon receive here the attention due to its practical uses, and at the same time to its interest merely as an element of knowledge".

The subjects allocated to the rector of this school were Latin, Greek, French, Mathematics (pure and practical), the practical parts of Natural Philosophy, the outlines of Astronomy, English Composition, and History. The number of pupils in the various subjects were Latin 17, Greek 4, French 8, Mathematics 7, English grammar 80, Geography 100, Arithmetic 200.

In the General Report for 1850 on schools of the Established Church of Scotland, Dr. E. Woodford stated that, "the subjects of physical science receive so much attention that, in some schools, common reading and spelling appear to suffer by it".

(1) Minutes 1851 p.842.

In Lauder School (88 pupils) were chemical apparatus and mineral substances, presented by the Earl of Lauderdale, while in the Madras Academy, Cupar, (490 pupils) were chemical and other apparatus. The Dunbar Mathematical School had been well attended formerly, but in 1850 there were only 5 pupils. It was well equipped with philosophical apparatus, also chemical, electrical and astronomical instruments. The inspector had been shown a large number of worked solutions in astronomy and navigation, performed by pupils in previous sessions.

In a note book written about 1850 by James Christie at Dundee High School, we find records of lessons on various branches of mathematics and "Natural or Mechanical Philosophy". This consisted of Statics (59 pages), Dynamics (19), Practical Gunnery (2), Central Forces (6), Hydrostatics (17) and Pneumatics (4). A practical problem in the section on centre of gravity is, "to find the centre of gravity of an inflexible physical straight line or a small rod of uniform density and dimensions". "The Tackle" is a compound pulley, but the "Spanish Barton" is a peculiar arrangement of a rope passing over one fixed pulley and fixed to two movable pulleys. There is a sketch of a "double cylinder capstain".

In Practical Gunnery is given a table which contains "the results of a few of Dr. Hutton's experiments at Woolwich", then there are numerical examples about range, velocity, weight and charge. Hydrostatics includes specific Gravity, e.g.

"If the body be soluble in Water, either cover it with a thin coating of varnish and proceed as in last case, or having formed a Saccharine Solution of the substance in water proceed as in Case first".

Hydraulics contains a section on the motion of water in conduit pipes and canals. The notes are carefully written and illustrated by neat diagrams. Schoolboys in 1850 were not different from their successors to-day, and on the final page is the inscription by one of his schoolfellows, "James Christie is a impudent cat". At the Royal High School, Edinburgh, an improved course of study was introduced in 1827 ⁽¹⁾ and it contained classes for General Knowledge, to which were added several "additional subjects of great interest and prodigal utility in 1834". A proposal had been made in 1836 ⁽²⁾ for the introduction of Natural Science, but it was opposed by the rector, Dr. Carson, and the scheme did not develop. In 1848, however, when Dr. Schmitz was rector, it was introduced, and lectures were given by the classical masters.

(1) Wm. Steven Hist. of High School of Edinburgh pp.226 & 270.

(2) W.C.A. Ross, Royal High School p. 58.

(1) & (2)

In 1849, the town council decided that, in addition to these instructions in elementary science which were given by the classical teachers, natural history and chemistry would be introduced into the curriculum, to be the subject of a course of eleven lectures by Mr. Wm. Rhind, M.R.C.S., and Dr. John Murray, M.D., F.R.C.S.E. respectively, on Saturday forenoons between 11 a.m. and 12 noon, at a charge of 2/6 per quarter. Attendance at these classes was optional, natural history being for the junior boys, and chemistry for the senior boys.

When the elements of science was introduced as a regular subject in the various classes in 1848, the time devoted to it was 1½ hours per week. Both the First and Second Classes studied "Introduction to the Sciences", the Third Class studied "Matter and Motion", the Fourth Class Mechanics, and the Fifth Class (the Rector's) studied Astronomy. Mr. George Lees, whose name appears frequently in these pages was a mathematical master in this school from 1829 to 1834.

At Falkirk Parochial School, (3) Mr. Downie who had been schoolmaster since 1836 gave his pupils lessons on digestion and circulation, and received a loan of diagrams from Dr. George Hamilton in 1839, when the latter was delivering a course of public lectures in physiology in Falkirk.

(1) Wm. Steven Hist. of High School of Edinburgh pp.226 & 270.

(2) W.C.A. Ross, Royal High School p.58.

(3) Jas. Love, Schools and Schoolmasters of Falkirk p.85.

Further instruction was given with the aid of these diagrams, and, as Dr. Hamilton states in his book "Rudiments of Animal Physiology", he was astonished at the progress made by the boys in this subject. Mr. Downie carried on this instruction as a regular part of his course until his death in 1841.

A school of a different type from those existing already in Edinburgh was established in 1848, with 32 boys, and was called the Williams Secular School.⁽¹⁾

It was intended to provide a useful "secular education" for the children of the working classes, and was modelled on the Birkbeck School of the London Mechanics' Institution. In 1849, girls were among the 160 pupils admitted to the new premises in Surgeon Square, The subjects of the curriculum included mathematics, natural history, chemistry, natural philosophy, social economy, physiology, and phrenology.

In the Scotsman of April, 7th, 1849 is a report of the examination of the school:-

"The third and highest class then underwent a most searching examination by Mr. Combe in Physiology-----

They were next asked who made all these vessels, bones and other parts and appointed their uses.

They answered - God.

Did God intend them for your happiness? - Yes.

Can you escape from the painful consequences of neglecting

(1) First Annual Report of the Williams Secular School 1850.

cleanliness, fresh air, exercise and temperance? - No. Why not? - Because God has made the organs, and made them act as they do; and they act well or ill according to our conduct".

Later they were examined in Natural Philosophy (on Cohesion, Heat, Evaporation and the Planetary System), then on Anatomy, Physiology and Phrenology.

In the last mentioned occurred the following:-

"What organ lies here? (pointing to a place on the skull)
- Combativeness.

What is the use of that faculty? - To give us courage to meet danger and difficulty in the discharge of our duty".

Donations of £227 were received for this school, of which the headmaster was Mr. Williams. The school fees amounted to £56, and the salaries to £103. Government grants were refused for this school, because it was secular.

At the second examination, held in 1850, an experiment was carried out, showing the expansion of air due to heat, and it was reported that the pupils had carried out an elementary course on the general properties of matter, the principles of mechanics, hydrostatics, pneumatics, heat and light, and were just commencing chemistry and electricity. In the report is appended a list of the class books used in school:-

Nicholl's Introduction to Natural Philosophy.
Dr. A. Combe's Physiology.
Chambers' Information for the People - Botany

- Phrenology

- Animal Physiology

G. Combe's Elements of Phrenology.

Chambers' Rudiments of Geology.

" Mechanics.

Nicoll's Introduction to the Sciences.

Tait's Mechanics.

At Edinburgh in 1850, lectures on scientific subjects were delivered in various schools. In Edinburgh Institution which had been established in 1832, the lectures were:-

Natural History including Meteorology, Geology and Zoology - W. Rhind, M.R.C.S.

Chemistry - John Murray, M.D., F.R.C.S.

Natural Philosophy - Geo. Murray.

At the Scottish Institution for Education of Young Ladies, which was situated at 9 Moray Place, and had been founded in 1832, lectures were delivered on chemistry, botany and geology with mineralogy by Dr. Murray F.R.C.S. Dr. Dubuc, and Alex. Rose respectively. The lecturer on natural philosophy is not named. Robert Anderson delivered lectures

on natural history and physical science at the Edinburgh Ladies' Institution for the Southern Districts, 1 Park Place, which was opened in 1833, while James Scott was the lecturer on chemistry at the Edinburgh Southern Academy, 5 George Square, which was established in 1829.

One of the most popular text books used in the teaching of navigation in Scotland was "A Treatise on Navigation and Nautical Astronomy, adapted to Practice and to the purpose of Elementary Instruction" by Edward Riddle F.R.A.S. Master of the Nautical School, Royal Hospital, Greenwich. It was first published in 1824 and by 1864, eight editions had been published.

In the preface of the fifth edition in 1849 it is stated that the employment of steam having given to Great Circle Sailing an importance which it did not previously possess, a short article on the subject would be included. Probably one of the reasons for the popularity of the book was that it served also as a text book of mathematics the first 125 pages being devoted to algebra, logarithms, geometry, plane and spherical trigonometry. There are 320 pages in the book in addition to 256 pages of tables. After discussing the principles of Navigation, various sections are concerned with the compass and the log, leeway,

plane sailing, traverse sailing, plying to windward, sailing in currents, parallel sailing, middle latitude and Mercator's Sailing, charts, quadrant, sextant. Nautical Astronomy next occupies 95 pages, after which the transit instrument, winds and tides are considered.

Equally popular as a text book was "The New Practical Navigation, being an Epitome of Navigation" by John Hamilton Moore, Teacher of Navigation, Hydrographer and Chart Seller to his Royal Highness the Duke of Clarence. It was published originally in 1772 as a book of 309 pages with 150 pages of tables.

In 1794, the tenth edition was published and, the nineteenth edition, enlarged and carefully improved by Joseph Dession was published in 1814. The modest nature of the author, who had "through propensity of genius been devoted to mathematical pursuits from early life" can be judged from this introduction and a full page portrait of himself. There is not as much mathematics in this book, which commences with geometry, trigonometry, Gunter's scale, logarithms, and at page 40, navigation is introduced. In trigonometry the term arch is used not arc. In succession the author deals with the mariner's compass, the half-minute glass, the log,

*See next page
to 216*

The first edition was published in 1824, the second in 1825 and the 30th edition in 1845. The first 40 pages are devoted to problems, e.g.,

Problem I. To find the apparent time by the altitude of the sun,

Problem V. To find the Longitude by Lunar Observations.

Problem VII. On finding the Longitude by Chronometers.

There are 136 pages of tables e.g.

- I. To turn degrees in time, or time into Degrees.
- II. Dip of the Horizon.
- IV. Moon's Augmentation.
- V. Contraction of semi-diameter of sun or moon.

The book concludes with 19 pages of directions for acquiring a knowledge of the principal fixed stars.

Another popular text book was "A new and Complete Epitome of Practical Navigation" by J.W. Norie, published in 1805. It reached a 21st edition in 1877, and a new edition was published in 1889.

The plane, traverse, middle latitude and Mercator's sailing (illustrated with diagrams of ships) winds, tides, Hadley's Quadrant, method of keeping a ship's reckoning or Journal at sea. Next is given a journal of a voyage from London to Madeira and Teneriffe. This was customary in navigation books of this period. The author then deals with parallax, oblique, trigonometry, oblique sailing, curvature of the earth, current sailing, explanation of the rigging of a first rate ship, explanation of sea terms, examination of a young sea officer. This last is a series of questions and answers, typical of many text books at this time.

In the 19th edition, published in 1814, "we have also added what we conceive will be an acceptable article in the present times of hostility - the method of exercising private ship's companies for war". This edition also includes a variety of methods of relieving ships in distress, the best means of saving people from wrecks and the process for recovering drowned persons; also a section on decimal arithmetic.

In some schools the text book used was "Lunar and Horary Tables, for new and concise methods of performing the calculations necessary for ascertaining the Longitude by Lunar Observations or Chronometers" by Capt. David Thomson, "inventor of the longitude scale".

This book commences with decimal arithmetic, logarithms, practical geometry, Gunter's Scale, the sector, plane trigonometry, geography (mainly definitions), log, half-minute glass and compass. Pages 66 to 122 are concerned with the various methods of sailing, plane, traverse, parallel, middle latitude, Mercator's, oblique and current, then the author deals with charts, maritime surveying, astronomy, winds, tides, Hadley's Quadrant, Hadley's Sextant, Rio's Circle. As in other books there is a journal of a voyage from England to Madeira then follows a navy journal and an East India Journal. Again there is an explanation of sea terms and an examination of a young sea officer. There are 304 pages of text and 252 pages of tables which include, Mean Refraction, Dip of Horizon, Sim's parallax, Moon's Augmentation, Sun's Declination, Sun's Right Ascension and Time of High Water.

Quite a readable text book is Hugo Reid's Elements of Astronomy, adapted for private instruction and use in schools. The author introduced the teaching of chemistry into the High School of Glasgow in 1834, and was afterwards lecturer on chemistry and natural philosophy at Liverpool High School.

It was published in Edinburgh in 1842 and contained

165 pages. The topics included fixed stars, solar system, day and night, climate, seasons, trade winds, tides, parallax, aberration, equinoxes, nutation, of the earth's axis, moon's phases, eclipses, and a sketch of the history of astronomy.

The section about the sun is treated thus,

- "311. The sun is the centre of the solar system and is found to be a globular body of immense magnitude.
312. Its mean distance from the earth is about ninety-five millions of miles (95,000,000). But the earth is nearly three millions of miles nearer to the sun in our winter than in our summer.
313. The sun is not perfectly spherical, but, like all the planets, is flattened at the two opposite points, termed poles. Its form is, therefore, a spheroid, like an orange.
314. The sun's diameter is about eight hundred and eighty-two thousand miles (882,000) or $111\frac{1}{2}$ times that of the equatorial diameter of the earth."

This book unlike some others was prepared specially for use in schools and reached a 4th edition in 1874.

Another book by this same author was "The Elements of Physical Geography" published in 1850 and attaining its 16th edition in 1887.

He also published A Catechism of Chemistry and A Catechism of Astronomy.

From the number of editions published of various text books, we are able to judge of their popularity.

A very popular text book was "A new Treatise on the Use of the Globes or a Philosophical View of the Earth and Heavens" by Thomas Keith, published first in 1805. In 1815 the fourth edition was published and in 1824 the 7th edition, while other editions appeared in 1831 and 1843. In the preface it is stated that amongst the various branches of science studied in our academies, there are few of greater importance than that of the Use of the Globes, and Milton's statement is quoted, "Ere half the school authors be read, it will be reasonable for youth to learn the use of the globes. The author's next remarks (1) are somewhat amusing, "The author of the following work will not pretend like many predecessors, that he was induced to write it at the request of several eminent instructors of youth, or that it was intended for private use, but the importunity of his friends induced him to publish it, etc. On the contrary, he will freely confess that it was written at different intervals of time, by way of a rational amusement

(1) p. VIII.

for the leisure hours which could be spared from the duties of his professional engagements."

He gives first an explanation of the lines on the artificial globes both geographical and astronomical, properties of matter, laws of motion, figure and magnitude of the earth, diurnal and annual motion, origin of springs and rivers, saltness of sea, flux and reflux of tides. Next he deals with mountains, floods, volcanoes, earthquakes, the atmosphere, air, winds, hurricanes, vapours, fogs, mists, clouds, dew, hoar frost, snow, hail, thunder, lightning, falling stars, Ignis Fatuus, Aurora Borealis and the rainbow.

Much of the work is expressed in theorems, e.g.

"Theorem VII. When the moon is nearest to the earth, or in Perigree (sic) the tides increase more than in similar circumstances at other times."

"For the power of attraction increases as the square of the distance of the moon from the earth decreases, consequently the moon must attract most when she is nearest to the earth."

One chapter is entitled Hypotheses of the Antediluvian World and the Cause of Noah's Flood and includes the following passage, "There have been various opinions, conjectures and hypotheses, respecting the original formation of the earth.

The writers of these hypotheses, not satisfied with the Mosaic account of the Creation, though they had no other certain foundation to build upon, thought themselves at liberty to model the earth according to the dictates of their own imaginations. Hence we have had as great a variety of theoretical systems as writers, and these so contradictory and discordant to each other, that, instead of throwing light on the subject, they have, if possible, involved it in greater obscurity. He then described the theories of six different writers.

The section on Thunder and Lighting is somewhat interesting, viz:-

"It has been already observed that the atmosphere is the common receptacle of the effluvia or vapours, rising from different bodies. Now, when the effluvia of sulphureous and nitrous bodies meet each other in the air, there will be a strong conflict or fermentation, between them, which will sometimes be so great as to produce fire. Then, if the effluvia be combustible, the fire will run from one part to another, just as the inflammable matter happens to be. If the inflammable matter be thin and light, it will rise to the upper part of the atmosphere, where it will flash without doing any harm; but if it be

dense, it will lie near the surface of the earth, where, taking fire, it will explode with a surprising force, and by it's heat, rarify and drive away air, kill men and cattle, split trees, walls, rocks, etc., and be accompanied with terrible claps of thunder."

Part II of the book deals with the Elementary Principles of Astronomy, the Solar System, Comets, Planets, Fixed Stars, Eclipses, e.g. "The sun is situated near the centre of the orbits of all the planets and revolves on it's axis from west to east in 25 days 15 hours 16 minutes. This revolution is determined from the motion of the spots on the surface of the sun from east to west."

Part III consists of problems performed by the Terrestrial and Celestial Globes, e.g.

"Prob. XXIV. A place being given in the torrid zone, to find those two days of the year on which the sun will be vertical at that place.

Prob. LV. To find the time of the year when the sun or moon will be liable to be eclipsed.

Prob. LVI. To explain the phenomenon of the harvest moon.

Prob. LXXI. To find when any star or planet will rise, come to the merridian, and set at any given place."

Part IV consists of a collection of questions and a table of

longitudes and latitudes. There are 355 pages in this book.

At Aberdeen was used a book entitled "The Elements of the Theory of Astronomy" by W. Maddy, M.A., revised by J. Hymers, M.A. and published at Cambridge in 1832. Many of the books on Mechanics and Astronomy were by Cambridge University lecturers. A typical extract from this book⁽¹⁾ is:-

"The sun's influence in producing warmth depends upon the time during which he is above the horizon, and the elevation he attains above the horizon; for the greater length of the day gives him a longer time to act, and the greater his altitude, the greater proportion of his rays does a greater horizontal surface receive (for the illumination of a plane varies as the sine of inclination of the plane to the direction of the incident ray), and the more directly do they fall upon the atmosphere, and consequently having a shorter distance to traverse through it, a smaller quantity of the solar light and heat is absorbed."

At Kilmarnock Academy and Glasgow High School a text book used was The Principles of Mechanics by James Wood, B.D., published in 1796. The contents are stated as propositions, e.g.

"Prop. XXII. In a system where the same string passes round

(1) P. 30.

any number of pulleys and the parts of it between the pulleys are parallel $P:W::1$: the number of strings at the lower block.

Prop. XXIX. When there is equilibrium upon the screw, $P : W::$ the difference between two contiguous threads, measured in the direction of the axis: the circumference of the circle which the power describes.

Every chapter ends with a Scholium, e.g.

" §151. The Pulley has, by some Writers been referred to the lever, and they have justly deduced it's properties from the proportions which are found to obtain in that mechanical power; for the adhesion of the pulley and the rope, which takes place at the circumference of the pulley, will overcome the friction at the center of motion; both because it acts at a mechanical advantage, and because the surface in contact is greater; and the friction depends, not only upon the weight sustained, but also upon the quantity of surface in contact; thus, in practice, the rope and pulley move on together, and the pulley becomes a lever."

This book is Part III of a series of five volumes written by Wood and Samuel Vince and entitled Principles of Mathematics and Natural Philosophy. Vince wrote the volumes on Fluxions, Hydrostatics and Astronomy while Wood

wrote on Algebra, Mechanics, and Optics. The Mechanics section reached a 6th edition in 1818.

It is rather surprising to find An Elementary Treatise on Mechanics by Wm. Whewell, M.A., Fellow of Trinity College, Cambridge, in use as a text book in Scotland, as it is very mathematical, including a great deal of differentiation and integration. It is a book of 346 pages published first in 1819 and in its seventh edition in 1847, and was certainly in use at Glasgow Western Academy in 1842, at Kilmarnock Academy in 1846, and at the Mathematical School, Aberdeen in 1854.

Another book in use, but not quite so mathematical, was An Elementary Treatise on Mechanics by Richard Potter, A.M., Professor of Natural Philosophy and Astronomy in University College, London. First published in 1846, it reached a fourth edition in 1859, and was used in the Mathematical School, Aberdeen in 1854. An idea of the book may be obtained from an extract.

"The principle of virtual velocities is thus enunciated: If any number of forces be in equilibrium at one or more points of a rigid body, then if this body receive an indefinitely small disturbance, the algebraic sum of the products of each force into its virtual velocity is equal to zero."

A later proposition is, "To shew that the principle of virtual velocities holds good for the wheel and axle in equilibrium."

The word centre is always spelt "center" in this book of 162 pages.

The Elements of Hydrostatics with their application to the Solution of Problems by Miles Bland, B.D. F.R.S. is mainly mathematical in its treatment and was published in 1824, a second edition appearing in 1827. Proposition 110 is, "When a body is immersed in a fluid, the weight lost is to the whole weight, as the specific gravity of the fluid is to that of the solid". The author then deals with the wheel barometer, syphon syringe, common suction pump, forcing pump, fire engine, air pump, and capillary tube.

The treatment of the syringe is as follows:- (1)

"A syringe consists of a barrel, furnished with a sucker made air-tight, and moveable by a rod. Suppose the lower end of the syringe immersed in a fluid, and the sucker at its greatest depression; then will the air within the syringe between the lower extremity and the sucker be in its natural state. But when the sucker is elevated, the air below it

occupying a greater space, its density, and therefore its elasticity will be diminished. Whence the pressure of the external air being less counteracted will raise the fluid into the syringe; and by the subsequent depression of the sucker this fluid will be expelled.

One of the text books used in Chemistry was Lessons on Chemistry by Wm. H. Balmain, published 1844. It is written in the form of lessons with an examination at the end of each lesson on such subjects as Constitution of Matter, Effect of Heat upon Matter, Chemical Attraction, Atomic Theory. A table of elements is given with their symbols and atomic weights. Some of these seem curious to us to-day, e.g. Oxygen 8, Carbon 6.12, Sulphur 16.1, Phosphorus 15.7, Calcium 20.5, Magnesium 12.7, Glucinum (G) 26.5. Iron 28, Tin 57.9, Vanadium 68.5, Colombium (Ta) 185, Lead 103.6, Rhodium 52.2, Osmium 99.7, Zinc 32.3, Zirconium 33.7. The atomic weights of Lantanum (La) and Didymium are not stated.

"An idea of the method used in the book will be obtained from Lesson VI on Water."

"Water is a compound of the two elements oxygen and hydrogen. One atom of water contains one atom of oxygen and

one atom of hydrogen; and its symbol is HO or H.

Oxygen and hydrogen, when by themselves are gases, but when united they produce water.

When oxygen and hydrogen are put into the same vessel, they simply mix and do not unite, unless assisted by intense heat or by exposure to a clear surface of the element platinum. When water is subjected to galvanic electricity, it is resolved into its elements oxygen and hydrogen.

Examination VI on the above lesson is:-

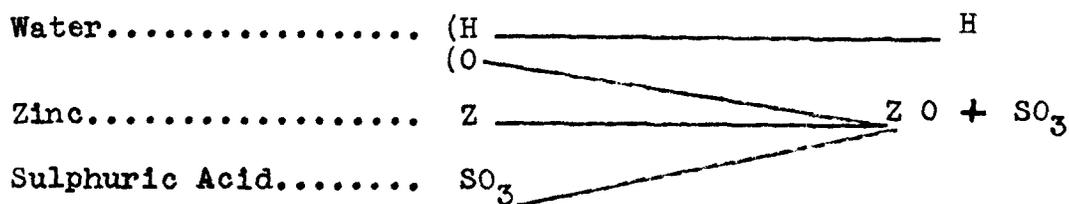
Of what is water composed?

What is the symbol of water, and what does it signify?

What number represents the weight of an atom of water?

In Lesson VII on Hydrogen, it is stated that hydrogen is obtained by acting upon zinc or iron with water and sulphuric acid when the zinc unites with the oxygen of the water and forms a compound called oxide of zinc which unites with the sulphuric acid and forms sulphate of the oxide of zinc, and the hydrogen which is set free rises as a gas.

The equation is represented in a curious manner:-



* "ZO + SO₃ (the sulphate of the oxide of zinc) is left in the undecomposed water."

As a test for alkalies litmus paper is not mentioned but the fact that they turn yellow turmeric paper brown.

Regarding Nitrogen, it is stated ⁽¹⁾ that when an electric spark is passed through air or any mixture of oxygen and nitrogen, the two elements combine, and form a compound called nitric acid. "One atom of nitric acid contains one atom of nitrogen and five atoms of oxygen, and its symbol is NO₅ or $\begin{matrix} \cdot\cdot\cdot \\ \cdot \\ \text{N} \\ \cdot \\ \cdot\cdot\cdot \end{matrix}$. Other compounds of nitrogen mentioned are Nitrous acid NO₄, Hyponitrous acid NO₅, Binoxide of nitrogen NO₂, Protoxide of nitrogen, NO.

Mention is made that carbonic acid is a colourless gas, CO₂ or $\overset{\cdot\cdot}{\underset{\cdot\cdot}{\text{C}}}$, that it is heavier than air, and has a pungent odour. The various carbonates named are carbonate of potash KO + CO₂, of soda NaO + CO₂, of lime CaO + CO₂, of oxide of zinc ZO + CO₂, of oxide of lead PbO + CO₂.

The preparation of "carbonic acid" is indicated thus,

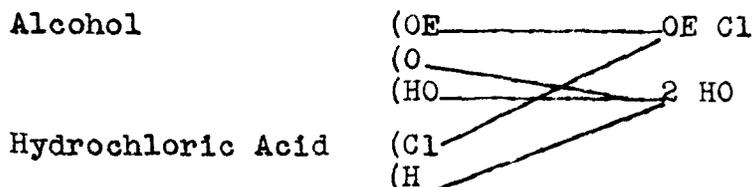
(1) PP.18 et seq.

* There is some confusion in this book between Zn and Z, e.g. oxide of zinc is indicated as ZO or Zñ (p.99). Elsewhere Z indicates Zirconium.

sugar, starch, alcohol wines, ethers and acetic, oxalic, citric, tartaric, tannic and benzoic acids.

The following passage ⁽¹⁾ is of interest,

"The elements of alcohol are supposed to be arranged thus $(C_4H_5 + O) + HO$. The compound C_4H_5 is called ethule and alcohol is a hydrate of the oxide of ethule. Chloride of ethule is obtained by acting upon alcohol with hydrochloric acid thus,



Lessons then follow upon ammonia, quinine, morphia, oils, soaps, cyanogen, albumen, and gelatine and in conclusion "remarks upon food and the changes which it undergoes in becoming a part of the animal." There is really a great variety of topics in this book of 208 pages each measuring 7 inches by $4\frac{1}{2}$ inches.

(1) p. 149.

Dalton's symbolic notation was first published in A System of Chemistry by Thomas Thomson, M.D., F.R.S.E., at Edinburgh in 1807.

Berzelius stated that it was easy to indicate the number of atoms of oxygen by points placed above the atomic

symbols, and sulphur by commas.

Graham used dots for oxygen atoms during the period 1835 to 1838 but from 1841 onwards he used the symbol O.

About 1802, John Dalton suggested "simple atoms" and represented by symbols, hydrogen @, oxygen O, and water @O.

In 1819 Berzelius used letters instead, H,O, H + O.

In 1766 Cavendish wrote regarding equivalents, and in 1792 J.B. Richter on equivalent quantities, then in 1802 Fischer drew up a table of equivalents.

In 1858 Cannizzaro chose the half molecule of hydrogen as the standard of molecular and atomic weights.

At Aberdeen, certainly prior to 1854, a text book used was named Outlines of Physical Geography, descriptive of the inorganic matter of the globe and the distribution of organized beings. Designed for the use of Schools and private Reading by Edward Hughes, F.R.A.S., F.R.G.S., Head Master of the Royal Naval Lower School, Greenwich Hospital. It contained 310 pages, the first edition being published in 1849 and the fifth in 1855, then a "new edition" in 1860.

The contents were extensive, beginning with the earth, apparent motion of heavenly bodies, day and night, seasons, Kepler's Laws, structure of the earth's crust, distribution of land and water, form of the great continents, features of the land, volcanic phenomena and distribution of minerals.

In describing curvature of the earth, Hughes states (1) "when cutting for a canal we find that we must allow a dip of about 8 inches in a mile in order to keep the water of a uniform depth throughout. If the earth were a plane, no allowance of this kind would be requisite hence we know that the earth's surface is curved."

The following two extracts concerning the rotation of the earth about its axis show the two styles used by the

(1) pp 3 and 6.

author, the scientific descriptive and the pious theological, (which is characteristic of text books of this period).

"Now, if we select a star, and observe it by means of an equatorial instrument when the star is on the meridian, or culminating, and note the time that elapses until it comes on the meridian again, we shall find it to be exactly 23 hours 56 minutes, and in the same period of time all the stars appear to describe parallel circles round the axis of the heavens; hence we may say that the sphere of the heavens performs one revolution in 23 hours 56 minutes, or a sidereal day.

One revolution of the earth about its axis in about 24 hours would bring about the daily phenomena of the heavens, and this revolving motion we believe the Almighty has assigned to the earth, because it is in harmony with the simplicity, beauty and economy of those portions of His works which are more evident to our senses, and is characteristic of the plans and operations of that Being who is "wonderful in counsel and excellent in working"; "who hath established the world by His wisdom, and stretched out the heaven by His understanding"; "who hangeth the earth upon nothing."

The next portion of the book deals with the ocean, tides, currents, inland waters, springs, rivers. (1)

(1) p 116.

e.g. "The most remarkable of the motions to which the ocean is subject, is that alternate rise and fall of its surface, known by the name of the tides, which usually take place twice in 24 hours, 50 minutes 28 seconds mean solar time. They are occasioned by the attractive forces of the sun and moon, particularly the latter, by which they are mainly governed." Then follow details of the causes of tides.

Meteorological phenomena occupy the following chapters, winds, dew point, clouds, rain, hail, then climate, electrical and magnetic phenomena, geographical distribution of plants, orders of animal existence, geographical distribution of animals and of man, productive industry and commerce of the different countries of the globe and finally the physical features of the British Islands. Appended is a list of the principal mountains and a list of the principal rivers with relative details.

In addition to the text book, there was a separate booklet of 40 pages published, "Examination Questions on the Third Edition of Edward Hughes' Physical Geography" in 1852. A few of the questions, taken at random, show the style of the book:-

"What is the shape of the earth?

What is meant by sidereal day?

Was the pre-Adamite earth inhabited, and if so, by whom?

How does the study of Geology minister to our reverence and humility?

Name parallel configurations between Africa and South America.

If the Pyrenees were spread over France, how much would its mean level be elevated?

What are Brancos, and what the Mesa?

What ideas of God does the ocean suggest?

What are Deltas? Name some large ones.

What is an excited body, and the electrical spark?

Where do the olive, the date palm, banana and cocoa nut palm flourish?

What is remarkable in the form and colour of the Arctic fauna?

For what are the Lowlands of Scotland remarkable?"

A popular chemistry text book was entitled Rudiments of Chemistry by D.B. Reid, M.D., F.R.S.E., first published in 1836 and in its fourth edition in 1851.

Dr. David Boswell Reid was for some time an assistant to Hope, and, as we have seen, lectured in various Edinburgh schools. From 1833 to 1847 he conducted chemistry courses (both theoretical and practical) in premises of his own.

His laboratory is reputed to have been among the first, if not the first in Britain, which was open to students who wished practical training in chemistry.

There are several items of interest in his book. In examples (1) leading to the establishment of the Law of Multiple Proportions (established by Dalton about 1808) we find as a compound, Atmospheric Air with 28.4 parts Nitrogen + 8 parts Oxygen giving 36.4 as the value of its "equivalent". The equivalents of hydrogen, oxygen and nitrogen are given as 1, 8 and 14.2 respectively. Between 1835 and 1850 there was considerable confusion owing to Gmelin's introduction of 8 as the atomic weight of oxygen.

It is stated that a Supersalt indicates that the properties of the acid predominate, without reference its composition, as in the supertartrate of potassa, whereas a Subsalt indicates that the properties of the base predominate, as in the sub-borate of soda.

The symbols used were introduced by the following statement:-

"Each dot prefixed to a symbol indicates 1 equivalent of oxygen. A dot is frequently used instead of O for oxygen, $2.H: S = 2.H + 2: S.$ "

The author states that in studying the composition of compounds, the chemical abacus will be found very useful. "It consists merely of the common abacus so much employed by the ancients and still used in different foreign cities, symbols representing elementary or compound bodies being placed along the side." Evidently such a chemical abacus could be bought for 6d or 1/-. The only specimen that we have been able to trace is preserved in the British Museum and measures 10 inches by $7\frac{3}{4}$ inches. ^X

A list of equivalents and symbols is given and these show considerable difference from those in present day use:-

	<u>Equivalents by weights.</u>	<u>Symbol.</u>
Hydrogen	1	H
Oxygen	8	O
Water	9	OH
Carbon (hypothetical)	6.12	C
Carbonic Oxide	14.12	OC
Carbonic Acid	22.12	O ² C

Several sections of this book seem strange in a Chemistry text book e.g. heat or caloric, exosmosis and endosmosis, communication of heat, distribution of caloric, light and electricity.

^X See Appendix I.

With regard to air he states (1) "air is not an element but a compound of two gases oxygen and nitrogen, and it's chemical properties depend principally upon the oxygen it contains."

Other chapters deal with organic chemistry, vegetable chemistry, oily and resinous substances, lignum, gum, starch and gluten.

Dr. Reid introduced what he termed "flat glass" experiments (2) "When slips of glazier's window glass are properly selected, they may be used for the following purposes:-
I Solution - broad slips 3" x $\frac{1}{2}$ " or 6" x 1" are best adapted for this purpose. They are held by one extremity, and a minute quantity of the substance to be dissolved, about the size of a mustard seed, is placed at the other, covering it with 8 or 10 drops of the liquid used for solution.

II Boiling liquids - use as thin as possible.

Crystallisation- Solutions to be crystallised may be spread over the greater part of the glass, and left to evaporate spontaneously, or concentrated by heating, removing the slip

(1) p.60.

(2) p 150.

from the heat the moment any solid appears on the edges; if the heat be continued longer, a confused mass is generally observed instead of crystals ---- Glauber salts, Oxalic acid, hydrochlorate of strontia, and bichloride of mercury give solutions which crystallise with great facility."

The Rudiments of Animal Physiology by Dr. G. Hamilton was published in Edinburgh in 1836, with later editions in 1839, 1845, 1855, and consists of 106 pages.

The various chapters deal with life, classification of animals, mastication, deglutition, digestion, circulation, respiration, secretion and nutrition, These are illustrated by wood engravings, sometimes with red and blue colours. Other chapters are on exhalation, absorption, the skin, locomotion, bones, muscles, nervous, system, the senses and finally reproduction.

An extract (1) illustrates the type of instruction given in this book .

"The lungs (vulgarly called the lights) are principally composed, first of air-tubes (bronchi) of which the windpipe (trachea) is the commencement and which divide and subdivide until they terminate, as has been supposed, in very minute bags or air-vesicles, and secondly, of the pulmonary artery,

(1) p.42.

which branches out upon the sides of these air-tubes."

Fig. 20. shows the windpipe, with the lungs entire on one side, and with the branches of the air tubes dissected on the other. These tubes are said to terminate in vesicles which vary in size from the 50th to the 100th part of an inch in diameter."

Many of the text books in use during this period in Scottish schools were produced specially for that purpose, some of them being published by the Scottish School Book Association, one such book being The Principles of Natural Philosophy published in 1845. At the end of each section is a glossary. Properties of Matter or Somatology is the subject matter of the first section and the following one example of the contents of its glossary:-

"Polarity; the disposition in bodies or their atoms, to assume certain positions when allowed freedom of motion; from the word "pole" - the action resembling the needle pointing to the pole."

Motion is next considered, then Mechanical Powers including crank, crown wheels and bevel wheels, rack, rag wheel, and wheel with wipers followed by Strength of Materials,

hydrostatics, Hydrodynamics, and Hydraulic Machines, e.g. Persian wheel, Archimedean screw, centrifugal pump, hydraulic ram, water wheels, and Barker's mill.

In Pneumatics, some of the questions asked and the topics of discussion resemble closely those in present day use, e.g.

"A child's plaything called a sucker---

Why is there a small hole in the lid of a tea pot?

Place a slip of paper on a wine-glass full of water----

Syphon. Intermitting springs.

Ink bottle. Bird fountain.

Air pump. Fire engine.

Balloon. Parachute. Diving Bell.

Winds. Trade winds."

The topics included in Optics are varied such as microscope, telescope, magic lantern, camera lucida, camera obscura, colour of natural bodies, rainbow, mirage, and Fata Morgana, while the book concludes with a section on Acoustics.

James Bryce, Jun, M.A. F.G.S., Master of the Mathematical Department in the High School of Glasgow, published in 1848, a book entitled First Principles of Geography and Astronomy with Use of the Globes.

He explained that the part dealing with geography has been drawn up many years ago by his brother, Rev. Dr. Bryce. It comprises The Terrestrial Globe, The Artificial Globe, Divisions and Subdivisions of the Earth, Eastern and Western Continents, Oceania, and finally Maps, all within 14 pages. After this is a set of questions entitled Praxis.

The second part of the book is concerned with Astronomy - the Celestial Globe, Bodies in the Sphere, Sun's Motion, Equinoxes and Solstices, Moon and Planets, Zodiac, Refraction, Parallax. Use of the Globes was the subject of the third section in which were considered Circles of the Sphere, Drawing of a Meridian and Problems. An appendix dealt with Late Researches respecting the tides, Calendar, Aberration, Keplers' and Bode's laws of the distances.

Refraction is explained thus, ⁽¹⁾

"Any space traversed by light, whether it be a material substance is termed a medium. The course or direction of a ray, so long as it continues in the same medium, and that medium of the same density, is always rectilinear. It even maintains this course when it enters another medium of different density, provided it enter it perpendicularly. But when it enters it obliquely, it is bent into a different course. This change of direction is

(1) p. 43.

called refraction."

An extremely popular text book was "The Rudiments of Modern Geography" by Alex. Reid, L.,L.D. It was first published in 1837 and reached a 53rd edition in 1893.

A popular text book in natural philosophy was entitled "A Catechism of Natural Philosophy in which the general doctrines of that science are explained in a popular form, illustrated by 56 woodcuts," by George Lees, L.,L.D., mathematical master in the Scottish Naval and Military Academy and lecturer on natural philosophy in Edinburgh," a new edition being published in 1851. It was a small book of 72 pages, and was one of Oliver and Boyd's Catechisms of Elementary Knowledge.

The treatment of the subject can be best observed in the following extract regarding gravity:-⁽¹⁾

"Question - What are we to understand by the gravity of a body?

Answer - The tendency which a body has to fall to the earth when left unsupported.

Q. - I should have supposed that a body had a tendency to fall in consequence of it's weight?

A. - I cannot say you are wrong, because weight is nothing else than a certain amount or measure of gravity. At the same time I must inform you, that

(1) p. 12.

though the term weight, properly speaking, designates the exact amount of tendency to fall, it neither points to any cause, nor assigns in it's own meaning any reason, for the existence of the simple tendency itself."

Everyday science and local conditions are considered in the following example:-⁽¹⁾

"Q. If the fountain-head were lower than the place where the water is required, the natural pressure of the water of course would be insufficient?

A. Clearly, in such cases the water must be raised by some mechanical means, such as pumps wrought by steam engines. We have examples of both methods in Edinburgh and Glasgow. In the former, there is a conduit - pipe extending under ground from a large reservoir on the Castlehill to the Crawley Spring, a distance of about 6 miles. Now, as the fountain head at Crawley is about 230 feet higher than at Castlehill, the water of course, flows at the latter with considerable rapidity. In Glasgow, again, which is supplied from the Clyde, the water is raised to an elevated cistern by means of steam engines working pumps."

The following may be of information to many modern science masters.

(1) p. 25.

"Q. What is the meaning of the term Catoptrics?

A. Catoptrics is derived from a Greek word which signifies a mirror, and is employed to designate that branch of Optics, which treats of the reflection of light from mirrors and in general from all polished reflecting surfaces."

Progress 1801 - 1850

1. The teaching of scientific subjects in parochial schools as well as the burgh schools and academies.
2. The publication of (i) scientific readers, and (ii) scientific text books for school use.
3. The teaching of elementary science from reading books in (i) primary schools, and (ii) more advanced schools by the English Master or the Classical Master.
4. Introduction of physiology as a school subject.
5. Encouragement from the Committee of Privy Council on Education, by grants for apparatus and text books.
6. Introduction of agricultural chemistry into schools.
7. In Edinburgh schools, lessons given by peripatetic lectures.
8. Introduction of experimental work in chemistry by Dr. D.B. Reid and others.

CHAPTER VI.

ADULT EDUCATION BEFORE 1850

During the eighteenth century there had been little attempt made at adult education. The lectures of various university professors, had, however, attracted persons other than the regular university students. As we have seen, this occurred while Cullen and Black lectured on chemistry, and Dick and Anderson on natural philosophy. In addition, courses of popular lectures were sometimes given, usually to obtain funds for some special purpose, e.g. the lectures by McLaurin in 1741 to help to build an observatory, and in 1745 to aid Miss Gregory, the daughter of his predecessor.

Towards the end of the century began a systematic attempt at adult education, owing to the bequest made by Professor Anderson in order to found another University in Glasgow. This was called Anderson's University and ⁽¹⁾ "the business of the university commenced on 21st September, 1796 by Dr. Garnets' reading in the Trades Hall to persons of both sexes popular and scientific lectures on natural philosophy and chemistry illustrated by experiments. In 1799, Dr. George Birkbeck was appointed as his successor." There was only one maker of instruments in Glasgow at this time,

(1) New Stat. Acc. VI. P. 79.

(1) and he was not considered reliable, so Birkbeck got instruments made by workmen of various trades working under his own direction, and for these workmen he procured admission to his lectures. They appeared to profit by, and to enjoy his lectures, with the result that in 1800 on Saturday evenings, he established a special class at a low fee, in addition to his regular classes. This new class was ⁽²⁾ "solely for persons engaged in the mechanical arts," and its subject was entitled, "Mechanical Affections of Solid and Fluid Bodies." It proved a great success, and soon there were 500 persons attending the class, which was continued after his resignation, in 1804, by his successor Dr. Andrew Ure.

There was a wide spread desire for such instruction, and in 1823, the mechanics of Glasgow formed the Mechanics' Institution for the Promotion of the Arts and Sciences, "with a view of disseminating mechanical and scientific knowledge among their fellow operatives, particularly those branches more immediately connected with their daily occupations." Lectures were given on chemistry and natural philosophy, and by 1835, there were three professors who lectured on chemistry, natural philosophy popular anatomy, physiology and phrenology. Among the lectures in Chemistry

(1) J.G. Godard, George Birkbeck. pp. 21 & 26.

(2) W.H. Marwick, Early Adult Education in West of Scotland. pp. 192-7.

were Thomas Clark (1826-9) and Thomas Graham (1829-30). It became the College of Arts and Science in 1881, and some years later, in 1885-6, it was amalgamated with other institutions to form the Glasgow and West of Scotland Technical College, which in 1912 was renamed the Royal Technical College, and became affiliated to the University in 1913.

In the suburbs of Glasgow, also, there was a desire for scientific education. "In the Calton, 450 students attended the natural philosophy class, of whom nine tenths were operatives, and 200 females attended the astronomy and geography classes, seven-tenths of whom were mill girls."

The Gorbals Popular Institution was established in 1833. The object of this institution is the diffusion of science by means of public lectures, and a library which now consists of 1100 volumes. In six years, 324 lectures were delivered to 3735 students, chiefly operatives, on natural philosophy, chemistry, geology, astronomy, political economy, popular anatomy and physiology."

For the cotton operatives at Barrhead, the Lavern Mechanics' Institute conducted "interesting annual courses of lectures on science and literature." At Lennoxton, there was "an excellent and flourishing Mechanics' Institution,"

but a similar institution in Paisley survived only eight years, from 1847 to 1855. At the Athenaeum, formed in 1847, besides public lectures, regular classes were carried on, those in 1848 including natural philosophy. Lectures on astronomy were given by Dr. Nichol. At Parkhead a Scientific Association was formed.

In Edinburgh also there was enthusiasm for scientific education and the Edinburgh School of Arts was founded in 1821,⁽¹⁾ "but there are traces of earlier sporadic efforts notably the Edinburgh Institute, which is described in a pamphlet published in 1811." In the 16th report of this school, issued in November 1842, we find among the lecturers Geo. Lees, A.M. and Andrew Fyfe, M.D., who taught mechanical or natural philosophy and chemistry respectively. The following are some of the statistics for the Edinburgh School of Arts, and show the number of students in the various classes:-

	<u>1840</u>	<u>1841</u>	<u>1842</u>	<u>1843</u>	<u>1844</u>	<u>1845</u>	<u>1846</u>	<u>1847</u>	<u>1848</u>	<u>1849</u>
Natural Philosophy	183	184	85	70	96	102	99	104	58	81
Chemistry	179	186	76	84	94	106	87	83	47	59
Natural History	31	-	-	-	-	-	-	-	-	-

Physiology was added to the curriculum in 1863, botany in 1870, and subsequently both geology and biology. "In 1879, this school was taken over by the Heriot Trust and

(1) W.H. Marwick, Early Adult Education in Edinburgh. P.389.

"converted into a fully equipped technical school under the name of Heriot Watt College". The later development of this institution was closely connected with that of the Science and Art Department in connection with which we shall consider it further.

It is of interest to consider the statistics of the Glasgow Mechanics' Institution, and to compare them with those recorded above for the Edinburgh School of Arts. The number of students at Glasgow in the various classes was:-

	<u>1845</u>	<u>1846</u>	<u>1847</u>	<u>1848</u>	<u>1849</u>
Chemistry	291	204	218	138	171
Mechanics	118	97	251	174	197
Anatomy etc.	161	134	138	74	41

At Edinburgh University in 1826, ⁽¹⁾ John Leslie, Professor of Natural Philosophy conducted popular classes for mixed classes of ladies and gentlemen.

The Edinburgh Association for Useful and Entertaining Science was formed, ⁽²⁾ and lectures were delivered in 1832-33 in Waterloo Buildings as follows:-

Geology	Dr. John Murray	- 95 tickets subscribed.
Chemistry	" " "	- 72 " "
Phrenology	Mr. Combe	- 84 " "
		<u>251</u>

(1) A. Grant, Edinburgh University, II P.354.

(2) Report by Directors 1832.

In the Second Report, 1833, it was stated that the fees were Geology 7/6, Chemistry 10/6, Phrenology and Physiology 10/6, and the numbers of tickets subscribed were 251, 229 and 225 respectively, i.e. a total of 705. The lectures were delivered at 8.30 p.m. Professor Drummond, Belfast was to give 24 lectures in Botany in May, June and July at 8.30 p.m., at a fee of 7/6, also at 4 p.m. at a fee of 15/-, "for the benefit of those in the higher ranks of society." In the Third Report, it was mentioned that 191 tickets had been sold for the Botany lectures, and the lectures announced for the ensuing winter were:-

Natural Philosophy-twice a week by Geo. Lees, A.M. of the Scottish Naval and Military Academy - 30 lectures - fee 10/6.

Astronomy-once a week - illustrated by a suitable apparatus including an Orrery by Rev. Thos. Gray, Kirkcaldy - 20 lectures - fee 9/-.

Physiology and Zoology - once a week by Mr. W.A.T. Browne, Surgeon - 25 lectures - fee 7/6.

In the 4th Report, 1835, mention is made of the number of tickets subscribed during the past session:-

Natural Philosophy	239	Botany-day class	60
Astronomy	298	" evening class	192
Physiology	293	Geology	251
Chemistry	229	Phrenology	225

The popularity of Phrenology at this time is shown by the 5th Report, in which the statistics are:-

	<u>Tickets subscribed</u>	<u>Visitors</u>
Phrenology	224	1114
Natural Philosophy	210	161
Animal Economy	197	334

The name was altered to Edinburgh Philosophical Association ⁽¹⁾ and the various lectures were:-

Mr. Geo. Combe - Moral Philosophy	- 20 lectures-fee	10/-
Dr. Fyfe - Chemistry	- 50	" - " 15/-
Rev. J. P. Nichol - Astronomy & Geology	25	" - " 10/6.

In December 1835 was formed "The Society for aiding the General Diffusion of Science" ⁽²⁾ in order to assist provincial associations by advice in procuring lectures, books, and apparatus.

In the New Statistical Account we find information regarding the establishment of Mechanics' Institutions or similar organisations throughout Scotland. ⁽³⁾ In Haddington, a Mechanics' School of Arts was begun in 1823 and lectures were given in chemistry, mechanics and physiology. There were in 1835 a museum, a library and "suitable apparatus"

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- (1) Reasons of Protest against the Laws of the Edinburgh Philosophical Assn. 1835.
 - (2) Address by the Society for aiding the General Diffusion of Science, 1835.
 - (3) II 15, 343, 414, V 71, VI 594, VII 292, 471, VIII 227, 443, VII 75, IX 768, 903, X 295, XI 47.

At Kelso, there had been a School of Arts in existence from 1825 to 1828, and lectures had been given in chemistry and mathematics, but by 1838 there was no such organisation. In 1839, lectures were being given at Hawick. The Mechanics' Institution at Ayr was founded in 1825 and lectures on scientific subjects were delivered. Weekly lectures on subjects of general science were delivered at the Useful Knowledge Society, Carlisle, which had been established in 1836. In 1845 there was "a museum of fossils, etc.," and there were 44 members of the society.

The Philosophical Institution, Paisley, was founded in 1808 and possessed both a library and a museum. A series of lectures was given on meteorology, physiology, astronomy, geology and electricity, and included among the apparatus were an excellent air pump and a variety of other philosophical instruments. At Greenock, the Mechanics' Institution was founded in 1836. The Vale of Leven Mechanics' Institution commenced in 1834, and a course of 26 lectures was given on Saturday nights. The School of Arts at Stirling was established in 1826 and had as its object, "to instruct the members in the principles of mechanical philosophy, and those other branches of science, which are of essential service in the exercise of the arts of life." There existed both a library and a museum, and of the 201 members, 115 were seniors, 56 were

juniors, and the remaining 30 were ladies.

One of the most interesting features of adult education at this time is recorded in the parish of Kilbrandon and Kilchattan in 1843, thus:-

"Mr. John Whyte, the engineer of the slate quarries, has during the last three winters, delivered a course of lectures on mechanics in the Gaelic language. The people in general, especially the young men at Easdale, seem to appreciate his laudable and gratuitous efforts for imparting to them useful and interesting knowledge. It is believed that this is the first attempt that has been made to communicate such knowledge to the Highlanders in their own language. Lord Breadalbane ----- has lately presented this infant institution with an air pump to enable Mr. Whyte to illustrate some of his subjects to greater advantage."

A Scientific Association was established at Kirkcaldy a few years prior to 1843, and it provided a course of popular scientific lectures during the winter, while at Dunfermline a Scientific Association was founded in 1834. Each winter, a course of lectures, was delivered "in one of the Dissenting Churches." In Auchterarder was a Mechanics' Institute in which lectures were delivered to mechanics during the winter months on literary, scientific and moral subjects,

the fee for the session being 1/6. There was an attendance of about 80.

The Watt Institution in Dundee was opened in 1825. There was a session of six months and 460 persons were enrolled but the numbers decreased, till by 1831 there were only 30 students and 110 annual members. The purpose was to instruct young tradesmen and others in art and science.

(1) During the first session of the Watt Institution, Mr. Macvicar delivered lectures on chemistry, and Mr. Roy on "Mathematics, Algebra and Mechanics." Each course consisted of twenty six lectures which took place in the meeting house of the Associate Congregation in Barrach Street. Accommodation was rented in an adjoining house to hold the library and apparatus. In the First Annual Report, 1825, is a list of apparatus including 2 furnaces, 4 furnace tongs, hook, rake and iron ladle, 14 retorts, 2 kettles, 2 tin pans, 1 chaffer, 1 oil gas apparatus, 1 small galvanic apparatus, 30 pairs of plates and cups, 1 electrical machine (porcelain plate) with Leyden phial and conductor, 3 Wedgewood evaporating dishes. During the second session, lectures were given by Mr. Dow on chemistry and by Mr. Roy, as before, in the church of the Associate Burgher Congregation, while Thistle Lodge, Barrack Street was rented. Prize tickets were awarded for diligence and proficiency to John Guilan, Millwright, Alex. Cross, clerk, and Wm. Kirkland, engineer. In the Third Report, in

(1) First Report 1825.

1827, it is stated that the lectures had been reduced from four to two per week. During the next session Mr. Roy became teacher of mathematics at Cupar. A day school was commenced in connection with the Watt Institution but only eight pupils attended. The Sixth Report, in 1830, shows that instead of a regular course of lectures, various members delivered lectures, and Mr. Roy gave three lectures on physiology. The Ninth Report shows the subjects of lectures given in 1833 by the members, including one on rain by a flaxspinner, mechanical powers by a flaxdresser, history of mechanics by a writer, ores by a banker, fishes by a tailor, and railways by a flaxspinner. Mr. Roy lectured on electromagnetism, Dr. Webster on chemical affinity, Mr. Mackenzie an architect, on strength of materials, and James Hamilton, teacher, on the history of geography. In 1834, some of the topics were brewing by Rev. Geo. Buist, gasmaking by Jas. Russel, Gas Works; structure of flowers by Rev. John McVicar, astronomy by Jas. Will, teacher, and in 1835 an umbrella maker did not chose the subject selected by a flaxspinner in 1833, but lectured on vegetable irritability and parasitic plants.

As a result of subscriptions received for the erection of a lecture hall and museum of natural history, a site was obtained in 1836 on the north side of Dr. Russell's Chapel. In 1837 Dr. Fyffe, Edinburgh gave a course of lectures in

chemistry and Dr. Cantor, Edinburgh on anthropology. Andrew Roy, A.M., of the Public Seminaries, gave fifteen lectures on chemistry and mechanical philosophy in 1840. The new buildings were opened in November 1839. The Twenty-second Report shows that in 1846, Dr. Reid, L.R.C.P. of Edinburgh and Dr. Henderson of London delivered lectures on chemistry and astronomy respectively. The prospectuses are still extant⁽¹⁾ of several courses of lectures, including lectures in 1843 by Mr. W.B. Roy on modern astronomy, in 1847 by Dr. W. Symington Brown of Glasgow on popular chemistry. Separate from this institution was a course of lectures by Mr. Goodacre in 1835 in the Caledonian Hall, Castle Street on astronomy.

It is interesting to trace the further progress of the Watt Institution. In 1853 it got into financial difficulties and the museum was transferred to a hall in Lindsay Street, where it remained until handed over to the Albert Institute in 1867. The excellent library of the Institution was taken over by the Free Library in 1867, and in 1868 the Watt Institution ceased to exist. The buildings opened in 1839 became, and are still the Y.M.C.A. Rooms. During the regime of the Science and Art Department they became a popular educational centre.

(1) In Albert Institute, Dundee with a complete set of reports of the Watt Institution.

Appointed as lecturer in science and mathematics in 1829 was James Bowman Lindsay, who in 1834 advertised a course of lectures on electricity to be delivered at South Tay Street. In 1841 he was appointed teacher at Dundee Prison. He was a pioneer of wireless telegraphy and in 1854 patented his plan for communication by conduction. His experiments were conducted at Glasgow, at Earl Grey Dock, Dundee, across the Tay at Glencarse and at Woodhaven, across the River Dee, and at Portsmouth.

In 1833, at Arbroath, ⁽¹⁾ the building for a mechanics' institution had just been erected. A pamphlet printed in 1860 contains the 6th Annual Report of the Directors of the Arbroath Scientific and Literary Association.

The Mechanics' Institution at Aberdeen was established in 1824 and courses of lectures on chemistry, natural philosophy and other subjects were delivered, but after a few years the lectures were discontinued, owing to the poor attendance. A valuable library, however, survived. "In 1835 it was remodelled on the pattern of the School of Arts in Edinburgh, by the establishment of classes at low rates in various branches of science and literature. These have been since continued and with a considerable degree of success." The new curriculum extended over three sessions

(1) New Stat. XI P. 81. XII P. 47.

and included instruction in chemistry and mechanical philosophy. ⁽¹⁾ The membership numbered 130. By 1849, the chemistry and natural philosophy classes had been given up.

In 1825, a society was founded at Inverness ⁽²⁾ and entitled the Northern Institution for the Promotion of Science and Literature, but like many other such societies did not long survive, and by 1845 it had handed over to the directors of the academy "their valuable museum of books, antiquities and objects of natural history".

Dr. Anderson, Rector of Perth Academy (1809-1837) frequently gave popular lectures on scientific subjects. ⁽³⁾ There were two important consequences of his courses of lectures. One was that gas lighting was introduced into Perth, one of the first Scottish burghs to adopt it, and the other was the construction of a water supply for the town, the River Tay being the source of supply. His name is still commemorated by an inscription on the pumping station tower in Tay Street.

In the same way, the Rector of Ayr Academy,

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- (1) J.W. Hudson, Hist.of Adult Education. P. 58.
(2) New Stat. Acc. XIV P. 31.
(3) E. Smart, Hist.of Perth Academy, P.118.

J.S. Memes, in 1827 delivered a course of lectures ⁽¹⁾ on "Chemistry with its application to the useful Arts," on Saturdays from May until the end of the session. The fee for the whole course was half a guinea, and for a family ticket the charge was one guinea. The underlying object of these lectures was to obtain funds to purchase chemical apparatus., and so avoid asking public subscriptions.

While Professor of Natural Philosophy at Aberdeen, Clerk Maxwell began an evening class for working men. ⁽²⁾ In 1857, he wrote, "a class of operatives on Monday evenings, who do better exercises than the University men about false balances, quantity of work, etc."

In Edinburgh various Apprentice Schools were organised by the Apprentice Schools Association. ⁽³⁾ Most of the pupils were over 17 years of age, while some were 25 and even 30 years old. The fees charged were 1/3 per month. In 1849, when addresses were given to the pupils of these schools assembled in the Music Hall, Edinburgh, Sheriff Gordon, who presided, stated that he had been a pupil of Mr. George Lees, twenty years previously, and "there never

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- (1) Letter from Dr. Memes in possession of present Rector, Dr. Ritchie.
 - (2) Lewis Campbell & Wm. Garnet, Life of James Clerk Maxwell. P. 292.
 - (3) Pleas for Educn., being addresses delivered to the pupils of the Apprentice Schools of Edinburgh at a meeting held in the Music Hall, Edinburgh, February 7th, 1849.

"was a better master nor one more able to communicate instructions." Mr. Lees delivered an address on physical science, illustrated by experiments. After various speeches there was "an exhibition of magic lantern and phantasmagoria, and the exhibition concluded with a display of two beautiful chromoscopes."

In 1850 the Apprentice School Association⁽¹⁾ had as honorary president the Lord Provost, as vice-presidents the Lord Advocate, R.S. Candlish, D.D., Prof. Wilson and James Grant, D.D. There were thirty-three directors, a secretary and treasurer and an inspector of classes, who was Mr. R. Dun.

Throughout all Scotland there was a considerable enthusiasm for mechanics' institutions, but in some cases they were rather short-lived. The general state in 1840 is shown by this report:-⁽²⁾

"Mechanics' Institutions, or schools of arts, or similar associations, by whatever name they may be called, exist in all our large towns, and in some boroughs whose population will not much exceed 2,000. Peebles, for example, with a population considerably under 2,000 has had a regular course of lectures on some branch of science, such as chemistry, geology every winter for the last five years;

(1) Oliver & Boyd's New Edinburgh Almanac 1850 - P.514.

(2) J.Gadsby, Report of the Manchester District Assn. of Literary & Scientific Institution.

"the course embracing 14 to 16 lectures, one being delivered weekly. Similar remarks apply to such boroughs as Selkirk, Dalkeith, Falkirk, Kirkcaldy, Dunfermline, in all of which there is at least one course of lectures every winter. Dalkeith with a population of about 3,000 will regularly produce a class of from 200 to 220."

Progress. Adult Education to 1850.

1. Lectures by university professors proving attractive to other than university students, e.g. Cullen, Black, Dick, Anderson.
2. Popular lectures by professors e.g. McLaurin.
3. Foundation of Anderson's University, 1796.
4. Special class for artisans established by Birkbeck, 1800.
5. Edinburgh School of Arts founded, 1821.
6. Mechanics' Institution founded at Glasgow, 1823.
7. Watt Institution established at Dundee, 1825.
8. Popular classes for ladies and gentlemen conducted by Leslie at Edinburgh University, 1826.
9. The Edinburgh Association for Useful and Entertaining Science formed in 1832.
10. Society for aiding the General Diffusion of Science founded, (1835).
11. Many Mechanics Institutions founded throughout Scotland from 1823 onwards.
12. Popular lectures by rectors of academies, e.g. Perth and Ayr.
13. Edinburgh Apprentice Schools Association established.

CHAPTER VII.

UNIVERSITIES 1851-1938.

We shall now study briefly some of the work done in the Scottish Universities since 1851, in teaching the various branches of science. This study will not be as detailed as hitherto, because secondary education in Scotland was gradually improving, and as it improved, the Universities were able to relinquish the elementary teaching they had found to be necessary, and to devote their attention to higher instruction, and in course of time, to more research. The University had no longer to combine with its own functions those of a secondary school.

NATURAL PHILOSOPHY.

Peter Guthrie Tait was Professor of Natural Philosophy at Edinburgh University from 1860 to 1901,⁽¹⁾ and introduced the practical teaching of natural philosophy, in an attic of the Old College, converted into a teaching laboratory. This accommodation was increased in 1880 when four rooms in the attic were used. There was no prescribed course, and practical work was not compulsory for graduation.

For the M.A. examination in physics at Edinburgh in 1869,⁽²⁾ the course covered couples, moments, forces, path of

(1) A. Logan Turner, Hist. of Univ. of Edinburgh, P. 248.

(2) Demogeot and Montucci, P. 473.

a projectile, laws of accelerated movements, theory of heat, decomposition of light and its polarisation, Kepler's laws, equation of time, explanation of phases of the moon, electricity-
statical and dynamical, formation of dew, and the essential character of a musical sound.

At Glasgow, in 1855, ⁽¹⁾ Professor Thomson fitted up a room as a physical laboratory and organised, apart from the lecture course, a course of practical instruction, in which students worked by themselves. Subsequently, to this laboratory was added an old examination room. Lord Kelvin, ⁽²⁾ as he afterwards became, sometimes spoke of the lower part of the laboratory as having been an old wine cellar of a formerly professorial house, but it was not a basement. His own researches made these laboratories world famous. He was a fascinating lecturer, "never dull, never trivial, never commonplace," and illustrated his lectures with experiments. "Some experiments were great annual events in the class and such was the firing of the shot into a log of wood."

Demogeot and Montucci, two distinguished French educationalists, describe a visit paid to Sir Wm. Thomson's class

(1) J. Coutts, Hist. of Univ. of Glasgow, pp 385 et seq.

(2) D. Murray, Memories of Old College of Glasgow, pp 132 & 123

in 1869. (1) Surrounded by sixty students, he explained to them, by the aid of experiments, the theory of capillary attraction. As he proceeded, he questioned some student in the most affable manner, so that there sometimes resulted a short scientific conversation. An adjoining room was reserved for the use of those students who wished to practice handling the apparatus and to repeat the experiments already seen. Unfortunately the situation of this room was faulty and it was badly lit. From his students Thomson exacted a written exercise every week, while Mondays were reserved for oral questioning. These were 80 students on the roll of the first year physics class and 25 in the second year class. On the retiral of Lord Kelvin in 1899, Andrew Gray was appointed to the chair.

James Clerk Maxwell was appointed professor of natural philosophy at Marischal College in 1856, but left soon to become professor of experimental physics at Cambridge. When Demogeot and Montucci visited Marischal College in 1869, they heard Dr. David Thomson deliver a lecture on the spheroidal state of liquids to a class of 80 students. They found that, when a Bunsen battery was required, in order to avoid unpleasant smells, it was placed on the floor above and wires were led down through a ventilator. Thomson was succeeded

(1) Demogeot and Montucci, pp. 493, 4, 502.

in 1880 by Charles Niven who retired in 1922. This Chair was next occupied by George P. Thomson until his promotion to London in 1930.

ASTRONOMY.

Demogeot and Montucci found that there had been no students of astronomy at Glasgow since 1808,⁽¹⁾ and that the professor in 1869, Robert Grant, was director of Glasgow's excellent observatory. At Edinburgh, ordinarily the professor of astronomy had no students, but in 1869 he had one student.

Grant had become Professor of Astronomy at Glasgow in 1859⁽²⁾ and the result of his observations from 1860 to 1881 are published in a Catalogue of 6,415 Stars for the Epoch of 1870.

CHEMISTRY.

⁽³⁾ The Chair of Chemistry at Edinburgh was occupied from 1858 to 1869 by Dr. (later Right Hon.Sir, and subsequently Lord) Lyon Playfair, who was later to prove himself also an able administrator, and by his influence to aid the cause of science.

(1) Demogeot and Montucci, pp. 412 and 420.

(2) J. Coutts, p. 448.

(3) A. Grant, II p. 399.

Demogeot heard him, in 1869, ⁽¹⁾ gave a lecture on aniline with numerous experiments to a class of 200 students. His teaching was "professorial" but two assistants shared the tutorial teaching of the students twice per week. There was a regular course of practical chemistry and another of analytical chemistry, the number of students being 30 and 20 respectively in 1869. His able successor from 1869 to 1908 was Alexander Crum Brown. In 1913, under Professor James Walker, ⁽²⁾ the Chemistry Department removed to High School Yards, while in 1920 was laid the foundation stone of King's Buildings which now house the Departments of Chemistry, Natural History, Animal Genetics, Engineering and Geology, while the new Zoology building adjoining these was opened in 1929.

At Glasgow, Professor Thomson's successor in 1852 was Dr. Thomas Anderson, ⁽³⁾ who suggested to Professor Lister the use of carbolic acid for the antiseptic treatment he was investigating. In 1869 there were about 140 students. Professor Anderson occupied the chair until 1874, when he was succeeded by John Ferguson. Sir William Ramsay was both a

(1) Demogeot and Montucci, p. 507.

(2) A. Logan Turner, p. 264.

(3) D. Murray, p. 256.

student and assistant at Glasgow.

At St. Andrews, the Professor of Chemistry from 1862 to 1884 was M. Forster Heddle. ⁽¹⁾ He was succeeded by Thomas Purdie, who, with his work on carbohydrates, established the renowned chemical research laboratories of St. Andrews, which have ever since attracted many clever and successful workers. The chemical laboratories presented by Mrs. Purdie were erected in 1891 and research laboratories were erected in 1901. During the occupancy of the chair by Dr. (now Principal Sir) James C. Irvine from 1909 to 1922, he established a world wide reputation as a chemist and a director of research, so that the research laboratories have had a complete complement of chemists undergoing training in research. In 1923 the chemical and physical laboratories were extended.

At Aberdeen, in 1869, ⁽²⁾ the Professor of Chemistry James S. Brazier taught only inorganic chemistry. He was succeeded in 1888 by Thomas Carnelley who died in 1890. Aberdeen has been fortunate in having such distinguished chemists as Professors Japp, Soddy, and Findlay in charge of the teaching of Chemistry.

(1) Votiva Tabella P. 184.

(2) Demogeot and Montucci, P. 456.

BOTANY.

While John Hutton Balfour was Professor of Botany at Edinburgh (1845-79), practical laboratory classes were commenced⁽¹⁾ with physiological experiments and microscopic objects. In 1858 and again in 1865 the Botanic Gardens were extended, while in 1876 the Arboretum was constructed, thus making an addition of over 42 acres to the gardens.

⁽²⁾ During the tenure of office of Professor Alexander Dickson (1879-87), the Arboretum was opened to the public, then while Sir Isaac Bayley Balfour was Regius Keeper and Professor (1888-1922), the gardens were developed as a centre of botanical and horticultural teaching and research, whereas at Edinburgh in 1869, the botany course had been conducted only during the summer session.⁽³⁾

At Aberdeen, on the Union of the Colleges, in 1860,⁽⁴⁾ the new Chair of Botany was attached to the Faculty of Medicine. In 1866,⁽⁵⁾ the Botany Department had only two microscopes, "both of them very much the worse for use." The summer course lasted only about 12 weeks. There was

(1) A. Logan Turner, Hist. of Univ. of Edinburgh, P. 241.

(2) Royal Botanic Garden, Edinburgh, P. IX.

(3) Demogeot & Montucci, De Penseignement Superieur, P. 421.

(4) R.S. Rait, Univ. of Aberdeen, P. 344.

(5) P.J. Anderson Hist. of Aberdeen, pp. 180 et seq.

no practical work, other than 7 or 8 excursions, but in 1879 a practical class was established, and it shared a room with physiology, as it lasted only 2 hours a week. In 1888 a laboratory was obtained for botany. All the teaching in botany, zoology, geology and physiology, in 1877 consisted of one elementary course of lectures. These were illustrated by diagrams, and in addition, in botany, by specimens. Nothing else in the way of practical teaching was attempted. The Botany Department benefited in 1898 by a gift of £15,000 and the Cruickshank Botanic Garden was established in the grounds of the disused school called The Gymnasium. This was a great change from the conditions which prevailed in 1869,⁽¹⁾ when botany was taught by the physics professor without botanic garden, herbarium, benches or diagrams. It seemed to him that these material means were not of any practical utility. Since the union of the colleges in 1860, there have been only four Professors of Botany, George Dickie, James Trail, Wm. G. Cramb, and James R. Matthews. At St. Andrews, botany has been taught systematically since 1888,⁽²⁾ when a botanic garden was laid out, and a lectureship was founded in 1891. This was

(1) Demogeot & Montucci, p. 456.

(2) *Votiva Tabella*, p. 183. J.Maitland Anderson, *The Matriculation Roll of the Univ.of St.Andrews, 1747-1897*, p. XXXI.

supplemented in 1900 by a lectureship in Agriculture and Rural Economy, while in 1928 the lectureship in Botany was raised to a Chair with R.A. Robertson as Professor.

In succession to Alexander Dickson, who held the post from 1868, the occupant of the Chair of Botany at Glasgow from 1879 to 1885 was Professor Bayley Balfour, (1) who commenced a class for practical work in 1881, and who was a son of the famous Edinburgh professor. When Balfour left for Oxford in 1885, Dr. Frederick Orpen Bower was appointed.

NATURAL HISTORY.

Professor Robert Jameson, of the Chair of Natural History, at Edinburgh was followed for a few months, 1854-5, by Edward Forbes, (2) and from 1855-70 by George James Allman. To facilitate the study of the specimens in the Government Museum of Science and Art, a bridge was specially built to connect the Museum with the University. Wyville T.C. Thomson, Professor from 1870 to 1882, was famed for his work on the expedition of H.M.S. Challenger, 1872-6, and while absent, his classes were carried on by Professor Huxley. Thomson had lectured previously in botany at King's and Marischal Colleges, Aberdeen. In 1871, Mineralogy

(1) J. Coutts, p. 468.

(2) A. Grant, II p. 434.

and Geology were removed from the syllabus when a separate Chair of Geology was established under Archibald Geikie.

(1) In the early seventies, classes in practical zoology were introduced, but only a small number of the students, attended, and these classes were not compulsory. Thomson's successor in 1882 was J. Cossar Ewart.

The following extract from the report of Demogeot and Montucci regarding the method of teaching in Edinburgh University is of interest. (2)

"Quant à la manière d'enseigner, elle était généralement cathédrique dans les classes de mathématiques et de physique, où l'on faisait toujours beaucoup d'interrogations. La chimie et l'histoire naturelle étaient enseignées ex cathedra; quelquefois le professeur terminait sa leçon par une conversation avec ses auditeurs sur les sujets traités, mais presque toujours, et dans toutes les branches, on demandait aux étudiants des exercices et des dissertations écrites. Tous ces moyens étaient, il faut le dire, excellents, et corrigeaient en grande partie les défauts d'organisation et de méthode."

At St. Andrews, Dr. Wm. Macdonald was appointed

(1) A. Logan Turner, p. 252.

(2) Demogeot & Montucci, p. 461.

Professor of Civil and Natural History in 1850,⁽¹⁾ but his courses in Natural History were rather irregular and were composed of a kind of cosmogony." A class in Civil History was conducted by him only once. He was succeeded in 1875 by Dr. Henry Alleyne Nicholson who discarded Civil History entirely, and taught Zoology and Geology in alternate years. A marine laboratory was fitted up in 1884 by the conversion of a temporary fever hospital, and in 1896 was opened the well equipped Gatty Marine Laboratory, where work was carried on under Professor Wm. C. McIntosh. He was succeeded by Professor (now Sir) D'Arcy Thompson, renowned for his work in connection with Scottish fishery, while he occupied a similar chair at Dundee, where his successor is Dr. A.D. Peacock, who has done much to further the study of biology as a subject of general education. The Chair of Biology at University College, Dundee was founded in 1888, and in the following year a separate Chair of Botany was established.

At Glasgow in 1866,⁽²⁾ Dr. John Young became Professor of Natural History and showed his keen and versatile powers. His lectures were on Zoology and Geology. After his death in 1902, the duties of this Chair were divided, John Graham Kerr being appointed Professor of Zoology, then in 1904, John W. Gregory was appointed Professor of Geology.

(1) *Votiva Tabella*, p, 177 et seq.

(2) *J. Coutts*, p. 577.

From 1853 to 1870, James Nicol taught Zoology at Aberdeen.⁽¹⁾ The next two occupants of this chair, Cossar Ewart and Alleyne Nicholson have been mentioned already. It was in 1879 that a laboratory was obtained for Zoology. Nicholson was followed in 1899 by J. Arthur Thomson, who, by his writing and lectures, did much to popularise natural history, throughout Scotland. On his retiral in 1930, Dr. James Ritchie carried on this good work, and by means of broadcast lectures has been able to interest large audiences in the study of Nature. When he was appointed to Edinburgh in 1936 he was succeeded by Dr. Hogben.

TECHNOLOGY.

At Edinburgh University, one Chair created by the Crown had only a single occupant in the short time that it existed. Dr. Geo. Wilson, M.D.⁽²⁾ was appointed Regius Professor of Technology in 1855. He had taught chemistry in an extra-academical school from 1840, and had a laboratory in Brown Square (where the Dental School now stands). Despite delicate health, he lectured brilliantly and published a text book of chemistry, which became very popular, a Life of Cavendish, and various other books. But for his

(1) P.J. Anderson, p. 181.

(2) A. Grant, II p. 464.

failing health, he would have been a candidate for the Chair of Chemistry on the death of Wm. Gregory in 1858, and when he died in 1859, no successor was appointed to the Chair of Technology.

In his inaugural lecture entitled "What is Technology?" he defined Technology as the application of science to industrial arts; and in 1857 he published a pamphlet, "On the Physical Sciences which form the basis of Technology." Unfortunately religious differences have, from time to time, affected the work of the Scottish Universities in the past, and in 1852, in a pamphlet entitled, "A Grievance of the University Tests as applied to the Professors of Physical Science in the Colleges of Scotland, a letter addressed to the Right Hon. Spencer Walpole," Wilson pointed out that, as a Baptist, and not a member of the Church of Scotland, he was consequently not eligible for a vacant chair at Glasgow University. The Disruption of 1843, it will be seen, thus affected the universities as well as the schools of Scotland, as all professors had to prove their loyalty to the Established Church.

The Royal Commission on Scientific Instruction and the Advancement of Science issued its first report in 1872 and in ⁽¹⁾ it are the following statistics of the science

(1) Vol. I. Appendix. p. 37.

classes at the Scottish Universities during session 1869-70:-

I. St.Andrews	Number of Students.
Natural Philosophy	33
Chemistry	19
II. Aberdeen	
Natural Philosophy	90
Natural History-Zoology, winter-71, summer 41 =	112
Chemistry theoretical	96)
" practical (summer)	62)
	158
Botany, only in summer	77
III. Glasgow.	
No returns printed	
IV. Edinburgh	
Natural Philosophy	185
Applied Mathematics	3
Physical Laboratory	20
Practical Astronomy	1
Agriculture	27
Engineering	26
Chemistry	232
" practical	135
Chemical Laboratory	15
Natural history and mineralogy - no return.	

	Number of Students.
IV. Botany	283
Vegetable histology	33

N.B. Attendance at the classes of botany, natural history and chemistry was required for graduation in medicine.

(1) In the Seventh Report, dated 1875, details are given of some of the classes. At Edinburgh the room used as a chemical laboratory "was never intended for the purpose. It is dark and ill ventilated, and altogether unsuitable." In session 1861-62 there had been 72 students in practical chemistry classes and in 1870-71 the number had increased to 140. As the university laboratory was able to accommodate only about 12 students at a time, it was found necessary to limit practical work to the more advanced students only. In natural philosophy there was no space available for a laboratory until 1868, when a small unsuitable room was provided, but when more than 8 or 10 students attended the laboratory at one time, some had to work in the class room or among the professor's collection of apparatus. The only table space for the exhibition of specimens in geology was the desk used by the professor of moral philosophy, and the only place where the specimens could be stored was a dark cellar, difficult of access, and a considerable distance

(1) Minutes of Evidence Vol. II Append. V. p. 12.

away.

At St. Andrews, the Professor of Natural Philosophy taught only one class and lectured 7 hours per week, while the Professor of Chemistry taught one class, lecturing 5 hours per week with the addition of 3 hours for a practical class. As regards Civil and Natural History, "Dr. Macdonald the present professor has occasionally managed to get a class but from many causes the class has not been regular." There was no laboratory work in any of these classes and the numbers of lectures per session were 168, 161 and 115 respectively.

The lectures in natural philosophy under Professor Tait at Edinburgh consisted of 5 to the ordinary class, and 3 to the advanced class per week, and laboratory work, occupied 25 hours per week.

The geology class conducted by Professor Geikie had 3 lectures per week in winter only, with 32 hours laboratory work, 8 excursions in the neighbourhood of Edinburgh and an excursion at the end of the session for 8 days, that year consisting of a traverse of the Highland line from Aberfoyle to Stonehaven. In botany Professor Balfour conducted an occasional course of 30 popular lectures in winter and in summer the ordinary course of 5 lectures per week with 3 demonstrations, each of one hour and a

weekly excursion on Saturday. There were no facilities for proper laboratory work, but in summer there was a special histological class for 4 days per week. In 1874 there were 354 students of botany, consisting of 308 medical, 4 pharmaceutical, 33 general and only 9 science students. Of these, 225 were first year, and 129 were advanced students, while 51 students attended the vegetable physiology class. The excursions visited (1) Gorebridge and Arniston, (2) Kinghorn and Burntisland, (3) Currie and Slateford, (4) Dirleton and North Berwick, (5) Broomlee and Dolphinton, (6) Linlithgow, (7) Beattock and Moffat, (8) Springfield and Ladybank, (9) East Linton and Tynninghame, (10) Bridge of Allan and Stirling, (11) Murthly, (12) Inveraran, Ben Voirlich, Loch Lomond. By railway, steamboat and walking 961 miles was the distance travelled. At each excursion the number of students varied from 15 to 132, and the total expense of the trips was £3: 7: 0.

The natural history class consisted of 5 lectures per week in summer only, under Professor Thomson. Owing to lack of accommodation, the number of students attending the laboratory was limited to 20. Professor Crum Brown in winter gave 5 lectures, and in summer 3 lectures per week in chemistry. A practical chemistry class of 5 hours per week

was held in January, February and March and two others during the summer term, chiefly for medical students who did not have sufficient time for a full laboratory course.

At Glasgow, natural philosophy, chemistry and astronomy lectures were delivered in winter only, and consisted of 10, 10 and 1 lectures per week respectively, i.e. 250, 250 and 20 lectures per session. Natural history lectures were given both winter and summer 5 per week and 120 in all, and there was no laboratory work. Only in summer were botany lectures given, a total of 60 lectures with the addition of a demonstration lasting 1 hour daily at the Botanic Garden.

DEGREES IN SCIENCE ESTABLISHED.

At Edinburgh in 1864, ⁽¹⁾ regulations were made for degrees in Science, - B.Sc., and D.Sc., - but there was then no Faculty of Science. The Commissioners of 1858 had instituted the M.A. degree with Honours, which included Natural Science, but during the twenty years which followed, only 9 honours graduates out of 176 took Natural Science, and 42 took Mathematics and Experimental Physics. In 1858 it had been made possible for any University Court to make Natural History or Botany compulsory for candidates for a degree in Arts, but in Edinburgh this was never done.

(1) A. Grant, II pp. 164, 121, 114.

Aberdeen selected natural history to be taught in Marischal College, ⁽¹⁾ and in 1869, St. Andrews introduced chemistry, but abandoned it nine years later.

At Aberdeen, B.Sc., and D.Sc. degrees were sanctioned in 1889, ⁽²⁾ the first B.Sc. being conferred in 1890 on Alex. Brown, A.M. Faculties of Science were instituted in the Scottish Universities in 1892. In this year new regulations for the B.Sc. degrees were issued at Aberdeen. Logic which in 1889 had been made optional in the First B.Sc., was deleted from these new regulations.

In 1876-7, at St. Andrews, ⁽³⁾ the degrees of B.Sc., and D.Sc., were established. Regular lectures had been delivered in Dundee from 1875, while in 1880, University College, Dundee was founded and began work in 1883. In 1897 this college was affiliated to form part of the University of St. Andrews,

⁽⁴⁾ At Glasgow, the first B.Sc. degree was conferred in 1873.

In 1921 a new type of B.Sc. was instituted in the Scottish Universities, and for it the fourth year of study was devoted to specialisation in one subject only, in order

(1) J.M. Bulloch, p. 199.

(2) P.J. Anderson, p. 183.

(3) Votiva Tabella, pp. 181 et seq.

(4) J. Coutts, p. 449.

to obtain an honours pass in that subject. In addition, an ordinary degree of B.Sc. was instituted. This new honours degree was more suitable for scientists entering industry or research, but not as suitable for teaching purposes as the former degree, which involved the study of three subjects on an honours standard.

University Local Examinations were instituted first by Edinburgh University ⁽¹⁾ in 1865 "to supply a common test of attainment both for pupils of public schools and for those privately educated." The examinations took place at various local centres, of which in 1884, there were 47. The majority of the candidates were girls. The other Scottish Universities followed the example set by Edinburgh.

The number of candidates in 1865 ⁽²⁾ (at Edinburgh and Inverness) was 58, in 1866 (at Greenock, Stirling and Newton Stewart in addition) was 72, and in 1867 (at Edinburgh, Inverness and Newton Stewart only) was 89. At the St. Andrews Local Examinations held in 1865, there were 25 candidates, and in 1866 only 23 candidates, while in 1867, owing to small numbers no examinations were held.

The position of science in the University of Glasgow

(1) A. Grant, II p. 157.

(2) Commission into Schools in Scotland, Third Report, p. 230.

Local Examinations which were held from 1877 to 1893 will be seen from the following table ⁽¹⁾ showing the number of candidates when these examinations were fully established:-

	<u>1888</u>	<u>1889</u>	<u>1890</u>	<u>1891</u>	<u>1892</u>
English	193	151	85	94	85
Natural Philosophy	4	2	4	3	-
Astronomy	1	5	2	3	5
Chemistry	2	6	2	2	5
Botany	-	-	-	3	-
Zoology	-	-	-	-	-
Physiology	20	20	18	11	8
Geology + Physics	13	5	3	1	6
Total for Science Subjects.	40	38	29	23	24
Senior Certificate	<u>1888</u>	<u>1889</u>	<u>1890</u>	<u>1891</u>	<u>1892</u>
English Literature	61	83	58	44	32
Natural Philosophy	2	3	2	-	1
Astronomy	3	2	1	6	3
Chemistry	-	1	-	-	-
Botany	-	3	-	-	-
Zoology	-	-	-	-	-
Physiology	12	20	15	18	6
Geology + Physics	12	8	1	4	-
Total for Science Subjects.	29	37	19	28	10

(1) Univ. of Glasgow Local Exams. 1892, p.9.

At Edinburgh University, a special course of lectures for the education of women was established in 1867,⁽¹⁾ several of the professors taking part. An "Association for the Higher Education of Women" was commenced, and building belonging to this association was used. When Sir Alexander Grant opened the sixth session of the classes in 1872 he emphasised⁽²⁾ the necessity of the secondary education of girls and stated that the numbers of ladies who had attended the classes during the five sessions previous were 265, 335, 292, 220 and 205 respectively. The title of the association became "Association for the University Education of Women" whose classes included experimental physics, botany, zoology and physiology..

In 1884,⁽³⁾ there was no admission of women to the ordinary classes at Edinburgh, but by the Universities (Scotland) Act of 1889, the graduation of women was made possible.

The demand for systematic higher education of women was met by St.Andrews University creating the diploma of

(1) A. Grant, II p. 158.

(2) Address by Sir A. Grant, 1872, "Happiness and Utility."

(3) A. Logan Turner, pp XIV & 41.

L.L.A.⁽¹⁾ (Literate in Arts). The scheme started in 1877 when 8 students entered. From 1894 to 1896 there were over 900 annually.

PROGRESS SINCE 1851 - UNIVERSITIES.

1. The gradual cessation of elementary teaching in the universities as secondary education improved in the schools.
2. The introduction of a university preliminary examination in 1892, so raising the standard of education of students entering the science classes in the universities.
3. The establishment of degrees in science and a faculty of science in each university.
4. The restriction of the syllabus taught by Professor of Natural History to Zoology only.
5. The establishment of practical instruction in all scientific subjects.
6. The increase in number of classes in each subject, e.g., ordinary, higher ordinary and honours, instead of only one class, also the institution of a summer session.
7. The establishment of lectureships and chairs in different branches of each subject, e.g. Inorganic, Organic and Physical Chemistry, and in other subjects such as

(1) Votiva Tabella, p.227.

Entomology, Parasitology, Biochemistry, and Animal Genetics.

8. Increase in post graduate research, partly due to the establishment of the degree of Ph.D. in each university in 1921.
9. The study of the application of science to industry and agriculture with the establishment of lectureships and chairs in engineering mining, forestry applied chemistry and agriculture.

CHAPTER VIII.

SCHOOLS 1851 - 72.

The annual examination of Mr. Williams' Secular School, Edinburgh, was held in 1851 in the Waterloo Rooms (1) in the presence of 200 visitors, and it appears to have been very well stage-managed.

Mr. Williams carried out a chemical analysis from instructions given by the pupils.

"At the end of the analysis, ammonia, barytes, and the oxides of silver and iron were proved to be the substances that were present in the solution. During the analysis, one of the children registered on the blackboard the results of each experiment, using the chemical symbols, the whole class being occasionally called upon to explain these symbols."

The upper division was examined on "the application of the principles of Natural Philosophy to the elucidation of geographic phenomena," then the third division was examined in physiology by Mr. Angell.

In 1853, (2) the subjects examined included Natural

(1) Report of Annual Exam. 1851. p. 7.

(2) 4th Annual Report.

History, Chemistry, Natural Philosophy, Social Economy, Physiology and Phrenology. This last subject is not unexpected when one remembers that one of the promoters of the school was George Combe, who also published a pamphlet "On Teaching Physiology and its applications in common schools."

The Directors of John Watson's Institution were concerned about the introduction of lessons on "Physiology and its applications to Health" into the Institution, so they appointed a committee to investigate the matter. The majority of the committee in 1854 issued a report⁽¹⁾ including evidence from various persons, interested in this subject and recommending it for inclusion in the curriculum.

In 1854, Williams was appointed master of the science classes at the Birmingham and Midland Institute.⁽²⁾ Difficulty was found in obtaining a suitable teacher and this, in addition to the infirm health of Mr. Combe, and the death of Mr. Simpson, a patron, caused the school to be closed in 1854.

One of the earliest teachers of Murray's Institution,

(1) Report of Majority of Committee of John Watson's Institution (1854).

(2) Chas. Gibbon, Life of Geo. Combe, pp. 247, 249, 351, 362.

Wm. Jolly, Educn: its principles and practice as developed by Geo. Combe. p. 218.

W.M. Williams, A Vindication of phrenology, 1894. p.XV.

Macduff, which was founded in 1849,⁽¹⁾ was a former ship captain, James Duff Cumming, who was regarded as a very proficient teacher of navigation, and conducted exceedingly popular evening classes in this subject. Mr. John Adam established a school on his estate of Scobbach, and appointed Capt. Cumming as the teacher, with the result that this little inland spot became a popular centre of instruction in navigation. To Scobbach School flocked young seafarers from Macduff and its vicinity, especially "when the ships were laid up for the winter, as was the custom in the age of the sailing schooner."

In the Census of 1851, information was obtained regarding evening schools. It was found that there were 438 such schools in Scotland, and in eight of these, navigation was taught, five of these being in the county of Forfar, one in Fife, and two in Linlithgow. Physical science was taught in five evening schools, three in Forfarshire, one in Lanark, and one in Linlithgow.

Similar information was obtained regarding literary and scientific institutions. These were very varied in character and size and consisted mainly of mutual improvement societies and mechanics' institutions. Many were quite small, such as the Duncanstone Mutual Instruction Class in Leslie parish, where lectures in science and other subjects

(1) W. Barclay, Schools and Schoolmasters of Banffshire, p.52.

were given to twenty members, and the Alloa Phrenological Society which was composed of only nine members.

In the Natural History paper of the examination for Schoolmistresses in 1851, ⁽¹⁾ we find the following questions:-

Section 1.

1. Mention the more common species of fresh-water and salt water fish that can be obtained in Great Britain.
Describe their appearance so that they might be recognised from your description.
2. What are the chief birds of passage that visit our country and where are they supposed to resort when away from us?
3. What quadrupeds are to be found wild in Great Britain; and what are their usual haunts and habits?

Section 2.

1. How are vegetables and animals made to depend on each other?
2. Describe the leaves and bark of the oak, ash, birch, beech, elm, poplar, hazel, elder and willow.
3. Describe, as to a class of children, the sugar cane.

In the reports on schools, 1851-2, there is mention of Johnston's illustrations of natural philosophy (two plates) in Houston and Killalan, and Auchencairn schools, also

(1) Minutes of Committee of Council on Education.

1851-2, pp. 697, 708 et seq, 730.

illustrations of natural history in Woodside and Broughty Ferry F.C. Schools.

Praise is given to a senior class in Madras Academy, Cupar, for their responses in an examination in physical geography and popular astronomy. Scientific subjects were evidently taken up enthusiastically by some teachers, as Dr. Woodford, H.M.I. states:-

"I have seen, in a rural district, the teacher not
"merely illustrating the Copernican system of astronomy, but
"explaining to his older pupils, with no small success, the
"effect of gravitation, in determining the orbits of the
"planets. In another school, the more favourite subject of
"the master appeared to be the physiology of the human frame,
"and the functions of the heart, lungs, and liver were pretty
"fully discussed. No objection can be justly made to such a
"practice, or rather every encouragement may be safely given
"to it, provided that the favourite subject does not occupy
"too exclusive a share of attention, and while it is the
"object of the teacher, not merely to cram the memory with
"details, but to impart an interest to subjects which promote
"the welfare of mankind and illustrate the wisdom and goodness
"of the Creator."

In 1852-3, ⁽¹⁾ at Scoonie, the physical geography was

(1) Minutes - 1852-3, pp. 1138 et seq.

excellent and at Milne's Free School, Fochabers, the apparatus was both ample and good, while there were both a large globe and a theodolite. Old Kilpatrick school had "sheets of illustrative astronomy" and at Castle Douglas, "the elements of natural philosophy were taught in a very superior manner." At Carridin, a portion of a large garden attached was laid out in flower plots, and kept by the senior girls in their play hours. Illustrations of natural history were to be found at Bannockburn and Old Cumnock, while Free West Church school, Airdrie, had a small chemical apparatus.

It was stipulated that for grants in Scotland in 1853-4, ⁽¹⁾ the school room must be 11 feet high and have a wooden floor, Often the floors had been found to be formed of large flagstones or of a composition of earth and clay. It was mentioned that "blackboards are still defectively supplied."

In that session, Kemback had a diagram of natural Philosophy, and in Dysart, the highest class was acquainted with the elements of physical geography, while at Irongray, (where there were 29 pupils), the only apparatus in the school consisted of three maps (Scotland, Palestine and the World) and two sets of illustrations of natural philosophy.

(1) Minutes 1853-4, pp. 980 et seq.

In 1855-56, ⁽¹⁾ at Madras College, St. Andrews, navigation and natural philosophy were taught, while in the following session, ⁽²⁾ lessons in geology and mineralogy were given at the mining stations of Leadhills, Dundyvan, and Jervistown and praise was given to the instruction in chemistry and botany at the Neilston Institution of Paisley.

"The Examination Papers of the Public Commercial and Mathematical School, Aberdeen given by R.A. Gray, A.M., at the Annual Competition October 1852" were printed, and the paper given to the Natural Philosophy class contains the following questions:-

3. Find the range upon an inclined plane and time of flight of a projectile.
4. When pressure generates or destroys motion, the moving force is as the pressure.
5. Two heavy bodies of weights P, Q hang over a fixed pulley, to find the accelerating force.
11. The height of a cylinder is double the diam. of it's base; required the angle of inclination of it's base with the horizon, when it is just ready to fall.
13. How high can a wall 4 ft. thick and inclined at an angle of 60° be built without falling?

(1) Minutes 1856-6, p. 659.

(2) Minutes 1856-7, p. 642.

16. "If a body is projected perpendicularly downwards with
"a velocity of 60 ft. per sec., how far will it descend
"in 5 secs?
20. "The latus rectum of the path of a projectile is a, and
"horizontal range b, determine the velocity and direction
"of projection.
22. "A seconds pendulum is shortened one inch, how many
"seconds will it gain in 6 hours, the length of the
"seconds pendulum being 39.1393 inches?"

In 1853 ⁽¹⁾ grants were offered by the Committee of Council on Education for the purchase of apparatus for instruction in science. It was recommended that a condition of award of the grant be that a room be set apart as a laboratory and that some person who had studied experimental science "should undertake to lecture upon it."

The book recommended in chemistry, as being of sound instruction but popular in character, was Dr. George Wilson's Chemistry, which we shall examine later. Mr. John Joseph Griffin was appointed to distribute the apparatus. Some of the prices quoted are rather astonishing to us now e.g. microscope and microscope apparatus £1: 5: 3, magic lantern with astronomical slides £1: 5: 0. Apparatus for performing the experiments in Johnston's Catechism of

(1) Minutes 1852-3 pp. 154, 165, 163.

Agricultural Chemistry and other experiments in elementary chemistry was quoted at £5:10, but of most interest to us is "the small set of chemical apparatus originally prepared "to accompany Johnston's Catechism of Agricultural Chemistry, "and used in the parish schools of Scotland, price in a "packing case, £1: 5."

The detailed list of this collection comprises:-

"Lamp, furnace cylinder, stoneware.
Stoneware, spirit lamp, and cotton wick, stoneware oil lamp.
Tops for furnace, trellis and two rings.
Gas bottle with leading tube and jet, for burning hydrogen gas.
Bottle and gas leading tube for chlorine gas.
8 ounces of peroxide of manganese in a bottle.
6 " " granulated zinc " "
2 oxygen gas retorts, with 1 delivery tube.
1 ounce black oxide of copper, in a bottle.
4 ounces of chlorate of potash " "
 $\frac{1}{2}$ ounce of red oxide of mercury " "
2 test tubes.
Books of litmus and turmeric test papers.
Tube holder for the oxygen retort.
Short wide hard glass test tube for deflagrations.
Tin crook and support for ditto.
2 ounces of nitrate of potash in a bottle.

Stoppered glass bottle to hold sulphuric acid.

" " " " muriatic "

Pneumatic trough and beehive shelf, stoneware.

Plain glass solution jar, 7 Inches.

Another ditto. 5 "

Stoppered glass bottle to collect chlorine gas.

Deflagrating jar with neck.

" spoon.

Taper mounted on a wire.

Tray to hold gas jars when filled with gas.

Glass retort, 4 ounce size.

2 test glass, 1 tall, 1 short, conical glass stirrer.

Pipette for dropping acids, etc.

2 pieces of glass tube.

Porcelain capsule with handle.

Pair of iron pincers.

Porcelain pestle and mortar.

100 circular filter papers.

Filter ring, earthenware.

Small glass funnel.

Capsule for evaporations and crystallizing, 4 inch.

Apparatus and Preparations for Experiments on the

Composition, Decomposition, and Properties of the

Saline on Mineral Manures.

50° Sulphuric Acid.

10° Phosphate of Soda.

50° Carbonate of Potash."

There are various items of interest in the lists of apparatus. Included under "Electricity" are Electrical machines, Leyden Jar, Head of hair, while under "Galvanism" is Galvanic Battery. "Galvanometer" is used for decomposing water and giving the oxygen and hydrogen gases mixed, while "Faraday's tube" is for decomposing salts and water and delivering the oxygen and hydrogen gases separately. In addition to pneumatic troughs are "gas bags," while there is mention of oxyhydrogen apparatus, consisting of a pair of Mackintosh gas bags with stopcocks. For experiments in heat is "Leslie's cubical tin box."

There are Graduated Measures for Centigrade Testing where the graduation is decimal. This however was not in the metric system but in decigallons.

"The septem is the bulk of 7 grains water. 1,000 septems = 1 decigallon = $\frac{1}{10}$ imperial gallon, and contains 1 lb. avoirdupois of pure water at 62 deg. Fahrenheit."

In the lists we saw "Sulphuric Acid 50°." The degree expresses the comparative strengths of the same measure of the respective solutions. Thus, 1 septem of sulphuric acid of 100° neutralises 2 septems of ammonia of 50°. This method is adopted in a book, "Chemical Recreations, a popular compendium of Experimental Chemistry for the use of Beginners", by John Joseph Griffin. This

was first published in 1826, and was in its ninth edition in 1849. In the minutes of the Committee of Council, reference is made to this book.

Griffin explains in his book, ⁽¹⁾ that when water is fixed as the standard of specific gravity, that of water is 1.000 while that of alcohol is 0.796, consequently 1000 septems of alcohol weigh as much as 796 septems of water.

His list of atomic weights includes hydrogen 6.2398, oxygen 100.000 and nitrogen 88.518, i.e. the basis evolved by Berzelius. The method of volumetric analysis used by him appears to be the first in use, ⁽²⁾ and is therefore of especial interest, viz.

"The atomic weights of chemical substances state a quantity of each which, when weighed in English grains, constitute what I will call a test atom. Thus 667.34 grains is the test atom of anhydrous carbonate of soda; and

(1) pp.261, 146, 264, 244.

(2) F. Mohr in 1859 gave a definition of normal solutions, but J.L. Gay Lussac had demonstrated the applicability of volumetric methods in analytical chemistry for alkalimetry in 1828, after theorising previously in an article "Sur l'acidite et sur l'alcalinite" (Annales de Chimie 91 - 1814 p. 130).

"501.165 grains is the test atom of anhydrous sulphuric acid. The bottle figured in the margin contains, when filled up to the mark on the neck, 1 decigallon, or 1000 septems, or $\frac{1}{10}$ gallon of any liquid.

"When a test atom of any substance is dissolved in water, and the solution is further diluted with water till it occupies the bulk of a decigallon, at the temperature of 62° F, I call that a solution of one hundred degrees of strength, and I mark it 100°. Thus, solution of carbonate of soda of 100° contains 667.34 grams of that salt in a decigallon of solution..... If two test atoms of the dry test are contained in the same bulk of solution, I call it's strength 200."

For these operations, he next describes the various graduated glass instruments necessary which he names a centi-grade alcalimeter, a test mixer, a pipette so graduated that when filled up to the mark it delivers exactly 100 septems of solution, and a pipette for measuring from 1 to 20 septems of a liquid.

For water, Griffin adopts the formula $H^2O = 112.48$. The book contains a reference to Griffin's Chemical Museum, Buchanan Street, Glasgow.

Chemistry by George Wilson, M.D., F.R.S.E., Lecturer on Chemistry in the Medical School, to the School of Arts,

and to the Veterinary College, Edinburgh, was published in Edinburgh in 1850. As we have seen, he and Dr. Reid were probably the foremost chemistry teachers in the Scottish capital.

(1) In a table of elementary substances with equivalents, we find Carbon, 6 - Glucinium 26.50, Norium - ,Mercury, 100. Ruthenium 52.11, Silicium 21.35, then we learn that "we denote the most familiar of liquids by calling it water, or oxide of hydrogen, or by using the letters HO," and that in the formular of oxysalts, the symbols of the base precede those of the acid e.g. sulphate of soda NaO, SO_3
carbonate of lime CaO, CO_2
nitrate of potass KO, NO_5

As was the custom earlier, heat is studied in chemistry and in the section on Heat of Liquidity, we learn that when 1 ounce of ice at 32° is mixed with an ounce of water at 172° the result is that the ice is melted and 2 ounces of water are obtained at 32° , showing that the hot water in cooling from 172° to 32° has lost 140° of heat; so that this is the value of the heat of liquidity of water, while those of sulphur and lead are 145 and 162 respectively. It is noticed that the metric system is not yet used here,

(1) pp. 34, 54 et seq, 79 et seq. 118, 134.

the units being ounces and degrees Fahrenheit.

In the experiment on heat of gaseity or vaporisation, one measure of steam raises $5\frac{1}{2}$ measures of water through 180° , so that the heat latent in steam is 990. Corresponding values for alcohol, ether and turpentine are 385.2, 162, and 133.2 respectively.

We read about Nitric Acid, synonyme Azotic acid, NO_5 , equivalent 54, while nitrate of water or hydrated nitre acid is HO_2, NO_5 , and carbonic acid CO_2 has as equivalent 22. In some experiments, instead of rubber connection tubes we find mention of "tubes of caoutchouc tied by threads to those of glass". Oil of vitriol is stated to be HO, SO_3 and sulphurettedhydrogen to be HS.

The Education Committee of the General Assembly recognised the importance of instruction being given in the principles and practice of Agriculture about 1852.

(1) In 1853, Mr. W.T. Ross commenced a class in this subject in the Edinburgh Normal School with eleven students, and in 1854-5 the number of students had increased to thirty. In consequence, agriculture was introduced in 1853-54 into two Assembly schools under qualified teachers, at Camiscross (Sleat, Skye) and Sabiston (Birsay, Orkney), then in the following session at Colbost (Duirnish, Skye).

(1) Report of Educn. Committee of General Assembly on Agricultural Schools. 1854-5. pp. 4 et seq.

Mr. Gordon, Secretary to the Education Committee of the Church of Scotland, in reporting on the class at Camiscross in 1853, stated that there were then eight pupils in the class, aged 10 to 16 years, taught for one hour daily from Murphy's Agriculture Instructor, the practical and chemical parts of the work being taken simultaneously. The lesson was taken by Mr. Neil S. Turner, the teacher, from 4.15 p.m. to 5.15 p.m. after the ordinary instruction was completed each day. Mr. Gordon also stated, "the prejudices of the people are becoming weaker."

At Birsay, book and oral instruction was given for one half-hour daily, and a half hour of the interval was utilised for practical work daily by the class of twelve boys. When Mr. Colin Livingstone introduced instruction in agriculture into the school in 1853, "he had to encounter particularly strong prejudices on the part of the parents," but in the following year, "the parents if not yet entirely reconciled, are at least no longer opposed to it."

There was a croft of five acres at Colbost where nine boys, aged ten to fourteen, were taught by Mr. Robert Macdonald, who "found considerable difficulty in forming a

"class owing to opposition of parents."

This subject was introduced in 1854-55 into two other schools in Skye, Tormore in the parish of Sleat and Uigg in the parish of Suizort.

For the school garden at Eyemouth, Berwickshire, 1066 square yards were handed over by the proprietors in 1854. A table of manuring by each boy there was appended in the report and the yield recorded.

The interest of Scottish teachers in natural science is shown by articles in The Scottish Educational and Literary Journal in 1853. ⁽¹⁾ In the first volume Mr. G. Lawson, curator to the Botanical Society supported botany as a branch of School Education and described the success of Professor Henslow of Cambridge in teaching botany to the children of the village school at Hitcham, all of whom were less than fourteen years of age. This journal also contained a report of a lecture on the study of Physiology as a part of Education, the lecture being delivered to the Edinburgh Association of the Educational Institute by Dr. Dubuc, who lectured in some of the private schools of Edinburgh.

(1) pp. 57 et seq.

The number of pupils given in the Return of Parochial and Burgh Schools, 1854, is as follows:-

Aberdeen - Town's Grammar School	255
" English "	183
Arithmetic, Mathematical and Commercial School	200
Ayr Academy	269
Cupar - Madras School	540
Dumfries Academy	445
Dundee Public Seminaries	675
Dunfermline Grammar School	111
Edinburgh High School	396
Elgin Burgh Schools (united into an academy)	205
Forfar Burgh Academy	150
Glasgow High School	473
Greenock Grammar School	70
Mathematical School	140
Hamilton Academy	170
Kilmarnock Academy	440
Perth 6 burgh schools under magistrates	594
1 charity school " "	
and kirk session	45
2 National schools, under magistrates	507
Stranraer Academy	95

A school which is no longer extant was the Gymnasium, (Chanonry House School), Old Aberdeen.

(1) In the early fifties there was a Botany class, with excursions to gather plants. The prospectus of 1854-5 showed a course of Geology by Rev. Mr. Longmuir, lecturer in King's College, Aberdeen, with excursions also, and in the Mathematical Department there was an extra class in Practical Mathematics and Physical Geography. Physics and Astronomy were later taught and the lighter side of Chemistry was described by a former pupil, "by the enforced desire of the learners, the tuition consisted largely of a series of experiments, which frequently ended in the destruction of apparatus, the defilement of the table and floor, the singeing of the preceptor's beard, or in other ways that contributed to the general entertainment."

In 1853 it was advertised that Dr. Brunton would instruct the pupils of Paisley Grammar School⁽²⁾ in all the branches of a Mathematical and Commercial Education and the subjects mentioned included Elementary Science, illustrated by experiments, Natural History and Astronomy.

(1) A. Shewan, Spirat Adhuc Amor.

(2) R. Brown, Hist. of Paisley Grammar School, p.217.

In the Report on the Grammar School and other Educational Institutions under the Patronage of the Town Council of Aberdeen, 1854, we learn that the education in the Grammar School was comparatively narrow, but it was supplemented by attendance at other schools, in fact 160 pupils of the 255 on the roll did so. Wm.D. Geddes, Rector of the Grammar School states:-

"As an auxiliary to English, and affording subjects of essays and descriptions, should be introduced a little of Natural History for an hour or two a week. Yet not the Natural History which is nothing but a pedantic muster-roll of names, neither the Natural History that is sometimes attempted to be taught with the dead machinery of pictures hung round a room. All of it that was ever learned from were book or picture teaching, says Wordsworth, on such a point the highest authority, is not worth in preciousness a single sight of Robin at the fireside at Christmas time. Rather let it be the Natural History which gives curious insight into the secrets of nature, without the cabalistic mysteries of terminology, and finds it's food in Saturday Excursions for shell collecting or wild flower gathering."

The Public Mathematical School had 230 pupils aged

8 to 20 odd years,⁽¹⁾ including 100 Grammar School pupils who attended one or two hours daily, about 20 girls, and in the College Recess nearly 70 students. There were five arithmetical and three mathematical classes. The second mathematical class, containing 20 pupils, studied natural philosophy elements of astronomy and mechanics. In summer there was also a class of 15 pupils for Physical Geography. It was composed principally of students who had been one year at the College, and the text book used was by Hughes. The books used in mechanics were by Whewell & Potter, also Goodwin's Exercises.

The third mathematical class studied navigation and mathematical astronomy from Norie's Epitome, Thomson's Time Tables and Riddel.

There is rather a novelty in Elementary Mechanics by Harvey Goodwin, M.A., published in 1851, in that the author adopted the conversational form,⁽²⁾ as Galileo had done in his physical treatises, e.g. in the chapter on the lever.

"Pupil - I find the moment of a force to be here
"defined as the product of a force by a certain distance.

(1) Report P. 44.

(2) pp. 40, 136.

"I confess that I cannot form to myself any distinct
"conception of the product of force and distance. Can
"you help me to any clear thoughts upon this matter?

"Tutor - I am glad that you have called attention
"to the point, as it certainly requires explanation. Let
"us resume the proposition which gave rise to the intro-
"duction of the term moment, it was this,

P: Q :: q: p.

"Now in this proposition P and Q are forces, p and
"q are lines. P and Q are measured by the number of lbs.
"wt. which they will support, p and q are measured by the
"number of feet, inches etc. which they contain."

The author deals with composition and resolution
of forces, principle of lever, centre of gravity,
parallelogram of forces, equilibrium, machines, and friction.

Another example of the dialogue is:-

"Pupil - I feel somewhat disappointed with the
"contents of this chapter; I had expected from the title
"Machines that it would have treated of steam engines and
"the like and have introduced me to some of the wonders of
"modern machinery.

"Tutor - you must remember that there are two
"subjects very similar in name but very different in nature,

"namely Mechanics and Mechanism. The science of Mechanism
"treats of the construction of complicated machines such
"as steam engines, looms, clocks, mills and the like and
"it describes the trains of machinery by means of which
"the moving power, whether it be that of steam, horses,
"weights, springs or wind, is made to produce the required
"result."

Part II of this book is concerned with Dynamics.

In Perth,⁽¹⁾ the Rector of the Grammar School, Mr. Steele, wishing to commence a class in botany in 1868, and to include young ladies among his pupils, as "Botany is a science specially suited for them," obtained permission from the Town Council, but the Rector of the Academy felt that this encroached upon his department. As a result of his objections, the Town Council qualified their permission of teaching botany "to ladies only, and that the class to be held on Saturdays."

The Town Council of Stirling⁽²⁾ gave instructions in 1853 that in the High School would be taught Natural History, Natural Philosophy, and Astronomy, but the necessary apparatus was not supplied until a much later date.

(1) E. Smart, Hist. of Perth Academy, P.107.

(2) A.F. Hutchison, Hist. of High School of Stirling, pp.187 & 169.

Into the Writing School of Stirling, Mr. Duncan Macdougall, master from 1846-1882 introduced natural philosophy as a subject, and sometimes held this class in his own house. A former pupil could recollect a lesson on electricity there with illustrative experiments.

(1) At Aberdeen in Autumn 1854, in the General Examination for certificates of merit for teachers were the following questions:-

Agriculture

1. Write out a calendar of the farmer's work in the months of April and November.
2. What is the chemical constitution of bone dust?
For what soils is it best suited as a manure, and in what manner should it be applied?
3. Name the principal varieties of soils, and the crops for which they are respectively best suited.

Mechanics and Physical Science.

1. State, as nearly as you can, the component parts of air and water.
2. Explain how a person is enabled to set himself in motion, and to increase that motion, on a common swing, supposing

(1) Minutes of Comm. of Council on Education, 1854-5, p. 98.

himself unable to touch the ground.

3. Carbonic acid is expressed by the formula CO_2 , and water by HO ; explain precisely the meaning of these symbols.

Teachers, however were not the only people who had to pass examinations, and by the minute of 1853, candidates for lectureships in Training Colleges, also had these.

The examination paper in Applied mathematics included:-

28. Describe and explain one of the following contrivances for obtaining varying ratio of angular velocity.
1. Roemer's wheels. 2. Huggen's eccentric crown wheel.
29. Describe and explain the following contrivances.
- The Geneva stop. The levers of Legrousse.
- The silent click and ratchet.
30. Explain what is meant by an epicyclic train and describe Fergusson's mechanical paradox and Watt's sun and planet wheel, and determine their velocity ratios.

At George Heriot's Hospital, Edinburgh, ⁽¹⁾ in 1855, Dr. W.B. Hodgson delivered a course of thirty lectures to the boys on Human Physiology and in subsequent sessions the House Governor gave a course of lectures on this subject.

(1) Wm. Steven, Hist. of Geo. Heriot's Hospital, p. 171.

On Friday evenings between 7 and 8 p.m.,⁽¹⁾ the House Governor delivered lectures to the two top classes on Natural Philosophy in session 1855-56, and in the following session⁽²⁾ he lectured on Physiology and Natural Philosophy in alternate weeks. This system continued until a teacher of Natural Science was appointed to conduct the classes.

(3) A German headmaster, Dr. J.A. Voigt, rector of the royal school at Halle, in an educational tour of Britain, visited various Scottish schools in 1855, and recorded his impressions. In Edinburgh High School he was surprised to find Latin, Greek, Religion, English, History, Geography, Natural History and Elements of Physics taught in each class by the same teacher, the Classical Teacher, instead of by specialists. Some of the pupils had classes during seven consecutive hours, and during a fifteen minute interval ate hard or soft biscuits sold by the janitor.

In the second class, Mr. Macmillan, in 1853-4 taught Physics (Introduction and Properties of Matter) and in 1854-5 the third class were taught mathematical and physical, geography also physics (statics and dynamics). Mr. Bryce

(1) Geo. Heriot's Hosp. 1855-6, List of Committees, Register of Boys & Course of Study. p. 18.

(2) Ditto, 1856-7, p. 17.

(3) J.A. Voigt, Mittheilungen über das Unterrichtswesen Englands und Schottlands.

taught the fourth class physical geography, mechanics and meteorology in 1853-4 and in the following session he taught the first class zoology. Evidently these were the only masters who taught any scientific subjects. These subjects were taught merely from reading books, properties of matter from a book of the Scottish Schoolbook Association, physical geography in a series of lectures, mechanics and meteorology from Chambers' series of text books, zoology from Patterson's book. The method is described a translation being, "it is the general practice in Scotland as well as in England, at least I found the same method in Mill Hill - that the sciences - geography, physics etc. were not taught in co-ordinated lectures, but a text book of the elements was learnt of which, for each lesson, a certain small prescribed portion was given out, on which the teacher then asked questions and explained."

In Edinburgh Academy the seventh class was taught physical geography by the Rector.

In Heriot's Hospital also "unter die Rubrick Englisch gehört übrigens auch Naturgeschichte."

The classes which were taught physics were the two highest. The lesson in physics which the rector conducted once a week - in the winter 1855 it took place on Friday evenings, but not regularly - was not held in the class

room but in a special room in which was a fine geological collection and some physical apparatus. When experiments were necessary, they were carried out in an adjoining room where they had been prepared by the Mechanical Master, i.e. the master responsible for Practical Mechanics, Woodwork.

In the ten schools under Heriot's Trust, physiology was taught.

Dr. Voigt found that natural history and popular physics were included in the English department, taught by Mr. Armstrong at the Madras College, St. Andrews, and illustrations were shown of mechanical subjects. For "general knowledge", a special book was used, and in the 'private class' he saw boys aged 15-16 at a lesson on the influence of air on the blood and the caused of paleness due to a sedentary life. This book contained mechanics and physics as far as they were of importance in everyday life. The walls of Mr Armstrong's lovely large room was well supplied with illustrations of zoology, physics, mechanics and geography.

He remarked about boys entering the university at the age of fifteen, and stated that in 1831 the average age had been as low as from 13 to 15.

Instruction in the principles of agriculture had been introduced, as we have seen into Assembly Schools

situated in the Highlands, and the books used were Johnston's Catechism of the Principles of Agriculture and Murphy's Agricultural Instructor. (1) Latterly all students in Edinburgh Normal College had attended lectures in agriculture.

For the mining, manufacturing and fishing population no instruction of a special nature had been provided in any of the schools inspected.

In 1853, medical opinion, addressed to the Board of Trade, had urged that instruction in Human Physiology or the laws of health should be given in ordinary schools. This had been done for a considerable time at Lennoxton, Campsie, and had recently been introduced into Heriot's Hospital and the Heriot foundation schools.

The need for teachers having received instruction in science resulted (2) in the Glasgow Normal School providing instruction to the students of the second year, five hours per week. The men were taught physical science by Rev. John Kerr, the books used being Wilson's Chemistry and Golding Bird's Natural Philosophy, while the female students were taught Domestic Economy by Miss Hood and used Johnston's Chemistry of Common Life.

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- (1) Minutes of Comm. of Council on Education. 1855-6, pp. 672 and 677.
- (2) Report of Comm. of Council on Education, 1858-9. p. 410.

In 1861, ⁽¹⁾ it was reported that, out of 305 schools scientific apparatus purchased with aid from the Committee of Council was in 13 schools, engraved illustrations of natural philosophy in 58 schools, and engraved illustrations or specimens of natural history by pictures or specimens, viz. vegetable productions, geology, mineralogy mining objects and operations, in 73 schools.

The Elements of Natural Philosophy by Golding Bird, M.D., F.L.S., F.G.S. was a book published in 1839 and it contained 400 pages. Section I consisted of the Physics of Ponderable Matter,- Statics, Dynamics, Hydrostatics, Physics of Aerial Fluids at rest or Pneumostatics, Sonorous vibrations of Ponderable Bodies or Acoustics. Incidentally, the title Law of Marriotte was used, not Boyle's Law.

Section II consisted of the Physics of Imponderable matter - Magnetism., Electricity (atmospheric, voltaic and organic), Luminous Undulations of Imponderable Matter or Light. Most of the work on electricity, at this time, of course, dealt with what we call statical electricity,- electric machines, dielectrics, Leyden jars. The chapter on Atmospheric Electricity contained descriptions of

(1) Report, 1860-61. p.207

electricity collected by a kite, lightning, paratonnerres (or lightning rods), Feu de St. Elme, Aurora Borealis. Volta's Electricity ("electricity excited by chemical action") was also called galvanism or voltaism. What we now call a simple cell was entitled "electromotor".

The following is the description (1) of the cell evolved by Professor Daniell, "the arrangement used by that gentleman consists of a cylinder of amalgamated zinc, placed in the centre of a hollow cylinder of copper, the former being surrounded by a piece of ox-gullet or bladder. The exciting fluid acting on the zinc is dilute sulphuric acid, the copper cylinder being filled with a solution of sulphate of copper". The improvement of apparatus is interesting in this passage, "As bladders and other membranous diaphragms have the disadvantage of becoming rapidly corroded, and pierced by the action of the exciting fluids, and if becoming torn by the sharp edges of the crystals of metallic copper deposited on the copper plate, various attempts have been made to substitute for them cylindrical vessels of porous earth.

(1) pp. 225-9 and 246.

Vessels of this kind, like wine-coolers, have been used by Professor Daniell and myself, but, on account of their thickness, so much obstruction is offered to the transit of the electric current, that their use became extremely limited. Lately some very excellent porous jars, composed of the thinnest unglazed white biscuit ware, have been introduced, and are so extremely convenient that I always use them, in preference to bladders."

The voltaic pile occupies considerable attention then electro-chemical decompositions or "electro-lysis," the galvanometer or "multiplier," especially the astatic multiplier, also "this instrument which I propose to call the inversor," which was really a commutator. Thermo-electricity deals with substances such as bismuth and antimony, after which electric fishes are discussed.

The Chemistry of Common Life by James F.W. Johnston, M.A., F.R.S. was published in 1855 in Edinburgh. He was the author of the popular Catechism of Agricultural Chemistry which we have examined already. This new book was issued in fourteen monthly parts, costing sixpence each, and fully justifies its title. (1)

(1). pp. 7,14.311.

In the chapter entitled 'The Air we Breathe' we find, that, "carbonic acid is easily prepared by pouring vinegar upon common soda, or diluted spirit of salt (muriatic acid) upon chalk or limestone-- every green leaf that waves on field or tree sucks in, during the sunshine, this gas from the air".

Let us listen to the language in the passage concerning dew, and contrast it with the customary language of the scientific text-book, e.g. Playfair p. 309.

"When the summer sun has sunk beneath the horizon, and coolness revisits the scorched plant and soil, the grateful dew descends along with it and moistens alike the green leaf and the thirsty land - the invisible moisture of the air thickens into hazy mists, and settles in tiny pearls on every cool thing. How thankful for this nightly dew has nature everything and always appeared, and how have poets in every age sung of its beauty and beneficence?"

We are told that the liquid hartshorn of the shops is only water impregnated with the gas ammonia.

The next chapters deal with 'The Water we drink, The Soil we cultivate, The Plant we rear, The bread we eat,

(1) pp. 7, 14, 311.

The Beef we cook, The Beverages we infuse, The Sweets we extract and The Liquors we ferment. Some of the titles are rather curious, — The Narcotics we indulge in, The Poisons we select, The Odours we enjoy, The Smells we dislike, Smells produced by chemical art, The Prevention and removal of Smells, What we breathe, What how, and why we digest, The Body we cherish and The Circulation of Matter.

It is curious in these days of anti-gas preparations to read, "Dr. Stenhouse has recently availed himself of the absorbent property of charcoal in the construction of a respirator." An illustration of this early respirator is appended in Johnston's book.

An extremely popular geographical textbook in the Nineteenth Century was entitled The Rudiments of Modern Geography by Alex Reid, L.L.D., Headmaster of Edinburgh Institution. It measured only 6 inches by $3\frac{3}{4}$ inches and contained 180 pages. The first edition was published in 1837 and the fifty-third edition in 1893.

The introduction included definitions, then continents and countries are considered, after which there is a list of

the principal mountains and rivers on the globe. Scotland is considered in sections entitled Boundaries, Counties, Islands, Capes, Friths (sic), Bays, Lakes, Rivers, Towns.

The following extract gives an indication of the scope of this book:--

"Edinburgh-shire or Mid-Lothian- Near the Frith (sic) of Forth, Edinburgh the seat of the supreme courts of law in Scotland, and of a famous university, on the Frith of Forth, Leith, the seaport of Edinburgh, eastward, on the coast, Portobello, and Musselburgh, southward, on the Esk, Dalkeith".

An appendix consists of four sections, Outline of Sacred Geography, Use of the Globes, Problems on the Terrestrial Globe, and Construction of Maps.

The Glasgow Secular School Society ⁽¹⁾ carried on the Glasgow Secular School in Carlton Place, and in 1855 the curriculum included Mathematical Geography and Physiology, while in 1859 Chemistry was added. The master, John Mayer was the first Scottish teacher to qualify as a teacher under the Science and Art Department. In 1859, he was successful in both Inorganic and Organic Chemistry

(1) Reports of the Glasgow Secular School Society 1855 and 1859.

and instituted a special class for the study of Chemistry. It consisted of forty lessons commencing 1st March 1860 on Thursdays at 5 p.m., and Monday mornings at 7 a.m., at a fee of 5/-. These hours were selected "as it seems most convenient both for boys attending school, and others who may be employed during part of the day." The class book used was Professor George Wilson's Book in Chambers' Educational Course, and it was stated that, where practicable, the lessons would be illustrated by visits to various chemical works.

In the Grange House School, Edinburgh, (1) of which the principal was John Dalgleish, lectures were given by Mr. W. Lees in Natural Philosophy, by Dr. S. Macadam, F. R.S.E, in Chemistry and by Mr. Fleming in Natural History during session 1859-60, the third session of this school for "a limited number of young gentlemen". Mr. W.S. Dalgleish, M.A. also conducted a class in Physical Science, one or more subjects connected with Physical Geography, Astronomy Mechanics or Optics being taken up each session.

The John Neilson Endowment Educational Institution, Paisley, took advantage of the offer of the Committee of Council on Education regarding provisions of apparatus,

(1) Annual Report of the Grange House School 1859-60.

by providing two thirds of the cost, and in 1857 ⁽¹⁾ obtained apparatus valued at £45-2-6 for the illustration of lessons on Hydraulics, Hydrostatics, Heat, Optics, Mechanics, and Mensuration. "The great advantage to the pupils of having ocular demonstration of those principles in Natural Philosophy which are treated of in their lessons must be very obvious."

The syllabus for 1857-8 included Geology, Mechanics, Physical Geography and a Systematic Course of Instruction in Natural Science, while the syllabus issued by the Rector, John Smart, for session 1860-61 included Mechanics, Botany and Physical Geography.

The relative popularity of the various scientific subjects in Great Britain at this time is shown in the pamphlet "Our Elementary School Books" by James Filbread, F.R.G.S in 1860. He stated the number of books ordered by managers of schools during the years 1856 to 1859 from the Committee of Council on Education under their scheme of aided purchase:-

(1) Report of the 5th Annual Examn. of the John Neilson Endowment Educational Institution, Paisley. 1857.

<u>Subject.</u>	<u>Books on list.</u>	<u>Number ordered.</u>
Physical and mathematical geography	22	6,140
Geology and mineralogy	18	1,193
Botany and vegetable physiology	21	1,527
Zoology and animal physiology	32	5,422
Chemistry	28	3,039
Natural Philosophy	58	6,712
Mechanics and mechanism and as comparison,	32	3,409
British history	53	62,768
History of Scotland	9	2,288

Herbert Spencer in his Essay on Education in 1861 pointed out that language exercised memory only, whereas science exercised both memory and understanding as well as cultivating judgment.

"Though to the progress of science we owe it, that millions find support where once there was food only for thousands: yet of these millions, but a few thousands pay any respect to that which has made their exestance possible."

He concluded that knowledge of the various branches of Natural Science was of the greatest value, and he put forward a very strong and elaborate plea for making the teaching of Natural science the essential of formal education .

In 1857, (1) chemistry was taught at George Street School, Paisley, at Saltcoats, and at Ardrossan.

1857-58 was the last issue of the Minutes of the Committee of Council on Education, and 1858-59 was the first issue of the Report of the same body. It is of interest to notice that in 1860 the use of a log-book in schools was made compulsory.

Mr. D. Middleton, H.M.I. reported (2) that in many schools in the North district he had seen scientific diagrams illustrative of mechanical powers, hydrostatics, gravity, simple machines and solar system, and that these had a fine pictorial effect on the walls of a school, and served to give the place a learned philosophic air, but they very seldom served any higher end. It was rare to find them referred to by the teacher or understood by the scholars.

"In one school a new teacher inaugurated his reign by introducing an unusual scientific reading book in his highest class, and, by carefully locking up the cabinet of scientific apparatus bequeathed to him by his predecessor. Of course it

(1) Minutes of Committee of Council on Education 1857-58.
(p.671)

(2) Report of Committee of Council on Education 1861-2
(pp. 219, 349).

was my duty to recommend the use of the apparatus, or the disuse of the book."

He praised the ways in which ingenious teachers supplied the deficiency of apparatus and stated that he had seen a sphere of wood turned by the village carpenter, or the roundest head in a geography class do duty very effectively as a terrestrial globe. The danger of the use of chemicals in unskilful manipulations was mentioned and it was stated that in several cases the chemical studies in a school had terminated after an explosion of oxygen, hydrogen and atmospheric air.

In 1861, physical geography had scarcely got a footing in schools, but in 1865-6, Mr. Scougal reported (1) that geography, especially in its physical aspect, had lately risen to the dignity of a distinct science, "by the beauty and extent of its generalization."

Wm. B. Hodgson, L.L.D. who was very interested in the teaching of physiology, stated (2) in 1860 that he had given a course of twenty five lessons in physiology to the teachers and some ninety pupils of Heriot's outdoor schools, a few years previously, then had given a course of thirty lessons to the

(1) Report 1865-6. p.342.

(2) J.M.D. Meiklejohn. Life and Letters of W.B. Hodgson. p.280.

senior pupils in Heriot's Hospital. He caused to be prepared at a cost of £70 a set of about two hundred diagrams to illustrate his lessons.

In 1860 he gave gratuitously a course of lessons to the class of the Rector, Dr. Schmitz, at Edinburgh High School. As a witness before the Education Commissioners he advised the general teaching of physiology in schools.

In a letter written in 1877 he stated,

"It is monstrous that in a city of educational renown like Edinburgh, you and I cannot, at any price, obtain a scientific training, or a training in science for our sons. It is more than time that a vigorous agitation were begun on this subject. The Merchant Company might have opened a new era, but they missed their opportunity."

The state of higher education in Scotland in 1861 is reflected in the "return of Grammar Schools, High Schools and other burgh schools in the burgh of Scotland, 1861" which gives the number of teachers in each school.

Aberdeen- Grammar School 4, English School 1, Arithmetic and Mathematical 1, Writing and Drawing 1,

Dr. Bell's 2, St. Clement's or Foot-dee 1.

Airdrie- Academy 3.

Anstruther Easter- Burgh School. 1

Brechin- Grammar School 2.

Burntisland-Burgh School 1.

Banff- Grammar School 1.

Craill- Burgh School 1.

Dumfries- Academy 4.

Dumbarton " 2.

Dunfermline - High School 1, Holland School 1.

Dunbar- Grammar School 1.

Dundee- High School 9.

Edinburgh " " 11.

Elgin - Academy 3.

Forfar - Burgh, Westend, Eastend and Northend Schools - 1 each.

Forres - 1 rector + assistants.

Glasgow - High School 7.

Haddington - Latin and Grammar, English and Mathematical
Schools - 1 each.

Irvine - Academy - 3.

Jedburgh - Burgh School - 2.

Kirkcaldy " " 1.

Kirkcudbright Academy 3.

Kirkwall - Grammar School 1.

Lanark - " " 1.

Linlithgow - Burgh 1.

Montrose - Academy 5.

Musselburgh - High, Burgh English and Fisher - now English -
1 each.

Paisley - Grammar, Town's English, Low Parish - 1 each.

Peebles - Grammar 1, Burgh English 1.

Perth - Academy, Grammar, English, Writing, Drawing and
Modern Languages Schools - 7 (all in one building called The
Seminaries).

Pittenween - Burgh School - 2.

Port Glasgow - " " - 1.

Queensferry - " " - 1.

Renfrew - Grammar, Old Burgh and Female Schools - 1 each.

Stirling - High School - 5.

Selkirk - Burgh School - 1.

Inspection of schools was denominational, and in 1864
there were ten Government Inspectors of Schools, six for
schools connected with the Established Church, three for Free
Church, one for the schools of the Episcopal Church.

Included in the examination papers set to candidates
for the benefits of the Dick Bequest in 1864, in Physics, we
find the following questions:-

5. Enunciate the laws of reflexion and refraction of
light. Account for total internal reflexion, and mention some
of its applications. Find the positions of the successive

images of objects placed between two mirrors inclined to one another by the angle of 30° .

6. State the physical explanations of sound and light. Give the relative values of the notes in the diatonic scale. Are the values of the different colours in the solar spectrum similarly related ?

At the meeting of the British Association in Dundee in 1867 a report ⁽¹⁾ was given on the best means for promoting Scientific Education in Schools. Distinction was drawn between scientific information and scientific training. The former it was stated should include a general description of the solar system, physical geography e.g. tides, currents, winds, climate, the broad facts of geology, of elementary natural history and the rudiments of physiology. Scientific training should consist of experimental physics, elementary chemistry and botany.

The work of this country was shown in comparison with that of other countries at the Paris Exhibition of 1867, and in various ways it compared rather unfavourably with the position it had held previously. This was discussed by Dr. Playfair in a letter to The Times and it led to a species of educational panic also an outcry for technical education, thus disturbing the apathy displayed previously by artisans and

(1) British Association report 1867.

employers.

In an article on Science in Schools published in 1867, (1) it was stated "the teacher should be provided with what is technically called a Laboratory , a terrible word, meaning, however, nothing more than a room filled up with apparatus, which in most cases, need be of very simple nature only". The chemistry taught should make the pupil conversant with the balance, the test tube and the funnel, rather than with pneumatic troughs and bladders of gas. These opinions were expressed by Rev. F. W. Farrar, one of the English pioneers in science teaching. To modern opinion, his views on botany are rather strange. "At first sight it appears too pleasant and agreeable a pastime even to be converted into rigorous study, but in able hands it can become an important means of encouraging accurate observation and an essential introduction to wider biological studies. It possesses moreover, this very great advantage, that it needs no apparatus and can be taught at any time and in any place. Even when flowers are wholly wanting, a handful of leaves will afford

(1) Quarterly Review vol. 123. No. 246. Oct. 1867. pp. 475
et seq.

material for a dozen lessons."

He displayed sense and foresight in his opinions regarding apparatus. Some incompetent teachers demanded of authorities large expensive and complicated pieces of apparatus, often at an expense of several pounds for a single showy machine made merely to demonstrate a trifling point. "It must be remembered too, that as soon as there is a large demand for simple and cheap philosophical apparatus, prices will fall, and the present golden days of instrument makers will pass away forever; and if every large school had what it ought to have, a workshop, a very great deal of what was wanted could be manufactured at home."

He pointed out that as long as science was allowed to rank hardly higher than fencing or drawing, and a little lower than French or German, it is simply absurd to imagine that it can even have any real effect on the learner's mind."

At the Schools Inquiry Commission (Taunton Commission), 1868, physical geography was recommended as the first scientific subject to be studied and descriptive botany or zoology as the second, followed by experimental physics or chemistry. With regard to Scotland, it was stated:

"The universities largely compete with the burgh schools and academies, and admit many to the professors' lectures, who

"would more naturally be still at school. Each institution in fact, takes its own independent line without regard to the others."

Mr. D. H. Fearon , Asst. Commissioner, reported that the burgh schools seldom retained their male scholars beyond the age of 15 or 16, and that, in some cases, they obtained instructions at a cheaper rate at the universities after that, than if they had remained at school.

One great defect was the lack of an admission examination to the university.

Generally, in Scotland, the mathematical teaching had a practical tendency, as at Perth and Dollar Academies, and "the teaching in mechanics is sometimes excellent", while in Perth Academy he found a class of twelve pupils who were reading Newth's Mechanics.

At Ayr Academy, in session 1863-4 the curriculum drawn up included in the 7th year (age 12-13), Outlines of Physical Geography, in the 8th year (age 13-14), under English - Physical Geography also Natural Philosophy and Astronomy, and in the 9th year (age 14-18), Elements of Zoology or Botany also Natural Philosophy, Chemistry and Electricity. The Young Ladies' Classes were taught at separate hours from the boys.

They were taught Physical Geography in the 7th class (age 12-13), and English included Elements of Natural History in the 8th and 9th classes (age 13-17).

From 1866 onwards, in the High School, Glasgow, Dr. Bryce included in his senior Modern Geography class, Elements of Astronomy, Globes from Bryce's Astronomy. He gave his pupils lectures on geology in a conversational and familiar manner, and these appeared "to excite the greatest interest in the scholars."

The curriculum of Glasgow High School was remodelled in 1867 on somewhat similar lines to that of Edinburgh High School some years previously, and a teacher of Natural Sciences, Mr. William Keddie, F.R.S.E. was appointed.

In the Girls' Department of the Royal Academy, Inverness, Physical Geography and use of the Globes were taught by the master who taught chemistry in the boys' department.

On Saturdays from 9 to 10am. Natural Philosophy was taught in Stirling High School.

In 1866, at Gordon's Hospital, Aberdeen, Mr. Gerrard taught Natural Philosophy of a popular and elementary kind, and Mr. Dale gave instruction in Chemistry in a similar manner.

At Glasgow Academy, natural science, introducing some acquaintance with animals, plants and minerals formed part of the regular course and the five highest classes were expected to

attend these lectures on Natural Science. The Modern 6th class studied Hughes' Physical Geography.

Engineering and practical mathematics were studied by 23 boys at Dollar Institution, also chemistry and natural science by 35.

At this time in the Prussian Gymnasien, the Natural Sciences were allotted 2 hours in the prima class and one in secunda while in the rest of the school, the time given was variable, and in the Realschulen, 11 hours were devoted to mathematics and natural sciences. The "Programmes d'Enseignement des Lycées Imperiaux" of France in session 1865-66 contained in Sciences Mathematiques, Cosmographie, et Mecanique (six huit lecons environ), while in Sciences Physiques were "Physique - pesanteur, chaleur, electricite et magnetisme, acoustique et optique" et Chimie.

Two Frenchmen, M.M.J. Demogeot and H. Montucci, both distinguished educationalists, made a report to the Minister of Instruction in 1868, after an educational tour of England and Scotland, and in it we obtain a contemporary view of scientific education then (1).

In the highest mathematical class of Greenock Academy, astronomy, mechanics and hydrostatics were included.

(1). J. Demogeot and H. Montucci. De l'Enseignement secondaire en Angleterre et en Ecosse.

Physics figured in the regular instructions of Madras College, St. Andrews, but the course at Ayr went further, for it also included chemistry, while in the English classes there, preference was shown for reading and composition subjects taken from geology, zoology and botany, so that at least elementary notions of these were obtained. Madras Academy, Cupar, included Physical geography in its programme, and in the English classes there, vegetable and animal physiology lessons were read. These gentlemen remarked a great difference between this method and the secondary school systematic scientific instruction of France.

A visit paid to the Royal High School, Edinburgh showed a better system of instruction. The first class (aged ten years) received a lesson once a week in botany, about forty lessons altogether, mostly the description of the parts of the plant and a glance at the system of Tournefort, Linnaeus, and Jussieu while the second class studied zoology in the same manner. During the third and fourth years, physics was studied, about eighty lessons in all. This they considered rather too little, as they reckoned twenty lessons barely sufficient for mechanics and hydrostatics, another ten for theory of steam and the locomotive, fifteen for heat and light with all the applications of optics, and twenty-five

lessons for electricity, magnetism and electro-magnetism. Thus there remained only ten lessons available for sound and meteorology. In the fifth year physical geography was studied with chemistry, which was continued in the following year. They considered that, in order to increase the time devoted to physics, chemistry might be confined to one session only. In the forty lessons might be studied the elements, theory of equivalent compounds and salts of the common metals only. This could not include organic chemistry, but that subject had now become so vast and complicated that it should be reserved for University study only. Chemistry, they reckoned, was not as necessary for the ordinary man, and only the most striking phenomena were sufficient for a general education.

In session 1866-67 the botany studied had included the physiology of plants, their classification, distribution on the surface of the earth, the flora of Britain and fossil flora, three visits to the botanic gardens and greenhouses, one excursion into the country, and three compositions written without the help of books or note books - all in the first year, at ten years of age. In natural history had been studied classification and mammals. Physics had included the general

laws of nature, centre of gravity, simple machines, air and hydrostatics, and in chemistry, air, oil, and gunpowder had been studied. There were three divisions of engineering study, military, civil and mining.

Unfortunately the day that they visited Glasgow High School coincided with a Fast prescribed by the Church for the cessation of smallpox, and several teachers had given a holiday to their pupils. In the prospectus of 1835 had appeared a statement (page 13) that Physics would include lessons and tests on the elements of mechanics, hydrostatics, pneumatics, electricity, galvanism, magnetism, optics and astronomy and that preparations for this class not having been completed, the public would be informed when the class would commence.

Thirty-one years later, in 1866, these Frenchmen were shown by Dr. Bryce, in a cupboard, amidst a collection of miscellaneous objects, some physical apparatus carefully wrapped up, with which he carried out physical demonstrations from time to time. This apparatus was the teacher's own property, not the property of this city of 400,000 inhabitants, which they considered better able to provide it. In the syllabus of 1866, there was no mention of physics.

At Montrose, once a fortnight, there was an elementary lecture on physics and the curriculum of Royal Academy, Inverness included Chemistry and Physics.

They bestowed praise on Perth Academy (1) for the scientific education there, the best organised in Scotland except perhaps that commenced in Royal High School, Edinburgh the previous year, but, as they pointed out, the rectorship had been held frequently by distinguished mathematicians and physicists e.g. Dr. Robert Hamilton, Dr. Anderson (both of whom afterwards became professors of physics), and Dr. Miller, while there had been many distinguished science teachers including Dr. Ritchie and Dr. John Forbes.

Every day, four hours were devoted to teaching the scientific subjects. Physics comprised statics, dynamics, hydrostatics, hydrodynamics, optics, electricity, galvanism, electro-magnetism and astronomy, while Chemistry consisted of laws of combination, chemical nomenclature, and notation, heat, oxygen, hydrogen, composition of water, nitrogen, atmospheric air, chlorine, and other gases, acids, alkalies, earths, principles of organic and agriculture chemistry. For several years, the elements of geology, natural history, botany, and animal physiology had been taught.

At the Madras College, St. Andrews, there was a daily lesson of an elementary nature of one hour in physics and another in

(1) P. 534.

physical geography and geology.

The highest mathematical class at Ayr Academy each year studied some part of applied mathematics, such as dynamics or hydrostatics. There were also informal talks with demonstrations in physics, not intended as a systematic study, but to put the pupils "au courant" with scientific ideas and terms and to inspire them with a taste for these studies. In 1863-4, inorganic chemistry and in 1864-5 heat had been studied in this manner.

At Greenock Academy, mechanics was treated in the upper mathematical class, and a weekly lecture was given on some physical subject such as air, hydrostatics and mechanics by Dr. Montgomery.

A lecture on natural science was given on Saturday mornings, in Merchiston Castle School, which possessed a laboratory, where practical chemistry was taught to those who wished it. Dr. Page, a geologist, also taught the fifth and sixth classes natural history.

France, it was concluded, had nothing to learn from Scotland as regards science instruction, as up to then, this had played only a very mediocre part in the Scottish school.

It was stated in the Third Report of Her Majesty's Commissioners appointed to inquire into the Schools in Scotland, 1868, regarding the Burgh and Middle Class Schools that there were 87 secondary schools in Scotland, 33 being burgh schools proper, 23 academies, and 31 parochial schools. In Scotland 1 in 205 of

the population attended public secondary schools, in France 1 in 570, in Prussia 1 in 249, and in England 1 in 1300. A Scottish Day School boy worked 1980 hours per year as compared with 804 at Eton, 1254 at Harrow and 1110 at Rugby. They reported Science has not got a great hold upon the schools, but there are indications of its probably increase. As an instance of this, allusion may be made to the growing popularity of the science department at Dollar Institutuin to the prejudice of the classical, and to the success which has attended the engineering pupils at that school since 1862. In like manner it appears that the lectures on science at the Edinburgh High School are well attended, and in the opinion of the rector are likely to be productive of much good. So also at the Edinburgh Institution and at the Madras College, St. Andrews, the science classes are in good repute, and appear to be attended with interest by the pupils who go there. As it is, however, there are but 545 scholars in physics, 165 in natural history, and 184 in chemistry or about 5% of the whole pupils.

It was recommended that there be two courses, literary and scientific, the latter to comprise mathematics science, English, French, German and music or drawing. Science was not taught systematically in any Scottish school, but in the

High School of Edinburgh, lectures on natural philosophy, chemistry and zoology were delivered by eminent men, while in the Edinburgh Institution, Dollar Institution and Madras College, St. Andrews a few branches of science were successfully taught to limited classes. Difficulties were presented in a lack of suitable school books and efficient teachers.

What was at that time considered the aim of instruction in science? The Report stated:

"The advantages to be gained by instruction in such subjects as these are mainly that by them the faculty of observation is quickened, and the power of rapid and accurate generalization is acquired. Such a study strengthens the mental habit of method and arrangement, arouses an interest in a kind of reasoning that is attractive, and stimulates an intelligent curiosity even in the idlest minds in the facts of nature that they see around them".

Physics and chemistry as experimental sciences and physiology and natural history as sciences of observation were considered the most suitable scientific subjects for educational purposes. In Germany the experimental sciences were preceded by the sciences of observation whereas in Britain usually this system was reversed and the sciences of observation were taught at the universities.

SCHOOLS 1873-1900

On the passing of the Education (Scotland) Act, 1872, the Scottish Education Department took over the administration of Education, and one of its first decisions was the classification of Higher Class Public Schools, eleven in number.⁽¹⁾ These were Aberdeen, New Grammar School, Ayr Academy, Dumfries Academy, Edinburgh High School, Elgin Academy, Glasgow High School, Haddington Burgh School, Montrose Academy, Paisley Grammar School and Academy, Perth Academy, Stirling High School.

Specific subjects were continued, and in the Code of 1873 the grant for a specific subject was raised to 4/-. Pupils in Standards IV, V and VI could be presented in not more than two subjects, but any scholar who had previously passed in Standard VI might be presented in three subjects. The specific subjects were.- 1. Mathematics, 2. English Literature and Language, 3. Latin, 4. Greek, 5. French, 6. German, and various Scientific subjects of which the syllabuses have been given here in detail, as these were the first general syllabuses issued for such work in Scottish schools.

The method of teaching had to be mainly by experiment and illustration, and in the case of Physical Geography, "by observation of the phenomena presented in their own neighbourhood," while learning by rote was not to be accepted as sufficient for a grant. "If these subjects are taught to children by

(1) Reports 1872-3.

definition and verbal description, instead of making them exercise their own powers of observation, they will be worthless as means of education."

The following are the syllabuses of the various scientific subjects:-

7. Mechanics.

1st Year. General ideas respecting the different states of matter, solid, liquid and gaseous with illustrations of compressibility, elasticity and resistance. Measures of space, time and velocity.

2nd Year. General notions of force and of the conservation of energy. The parallelogram of forces. General notions of gravitation.

3rd Year. General notions of the mechanical powers.

8. Chemistry.

1st Year. Elementary and compound matter. Illustrations of combination and decomposition in such bodies as hydrochloric acid, water, oxide of mercury and rust of iron.

2nd Year. Decomposition of ammonia and marsh gas. Preparation and properties of oxygen, hydrogen and chlorine.

3rd Year. The preparation and properties of nitrogen and carbon. Illustration of the general differences between metals and non metals. Combination by weight and volume. The use of

symbols and chemical formulae.

9. Animal Physiology.

1st Year. The build of the human body, names and positions of the internal organs.

2nd Year. Circulation and respiration and the broad structure of the organs concerned.

3rd Year. The organs and functions of alimentation. The properties of muscle and nerve.

10. Light and Heat.

1st Year. General notions respecting the formation of shadows and the reflection of light. The formation of images by a looking glass.

The three modes in which heat may be conveyed from one place to another. Effects of heat; expansion, melting, boiling and evaporation.

2nd Year. Refraction of light, appearance of objects under water. Separation of white light into its components by a prism. Explanation of the thermometer. The disappearance of heat in the melting of solids and the boiling of liquids.

3rd Year. Rudimentary explanation of the camera obscura, burning glass, magnifying glass, microscope and telescope. Illustration of the difference of the specific heat of bodies. The causes of cloud, rain, and dew.

11. Magnetism and Electricity.

1st Year. Attraction, repulsion and polarity, as illustrated by the magnet. Terrestrial magnetism and the mariner's compass.

2nd Year. Attraction of light bodies by rubbed sealing wax and glass. Experimental proof that there are two forms of electricity. Attraction and repulsion. Gold leaf electroscope.

3rd Year. Construction of electrophorus, electrical machine, and Leyden jar. Construction of a common battery. Explanation of a thunderstorm. Action of a current on the magnet.

12. Physical Geography.

1st Year. The nature of a river or stream, whence it is supplied and what becomes of it. Evaporation and condensation. Rain, snow and hail, dew and mist. The atmosphere and its composition. Winds. An explanation of the terms river-basin and watershed. The boundaries of the great river basins of Scotland.

2nd Year. The ocean, its extent and divisions, depth, saltness and currents. Action of waves. Sea beaches. The phenomena of tides.

3rd Year. Form and size of the earth, and its motions. Day and night. The seasons of the year; how they depend upon

the relative positions of the earth and sun. Moon's dimensions and distance, explanation of her phases. General arrangement of the planetary system.

13. Botany.

1st Year. Characters of the root, stem, leaves and parts of the flower, illustrated by specimens of common flowering plants.

2nd Year. Structure of wood, bark and pith, Cells and vessels. Food of plants and manner in which a plant grows. Functions of the root, leaves, and different parts of the flower.

3rd Year. The comparison of a fern and a moss with a flowering plant. The formation of different kinds of fruits. The structure of a bean and of a grain of wheat or barley. The phenomena of germination.

In order to encourage training college students to acquire a knowledge of scientific subjects, it was ordered in 1872 that marks obtained in the Science and Art examinations would be included in the fixing of the order of merit of those qualifying as teachers. It was in that year also that inspectors became undenominational in their work.

More Higher Class Schools were added to the list, Leith High School and Irvine Academy in 1874-75, Bonnington Park School, Peebles, and Hamilton Academy in 1876-77, and Dunfermline Grammar

Grammar School in 1877-78.

A Board of Education for Scotland was in existence from 1873 to 1879, and in its first report⁽¹⁾ it was stated that sound elementary teaching in Natural Philosophy could scarcely be expected, and that harm might be done by unsound teaching in such a subject.

Good pecuniary awards could be obtained by teachers presenting pupils for the examinations of the Science and Art Department⁽²⁾ and this led to scientific subjects being chosen for study in schools in preference to languages. It was forbidden in the Code of 1871 to claim a grant for a subject examined under the Science and Art Department and as a Specific Subject, but this was not always strictly obeyed, and the same matter might be presented under different titles for grants from both these sources.

It was found to be possible to obtain a pass in such Specific Subjects as Physical Geography and Animal Physiology with only a few weeks' teaching, whereas a language required a whole year's hard work to obtain the same grant. The pursuit of these grants caused Mr. Dey, H.M.I. for South Forfarshire, to remind teachers that the vast majority of schools were elementary and must remain such, also that their object was to give a good sound practical education to the masses.

(1) Board of Education, Scotland. 1st Report, 1874. p.81.

(2) 3rd Report 1875-6. pp.XXIV 131, 144.

A change had come over education in the North, for Mr. Macleod advocated at considerable length the teaching of Navigation, which, as we have seen, was formerly a very common subject there.

Mr. A. Ogilvy Barrie, H.M.I. for Dumfries and Galloway, and with whom his brother, Sir J. M. Barrie, resided for part of his boyhood, was extremely critical of the teaching of Physiology as being of educational value.⁽¹⁾ "It was a knowledge mainly of names. Physiology with several other subjects, such as chemistry and physics, are not subjects that can be taught in many elementary schools. Physiology can hardly be taught in an elementary school except from text books, and we have Professor Huxley's judgment that so taught, its value as an intellectual discipline is almost entirely lost."

In 1874-5 the only science in Glasgow High School⁽²⁾ appeared to be the Natural Science taught in the 4th Modern Class.

At Ayr Academy,⁽³⁾ a Chemistry Medal (McCreath) was instituted and frequently girls were medallists:-

1887	Emily McCrorie
1888	E. F. W. Mondy
1889	George T. Samson
1890	Robert H. Morrison.

(1) Report of Comm. of Council on Educn. in Scotland 1874-5. p.38.

(2) J. Cleland. Hist. of High School of Glasgow. p.66.

(3) D. Patrick, Air Academy and Burgh Schule.

- 1891 Lizzie McIntyre.
1892 { Isa Symington.
{ A. H. Dewar.
1893 James Maclaurin.
1894 Alfred Jack.

In the Extract Answers to Heads of Inquiry with reference to an Educational Code for Scotland under the Board of Education for Scotland in 1873, ⁽¹⁾ it was stated that the metric system was required under the New Code (1872) and it was thought that it should be included in the Scotch Code, as "Its future importance recommends it."

The Royal Commission appointed to enquire into the Endowed Schools and Hospitals (Scotland) issued its first report in 1873, and the evidence given in it is of interest. ⁽²⁾

Rev. James Currie, who had been a master in Heriot's Hospital, stated that chemistry, practical mechanics and gardening were added to the curriculum, but this attempt was not continued.

The Scottish Institution for Young Ladies had come to an end in 1871, owing to the establishment of the Merchant Company's Schools. It had had about 100 pupils each session, and as we have seen already, science was taught by outside lecturers.

Dr. Lyon Playfair remarked on the want of a trade and commercial school, so common in the Continental cities, where the

(1) Form No.14. Feb. 1873.

(2) First Report pp.125,200,282,325,533,543,560,591,605,637,702,711.

sciences bearing upon trade and commerce were taught in a systematic manner up to about seventeen years of age, and he pled for the conversion of Heriot's School into such a school. He did not think that scientific education existed in schools at all, except in rare instances. "It scarcely exists in the provinces, and is only beginning to have a small development in the Capitals."

"There is a strong tendency everywhere just now to supplement instruction in all the sciences by a manipulative and practical acquaintance with them." He had recently visited Professor Huxley's class at South Kensington and found over thirty teachers, including a Scottish schoolmistress, engaged in dissecting pigeons and frogs, "so that not only are we having chemical and physical laboratories, but natural history laboratories."

Dr. Findlater, who had been headmaster of Gordon's Hospital 1843-9, had given the more advanced boys lessons in chemistry. They also received "a slight sketch of natural philosophy."

In George Watson's College Schools, science was taught on Friday afternoons to Classes IV and V of the Classical side and Classes II, III, IV of the Commercial side, by Dr. Davidson.

Dr. Davidson also lectured on physiology once a week at Daniel Stewart's Institution, where Balfour Stewart's Outlines

was the book studied in natural philosophy, also the non-metallic elements from Wilson's Chemistry. The only science taught in James Gillespie's School was physiology, on Friday from 1 p.m. for one hour, by Mr. Geo. W. Davidson, M.A., while as an extra subject there was botany consisting of "ideal representation of plant, with its parts or organs." In John Watson's Institution, Classes V and VI studied natural science for one half hour on Wednesdays. The pupils who were not deaf mutes in James Donaldson's Hospital had had science lessons, introduced in September, 1872, in physical geography, chemistry, botany, physiology and astronomy. Natural science was studied at Fettes College.

The boys of Robert Gordon's Hospital, in the 4th section were taught natural philosophy and physical geography by Mr. Gerard, also in winter on Thursday evenings chemistry by Mr. Bale. In the "Boys' and Girls' Hospitals of Aberdeen, King Street," physical geography was studied by both boys and girls, and natural philosophy by boys only. The boys of Samuel Douglas' Free School, Newton Stewart, received lessons in chemistry from McAdam's book, and in botany and animal physiology from Chambers' publications.

The Second Report, issued in 1874, contained further particulars of schools. ⁽¹⁾ There was a department of natural science in the Grammar School, Aberdeen, where physical geography,

(1) Second Report. pp 345, 347, 353, 362, 369, 379, 392, 405, 418, 422, 437, 449, 460, 469, 471, 477, 495, 527, 532, 537, 553, 560, 566 577, 595, 600.

and elementary mechanics were taught with botany by John Roy during the summer and autumn quarters. In Annan Academy the fee for navigation had dropped to 1/- per quarter, and mechanics was studied during the dinner interval for twenty minutes daily from Newth's Natural Philosophy.

Mechanics and natural philosophy were included in mathematics at Arbroath High School, while English included physical geography and astronomy, and navigation was an extra subject. At Ayr Academy, mechanics and experimental physics were included in mathematics, while navigation was separate. Elementary chemistry was studied at Bathgate Academy.

At the Grammar School, Burntisland, lectures were given by the teacher on science, with experiments in chemistry, physics and navigation being also studied.

Schools under Morison's Trust, Crieff, studied elements of science, and the sixth class at Madras Academy, Cupar, read Chambers' Natural Philosophy.

In Dollar Institution, the gardener still taught botany, and mechanics was included in mathematics, while at Dumbarton Academy chemistry and electricity were studied under the Science and Art Department.

A course of lectures on chemistry and natural philosophy was delivered in Dumfries Academy, one lecture each week. In Dundee High School the seventh year class studied natural

philosophy and chemistry or physical geography, and the eighth year added astronomy to these. The teachers of science in Edinburgh High School were John Nicol, Ph.D. in physiology and chemistry, Wm. Lees, M.A. in natural philosophy, and John Sadler in botany and zoology. John Mitchell, of the English Department, taught zoology and botany in Elgin Academy, while navigation and fortification were the work of the mathematical Department, and natural philosophy was taught to the fifth and sixth classes.

Chambers' Natural Philosophy was the text book in use at Forfar Academy, while the science studied in Fraserburgh Academy consisted of acoustics, light, heat and physical geography from various text books.

The curriculum at Glasgow High School contained natural science taught by W. Keddie, zoology, geology and botany, for two hours per week, noon till 1 p.m. on Tuesdays and Thursdays. In the English Department, the sixth class studied physiology, also modern geography with astronomy and natural philosophy.

A laboratory was still a rarity, but that at Trinity College, Glenalmond, measured 20 feet by 30 feet, and chemistry was taught (on Monday and Friday from 3 p.m. to 3.45 p.m.) by W. Rosses, M.D. the Medical Officer, from Roscoe's book. In mathematics, work was included from Newth's Natural Philosophy. Both chemistry and natural philosophy were taught at Inverness

Royal Academy, while at Moffat Grammar School, physiology was studied from Chambers' "Science and Literature" and in Dr. Bridges' "Gatechism of Health." Navigation, natural history and natural philosophy were taught at Rose's Academical Institution, Nairn. In the Ewart Institution, Newton Stewart, there were forty lectures and eighteen essays on physical geography, studied from Chambers' book; and physiology was learnt from a similar book. At John Neilson Institution, Paisley, elementary problems in mechanics were studied, and in the "initiatory school" natural history was a subject. Science was taught in the Burgh Grammar School, Peebles.

The Rector of Perth Academy stated that a large number of pupils, about 14 or 15, came "from the country with the view of attending chiefly the classes for Mathematics, Natural Philosophy, Chemistry and other branches of Science." He taught practical mathematics and problems in natural philosophy daily from 10 a.m. till 11 a.m., also chemistry, electricity, magnetism, and natural philosophy. The books used were Newth's Natural Philosophy, Lockyer's Astronomy, and Wilson's Chemistry.

The course in physics at Madras College, St. Andrews, comprised modern views of the natural forces, including the laws of energy, sound, heat, light, after Balfour Stewart, and in geography the pupils used Page's Advanced Text Books of Geology and Physical Geography.

At Stirling High School natural philosophy was studied, and at Royal Academy, Tain, the highest class were taught the elements of chemistry and natural philosophy.

In the Third Report, issued in 1875, Glen's School, Glasgow, was described ⁽¹⁾ as an outdoor Hospital, "a very good primary school with the germ in it of a secondary school."

In advocating botany as a branch of female education, Dr. W. Lauder Lindsay in 1874, had stated ⁽²⁾ that Dr. Steele, Rector of the Grammar School, Perth, had a Saturday class for botany and that it was attended by 20 gentlemen and 40 ladies, and that he also lectured in botany at Dundee. There was no botany now, however, in Perth, but it was taught at the Watt Institution, and Madras College, St. Andrews. In the latter school, lessons on Common Things were given in the Primary School, and the Elements of Natural History in the English Department. Dr. Smith, Perth, had established a useful Class Museum. In an article written in 1872, ⁽³⁾ Dr. Lindsay remarked on there being no botany, natural history, natural philosophy or chemistry in Queen Street and George Street Institutions for Young Ladies unless they were included in "Lectures on Literature and Science."

The Committee on the Teaching of Physics in Schools

(1) Third Report p.297.

(2) W. Lauder Lindsay. Botany as a Branch of Female Educn.

(3) W. Lauder Lindsay. "Education of Girls" in Perthshire Constitutional 1872.

reported to the British Association in 1874,⁽¹⁾ and recommended that the first teaching of all branches of Physics should be of an experimental nature, the experiments being done by the pupils themselves, and not by the teacher. The Committee considered that although text books might be desirable, they should be merely for reviewing work already learnt by experiment, demonstration or lecture and not for preparing for subsequent lessons. The opinion was expressed that, in schools, the teaching of physics should be commenced by the study of mechanics including hydrostatics and pneumatics, all treated in a purely experimental manner, and that this should be followed by the study of heat, then optics, and lastly magnetism and electricity, while, if time permitted, elementary astronomy should be given an early place.

In the Higher Class Schools in 1874⁽²⁾ there were 3343 pupils, and of these 415 studied Science, 1395 Latin. 1028 French and 475 Mathematics. 336 boys were on the roll of Edinburgh High School, and from these there were 334 students of science, namely: 135 botany and geology, 60 chemistry, 2 engineering, 121 natural philosophy, and 16 mechanics. This shows that of the remaining 3,007 pupils throughout Scotland only 81 pursued scientific studies - 29 in physical science at Dumfries Academy, 12 in natural science and 24 in mechanics and physics at Glasgow High School, also 8 in natural science and 8 in natural

(1) British Assn. Report 1874 p.71.

(2) Board of Educn. for Scotland. Second Report 1875.

philosophy at Perth Academy.

In 1875, of 3401 pupils, 387 studied natural or physical science, namely.- 8 at Arbroath, 43 at Ayr, 38 at Glasgow High School, and 298 (179 natural philosophy and 119 botany) at Edinburgh High School.

Owing to some change in the arrangements of Edinburgh High School, in 1876⁽¹⁾ only 228 pupils out of 3573 studied natural and physical science, 18 at Arbroath, 38 at Ayr, 75 at Edinburgh High School, 67 at Glasgow High School, and 30 at Dumfries Academy. In addition, 38 pupils studied natural philosophy(28 at Edinburgh and 10 at Perth), 10 studied chemistry (at Perth), and 50 botany(at Edinburgh).

In 1877⁽²⁾ there were 3770 pupils on the rolls of Higher Class Schools, and 467 attended scientific classes:-

Navigation.....	1	... at Perth
Physical Geography..	37	... at Paisley
Engineering.....	2	... at Edinburgh
Mechanics.....	56	... (Dumfries 4, Elgin 8, Montrose 6, Edinburgh 25, Glasgow 2, Perth 11.
Mechanics and Physics	46	... (Edinburgh 25, Perth 11, Montrose 10.
Natural Science.....	89	... Perth 11, Glasgow 78.
Physical Science....	67	... (Arbroath 7, Edinburgh 7, Dumfries 19, Perth 11, Glasgow 23.
Physiology.....	7	... Edinburgh.
Natural Philosophy..	74	... (Ayr 19, Edinburgh 25, Dumfries 19, Perth 11.
Chemistry.....	35	... Dumfries 18, Perth 11, Peebles 6
Botany.....	53	... Edinburgh.

(1) Ibid 1876-77. p.154.

(2) Ibid 1877-78. p.142.

The only girls among these pupils were 5 in Mechanics and Physics at Montrose, 17 in physical geography at Paisley, and 4 in natural philosophy at Ayr.

Matthew Arnold in his report as H.M.I. in England wrote in 1876, ⁽¹⁾ "I should like to see what the Germans call 'Natur-kunde' - knowledge of the facts and laws of nature - added as a class subject to grammar, geography and English history. If we have Natur-kunde as a part of the school course, we do not require for such children animal physiology, physical geography and botany as extra or specific subjects."

In 1878 he continued his advocacy of Natur-kunde, "for school children under 13 as much of mechanics, animal physiology, physical geography and botany as they need, may surely be comprised in their class lessons in elementary Natur-kunde." The proper place, he stated, for these various subjects was in evening classes after the child was past thirteen and had left the elementary school.

Professor G. G. Ramsay of Glasgow University writing about secondary education in Scotland in 1876, ⁽²⁾ criticised severely the system of payment of grants in specific subjects, whereby it was possible to obtain much larger payments by a few weeks of cramming in certain scientific subjects than by several years of hard work in classics. He concluded by stating, "but

(1) Matthew Arnold, Reports on Elementary Schools H.M.S.O. p.p.169 & 183

(2) Fraser's Magazine, April, 1876. p.411.

of all subjects, science lends itself most easily to be taught on the principle of cram, and in science it seems to be more difficult than in any other subject to find men who can teach it in such a manner as to extract from it a high educational value."

It was not only in the higher class schools, however, that science was taught, ⁽¹⁾ but in the burgh and parish schools it appeared among the specific subjects, as is shewn by the following table for 1876-77:-

<u>Subject</u>	<u>Schools</u>	<u>Boys</u>	<u>Girls</u>	<u>Total.</u>
Mechanics	20	151	22	173
Chemistry	11	301	163	464
Animal Physiology	173	3,275	1,866	5,141
Light and Heat	5	47	22	69
Magnetism and Electricity	24	777	509	1,286
Physical Geography	581	9,082	6,035	15,117
Botany	22	349	377	726
c.f. Latin.	1,168	9,284	1,769	11,053

The number of burgh schools studying the above subjects was 3, 3, 38, 0, 14, 79 and 4 respectively. It is interesting to study the distribution of pupils taking the various subjects. Mechanics was studied principally in rural schools, e.g. Monzie 21, Knockbain (Ross) 16, Wick 5, Forgue 26, Caerlaverock 18, Walston (Lanark) 13. Chemistry was a subject taught in the

(1) Report of Comm. of Council on Education in Scotland 1876-77.

Glasgow district, e.g. Glasgow 65, Shettleston 8, Cathcart 93, Kilmarnock 52, but we find also Perth 151 and Watten(Caithness)8. "Light and Heat" was a subject supported chiefly by King Edward School 33, and Cromdale 16. Botany was well distributed, e.g. Glasgow 135, Penninghame 109, Bothwell 102, Aberdeen 55, Perth 44, Prestonkirk 48, Melrose 15, Biggar 38, Old Cumnock 20, Middlebie 1, Cromdale 34, Fettercairn 27. Kinloch-Luichart (Ross) had 9 pupils in each of Mechanics, Chemistry, Light and Heat.

The subject of physiography was introduced and developed by Huxley until it became one of the prominent subjects of both Science and Art examinations and of Scottish schools. The lectures on physiography were delivered at the London Institution in 1869, repeated at South Kensington in 1870, and were published as a book entitled "Physiography, an introduction to the study of nature by T. H. Huxley, F.R.S." in 1877. He explained the subject thus, (1)

"I endeavoured to give them in very broad, but I hope, accurate outlines, a view of the place in nature of a particular district of England, the basin of the Thames; and, to leave upon their minds the impression that the muddy waters of our metropolitan river; the hills between which it flows; the breezes which blow over it; are not isolated phenomena, to be taken as understood because they are familiar. On the contrary, I endeavoured to show that the application of the plainest and

(1) p.VII.

simplest processes of reasoning to any one of these phenomena, suffices to show, lying behind it, a cause, which again suggests another; until, step by step, the conviction dawns upon the learner that, to attain to even an elementary conception of what goes on in his parish, he must know something about the universe."

The subject matter of the book comprised:-

The Thames, Springs, Rain and Dew.

Crystallisation of Water, Snow and Ice.

Evaporation, The Atmosphere.

Chemical Composition of Pure Water and of Natural Waters.

Work of Rain and Rivers.

Ice and its work, Sea and its work.

Earthquakes and Volcanoes.

Slow Movements of the Land.

Living Matter and the effects of its activity on the distribution of terrestrial solids, fluids, and gases - deposits formed by the remains of plants.

Formation of land by Animal Agencies - Coral Land and Forameniferal Land.

Geological structure of basin of Thames.

Distribution of land and water.

Figure of the Earth - Construction of maps.

Movements of the Earth.

The Sun.

In 1878-9⁽¹⁾ various alterations were made in the

(1) Report of Comm. of Council on Education in Scotland 1878-9, p.105.

syllabus of specific subjects. In mechanics were included liquid pressure and parallelogram of velocities, and it was stipulated that instruction "should be purely descriptive and experimental." The Senses were now included in Animal Physiology, and it could not possibly be experimental when instruction "should be illustrated by diagrams or models only." The figures in the various subjects were:-

Mechanics	31	Animal Physiology	5,061
Chemistry	188	Light and Heat	76
Magnetism and Electricity	830		
Physical Geography	12,102	Botany	445.

In this session only 2.82% of the 508,452 pupils on the school rolls were over 14, 4.35% aged 13, 8.78% aged 12, and 11.11% aged 11 years. Pupils came to school earlier than now, e.g. in 1874-5 there were 260 pupils aged 2 years, 2,462 aged 3, and 11,196 aged 4 years, in fact 3.25%.

In 1875, Standard V was the lowest class permitted to be presented (for grants) in specific subjects.

In 1880 a report was presented⁽¹⁾ to the British Association by a committee in the following terms:-

- "1. It has come to their knowledge that the teaching of the scientific subjects is practically discouraged by the incapacity of many of the H.M. Inspectors to examine them.
2. This incapacity is explained by the fact that the Inspectors are not generally chosen so much for their fitness to judge of such educational work, as on account

(1) Brit. Assocn. Report. p.219.

of their high scholarship, or through political patronage."

The committee suggested that elementary school teachers should be given an opportunity of appointment as inspectors, and that candidates be tested as to their ability to examine the scientific subjects.

At Montrose, in 1881,⁽¹⁾ there was no laboratory, but the "Mathematical master indeed dabbled in science, and conducted a voluntary class, where those of us who cared to attend learned the names of our bones and saw him ignite potassium by floating it on water; but not much more." Thus was stated the personal experience as a pupil, of a chief inspector, Dr. J.C. Smith, who also remarked that, in 1896, the least satisfactory feature in the curriculum at Stirling High School was the position of Science. It was not compulsory at any stage, and it was not popular.

At the Gymnasium, Aberdeen,⁽²⁾ there was an Engineering Class-room.

One of the foremost schools in Scotland as regards science instruction is, and has been since 1876, Allan Glen's Institution, Glasgow. It was described by the Royal Commissioners on Technical Education⁽³⁾ as "one of the very best examples of a secondary (technical) school." Allan Glen, a master-wright, provided in his will for a free practical education to

(1) Dr. J. C. Smith, Scot. Educational Journal, 1932. p.1593.

(2) The Gym. by an Old Boy, 1885. p.10.

(3) A. Humboldt, Sexton, The First Technical College. pp.138,140, 142,148.

about fifty boys, sons of tradesmen, and in 1853 accordingly, his trustees built a school which was placed under the head-mastership of Mr. Meikleham. By the Allan Glen's Institution Act of 1876 the scope of the school was greatly extended, and in 1878 Mr. Meikleham was succeeded by Mr. Edward Maxwell Dixon, B.Sc. The changes were described by Professor Ramsay at the Prize-giving in 1887:-

"The trustees had received large powers and, looking to the state of education in Glasgow, they felt that it would be a mistake to add one more to the Endowed schools of the type then existing while there was a large field almost wholly unoccupied, and to which attention was being strongly drawn by the newly born demand for technical education. This field was the field of science, to be treated not simply in its application to manufacture and commerce, but as an engine of liberal education to be taught by the methods most appropriate for the cultivation of boys' minds, from the age of 11 or 12 to that of 16 or 17; and to be taught especially to those boys of promise, to whom an education based upon some real knowledge of science was likely to be of service in their after lives."

Mr. Dixon decided that the curriculum should provide for a liberal culture and should include language, literature, mathematics, drawing, history, geography and manual instruction in wood and iron. After 1886 the school was controlled by The Governors of the Glasgow and West of Scotland Technical College.

In 1891 Mr. John G. Kerr, M.A. became headmaster, and by his brilliant leadership he continued and extended the work of Mr. Dixon. Prior to 1894, many quantitative instruments had been acquired for courses of practical physics work, especially in electricity. These courses were in addition to the lessons in sound, light and heat which were illustrated with class experiments. Applied mechanics and steam were also studied. The study of chemistry was commenced in Class II, which did easy analysis. Class III carried on Advanced Analysis in addition to the preparation and properties of Metallic Compounds. Class IV studied the preparation and analysis of Organic Compounds. In Class V specialisation was permitted in Advanced Organic or Inorganic Chemistry, in Metallurgy, in Quantitative Analysis. The large elementary laboratory had places for 80 students, an astonishing number. It was, moreover, lit by electricity and had a special ventilating system. In both Inorganic and Organic Chemistry, Allan Glen boys had occupied the foremost places in the Science and Art Department examination lists.

Regular science instruction was commenced in 1878 at Stirling High School⁽¹⁾, with Mr. Alexander Croall as teacher of botany and natural history, the practical work including field excursions. The efficient scientific equipment of the school, when it was extended in 1887 is shown by this description:-

(1) A.F.Hutchison. Hist. of High School of Stirling.
pp.206, 216.

"The portion set apart for science comprises a large theatre or lecture room, preparation room, physics laboratory, and private laboratory or still room. Immediately above, in the tower in the chemical laboratory, communicating with the preparation room by a hoist, the balance room, and a dark room for photographic purposes. . . ."

Generous donors provided astronomical instruments for the observatory buildings which consisted of a telescope house, with revolving dome, and a house for transit instrument and astronomical clock.

The Commissioners on Endowed Institutions in Scotland under Lord Moncrieff, issued a report in 1881.⁽¹⁾ In it, Dr. Chas. E. Wilson, H.M.I. stated that only once, when examining botany, did he present a plant to the class, one May at Aberlady, when primroses were in bloom, and he feared that, in general, instruction was too much given from manuals. He approved of scientific subjects in the abstract, but thought they were not taught as they ought to be. Dr. Kerr, H.M.I. considered it impossible to teach science to children of school age. Mr. Alex. Mackay, Torryburn, thought there would be difficulty in teaching a scientific subject satisfactorily in an elementary school. Mr. James Smith, secretary of the E.I.S. stated, "I am very anxious that every one should be taught

(1) First Report. pp.46,50,56,60,67,78,96,129. XII,XVII.

science, but there is science and science, and certainly science that is taught by the handbooks upon which the pupils are examined is not science at all." He complained that pupils were passing the third stage of mechanics without a knowledge of algebra. "What is the use of it? They don't know a single formula." This complaint indicates the quantitative bias of science at that time and for many years afterwards. Prof. G.G.Ramsay of Glasgow, considered that animal physiology was seldom well taught and was usually mere cram. Prof. Crum Brown, Edinburgh, was of the opinion that what was called science teaching was really either a memory lesson, in which case it was perfectly useless, or an object lesson. Sir Francis Sandford thought it would not be wise to omit the science subjects from the curriculum, or to discourage them.

The Commissioners decided that "the science subjects are of little or no value as they are at present taught, and that it is impossible to teach them in a truly scientific way to children of school age. We have abundant evidence to show that these subjects (i.e. mechanics, chemistry, animal physiology, light and heat, magnetism and electricity, botany) are at present taught from text books, which are learned by rote without awakening any interest in the subject or leaving in the mind of the children any intelligent appreciation of the phenomena with which the science deals.

There seems reason to doubt whether the inspectors generally are specially qualified to examine upon these subjects." They recommended that the only scientific subjects to be retained among the Specific Subjects should be physical geography and animal physiology, and that elementary science should be taught by object lessons only.

These Commissioners also recommended⁽¹⁾ the conversion of Heriot's and Gordon's Hospitals into day schools which would include in their curriculum the teaching of science.

Lord Balfour of Burleigh was chairman of the Educational Endowments (Scotland) Commission, to which evidence was given by Prof. Ramsay regarding "Allan Glen's Institution."⁽²⁾ In their report published in 1884, he stated that boys from the age of 10 to 14 were given the best possible education in pure science, with a view to founding upon that such special scientific training as they might require in later life. After three years in the secondary department a boy proceeded to the technical department where the teaching was more specialised. There was also an elementary department, whose suppression he advocated, so that teaching might be concentrated on scientific subjects. What was said by him then is still true today, "The school is mainly intended to be a secondary school, in

(1) Second Report pp. XXXVI, 237.

(2) pp. 178, 1067.

which the utmost is made of science as a general instrument of education."

The Commissioners gave instructions that at least one branch of natural science should be taught in the schools under Mutcheson's Trust, Glasgow. Their fourth report issued in 1887 contained information concerning Sharp's Institution, Perth, which had been opened in 1860. There was a well furnished laboratory which Captain Abney, assistant secretary to the Science and Art Department, had stated was the best he had seen in Britain, with the exception of the one at Hull.

In the Second Report of the Royal Commission on Technical Instruction issued in 1884, it was stated⁽¹⁾ that in Glasgow High School science was studied in the senior division, then throughout the whole of the modern side of the school, and that of a total roll of 762 boys, 223 studied science, viz:-

1st form	- Physical geography	- 1 hour per week
2nd "	Chemistry	- 2 hours " "
3rd "	Physics	- 2 " " "
4th "	Theoretical Mechanics	- 2 " " "

The Commissioners visited Allan Glen's Institution, which had been founded in 1853 for gratuitous elementary education, but in 1876 secondary and technical education had been added. They considered the arrangements for teaching practical chemistry excellent and appreciated the workshop instruction

(1) pp.486 et seq.

in the use of tools. "This, the Commissioners were informed, is the only day school in which science teaching was on an altogether satisfactory footing in Scotland; and we consider that is one of the very best examples of a secondary technical school(except as to the buildings, which are poor) that we have met with in the course of our investigations."

The Glasgow College of Science and Art founded in 1823 had been carried on more or less as a Mechanics' Institute until 1880, when its constitution had been altered. There were 758 day and evening students. Included in the accommodation were two chemical laboratories and one physical laboratory. In Anderson's College, Glasgow, there were 1,219 students attending the evening classes in 1882. Former professors of chemistry there included Graham and Penny, while Livingstone, Young and Playfair were amongst the former students. In 1882 there were 2,871 students in the Watt Institute and School of Art, Edinburgh.

At the International Conference on Education held in connection with the Health Exhibition at South Kensington in 1884, Prof. Henry E. Armstrong, Ph.D., F.R.S., delivered an address "On the Teaching of Natural Science as a part of the Ordinary School Course and on the Method of Teaching Chemistry in the Introductory Course in Science Classes, Schools and Colleges." He pointed out ⁽¹⁾ that a great objection to the method at present in vogue was that it did not differ in

(1) pp.72,75,89,119.

schools from science colleges, and he advocated that, instead of a single branch of science being taught, the instruction should consist of the elements of the science of everyday life, including astronomy, botany, chemistry, geology, mechanics, physics, physiology and zoology - the olla podrida comprehended by Huxley under physiography, but which is perhaps more happily expressed in the German word Natur-kunde - in so far as is essential to the understanding of the ordinary operations and objects of Nature. He recommended that such teaching should be as practical as possible, in order to cultivate the faculties of observing, comparing and reasoning from observation, and that the most suitable subject for the commencement of the course was botany.

Perhaps the most important change suggested was the abolition of the teaching of tables for the detection of simple salts, as the teaching of analysis, Prof. Armstrong believed, was in most cases of little use except as enabling teachers to earn grants. In the discussion which followed, Mr. A. W. Watts stated that the method of payment by results had done much to introduce a mechanical mode of teaching science.

Mr. W. Jerome Harrison, F.G.S. then described the itinerant method of science teaching which had been commenced in Birmingham in 1880. The demonstrator toured the various

schools and conducted the science classes.

When Robert Gordon's College, Aberdeen, ceased to be residential in 1882 it was transferred into a day school for boys and an evening school. The former consisted of a Commercial School and a Trade and Engineering School, while the latter consisted of a General and Commercial Section and a Science and Technology Section. In both day and evening schools scientific studies played a prominent part,⁽¹⁾ and "to the physics and chemistry lecture rooms are attached a large apparatus room and commodious laboratories." In addition, by 1886 electric lighting had been introduced into four large classrooms and an arrangement made so that the current generated for lighting purposes might be applied to experiments in illustration of the lectures on electricity, and we are told that "these can now be performed in a manner at once most striking and instructive."

In the Code for 1883⁽²⁾ appeared another specific subject, Principles of Agriculture. One inspector, Mr. Muir, reported "Science, falsely so-called, continues to interrupt the work of education in some schools where 'wisdom lingers.'" In the following session⁽³⁾ Mr. McLeod stated that in only one school in Elginshire were the children examined in magnetism and electricity, and the questions he asked there were:-

(1) A. Walker. Robt. Gordon, His Hospital and His College

P. 41.
(2) Report of Comm. of Council on Educn. in Scotland, 1882-3.

p. 160.
(3) Ibid 1883-4. pp. 149 & 158.

1. What is the pole of a magnet?
2. What keeps the needle in its place?
3. The needle does not point due north; what do you call the difference?
4. Effect on needle placed on cork in water?
5. How will dip-needle stand if you are at north magnetic pole?
6. What poles attract each other?
7. Turn the compass box in any direction, would the marked pole keep north?
8. Is it really north pole of magnet which points north?
9. What is the present angle of declination?
10. What is the present angle of inclination?
11. Are these constant?
12. Are these the same everywhere? Why not?
13. What happens to a piece of iron brought near to a magnet? What is this called?

The examination was conducted orally and experimentally.

This set of questions, and the syllabus we have studied already, give us an idea of the scope of a specific subject.

Mr. Walker stated, regarding specific subjects, that the year's work was often comprised in a pamphlet of 32 pages, so it was easy to prepare, and a written examination failed to find a flaw in the answers, though an oral examination did disclose the hollowness of the whole thing. In too many cases these pamphlets represented all that was known of the subject by master and scholars alike, and frequently they were

not free from error, e.g. that ice floats with one third of its bulk out of water.

In the Code of 1886⁽¹⁾ elementary science was included as a class subject, not a specific subject, but in 1887-8⁽²⁾ only 59 departments studied it, whereas 1,595 studied history and geography.

In order that elementary science might be made a foundation stone for technical education, it was made by the Code of 1888 an alternative to English as a class subject, rather an extraordinary proceeding. This subject was only vaguely defined, so it appeared in various forms. In the Northern Division, "among subjects taken up were natural history, a combination of natural history and physics, and melange of various specific subjects, including agriculture and the manufacture of special substances, such as gas and paper. This variety of subjects is sufficiently wide, but each and all of them afforded, though in different degrees, opportunity for genuine, interesting and valuable instruction."

It was stated that as the reasoning faculties are much later in development than the observational, the science instruction in the lower standards must always be mainly observational.

In 1888 the Leaving Certificate Examination was

(1) Report of Comm. of Council on Educn. in Scotland, 1885-6.

(2) Ibid 1887-8. pp XVIII & p.301.

established, but as yet Science was not a subject in it. 29 schools obtained 972 certificates then. The Elementary Science required as a class subject consisted of " a progressive course of simple lessons on some of the following topics adopted to cultivate habits of exact observation, statement and reasoning:-

Standards I, II & III.- Common objects, such as familiar animals, plants and substances employed in ordinary life.

Standard IV.- A more advanced knowledge of special groups of common objects such as:-

- (a) Animals or plants with special reference to agriculture, or
- (b) Substances employed in arts or manufactures, or
- (c) The simpler kinds of physical and mechanical appliances, e.g. the thermometer, barometer, lever, pulley, wheel and axle, spirit level.

Standard V.-

- (a) Animal or plant life, or
- (b) The physical and chemical principles involved in one of the chief industries of the United Kingdom, among whom agriculture may be reckoned.
- (c) The simpler principles of navigation.

Standard VI.- The preceding in fuller detail.

Despite the recommendations of the Commission on Endowed Institutions, specific subjects were continued, the numbers in 1888-89 being:-

Physical geography	19,605	Mechanics	119
Animal Physiology	5,662	Chemistry	416
Light and Heat	136	Botany	1,097
Magnetism and Electricity	1,582		
Principles of Agriculture	1,010		

Specific subjects were the survival of the laudable endeavours⁽¹⁾ of the parish schools to link themselves with the universities, and Scotland had few real secondary schools, so that most university entrants passed direct from the primary schools. In England, specific subjects were not studied to any great extent, but in England the ratio of university students to the population was 1 to 5,000, whereas in Scotland it was 1 to 617.

In evidence before the Committee appointed to inquire into certain questions relating to Education in Scotland, in 1888,⁽²⁾ Dr. Merry, rector of Dundee High School, stated that in addition to the 9 hours per week given to Latin in the first year of the middle school, 9 hours were devoted to English, 1 to Science, and 5 to Arithmetic. In the second year 5 hours were required for French, 5 for English and 9 for Latin.

There is a detailed description of the teaching of science in several schools in a report issued in 1888⁽³⁾ by

(1) Ibid 1889-90. p.271.

(2) Published as C.5336.

(3) Alex. B.W.Kennedy, Report on the Examination of the Science and Technical Teaching in Blair Lodge School, Polmont, Dundee High School, Sharp's Institution, Perth, Robert Gordon's College, Aberdeen, and the George Heriot's Hospital School, Edinburgh, 1888.

Alex. B. W. Kennedy, Professor of Engineering in University College, London. On behalf of the Scotch Education Department, he examined the science and technical teaching in Blair Lodge School, Polmont, Dundee High School, Sharp's Institution, Perth, Robert Gordon's College, Aberdeen and George Heriot's Hospital School, Edinburgh.

Science was only recently begun at Blair Lodge School, Polmont, a private residential school with about 140 boys. 3 hours were devoted to chemistry and 3 to physics per week, in lesson and laboratory work. In physics they had done mechanics and "accurate measurements" of everything up to specific gravities. This school had been opened in 1843 in succession to Polmont House Academy, which had commenced in 1841 under Rev. Robert Cunningham. In 1851, Robert Hislop became headmaster and later proprietor. Ultimately the school was transformed into a large Borstal Institution.

At Dundee High School science had been taught for some time, but the enlargement of the science classes and their development into an organised science school began only that session. In the "middle school" instruction was by means of object lessons illustrated by an excellent museum. The first and second years of the "upper school"(age 15-16) had 3 to 4 lessons per week and 4 to 5 hours practical work. The chemistry laboratory was a large airy room with space for 32 boys, who were taught by Mr. Frank Young.

There was a reasonably large collection of physical apparatus used in teaching, but as yet no practical work was done in physics or mechanics.

About 30 boys aged 14 to 15 formed the two upper classes of the senior school of Sharp's Institution, and these formed an "organised science school." They were examined in chemistry, electricity and mechanics. In chemistry they had studied a great amount of theoretical work, for boys of that age. The chemistry laboratory was very small, but, judging by results, it appeared to have been well utilised.

The three highest classes in Robert Gordon's College, Aberdeen, were taught science. Boys in the lowest class, aged 12 to 13 had been taught a little very elementary mechanics, light, and sound. Chemistry was taught to all the boys in the fourth division as well as some branch of physical science, magnetism, electricity or light. In the first commercial class, i.e. the second highest in school, mechanics was a subject taught for $3\frac{1}{2}$ hours per week, including 1 hour of laboratory. In the highest class, the second commercial class, 4 hours per week were devoted to physical science, i.e. 2 hours lessons and 2 hours laboratory work. During the past session they had been working mainly at mechanics and heat. Their answers were ready and intelligent. The boys learned

chemistry also, the science master being Mr. John Buchanan.

A detailed scheme of work was given for the first commercial class. It began with the elasticity of a spring and of india rubber, then followed the mechanical advantage of pulleys, screw-jack, wheel and axle, lever, pendulum, torsional vibrations, bending of lath, strength of timber, friction, model derrick crane and model wall bracket. The next section dealt with specific gravity of metals, woods, liquids, mechanical advantage of compound wheel and axle and differential pulley, then model girder beam, inclined plane, endless screw, sonometer, and triangle of forces.

George Heriot's Hospital School, Edinburgh, had been recently reorganised under a scheme of 1885. One of the changes was a "technical side" in which were taught chemistry, physical science (including mechanics), drawing, and the use of tools. Only one session had elapsed since the new workshops and laboratories had been put into use. Mr. Samuel Walker taught chemistry, and Mr. A. Y. Fraser taught physical science. There was a lecture room for each and large separate laboratories, well equipped and well arranged. Three periods per week were devoted to physics, including practical laboratory work, in the 3rd division to mechanics, with elementary applied mechanics, including a little hydrostatics and pneumatics, in the 4th division to electricity and magnetism, and in the 5th division to heat.

Chemistry was studied by the 3rd division for 2 periods per week, one being a lesson and the other laboratory work on the preparation and properties of simpler elementary and compound gases, the chemistry of carbon, water, nitric acid, etc. The two higher divisions devoted 3 periods per week to chemistry, two being for lessons and one for practical work. They were learning something of chemical theory as well as continuing the work done in the 3rd division. The 4th division carried out simple quantitative analysis, and the 5th division went on to the analysis of mixtures of salts and the separation of bases in the Silver, Copper and Iron groups. In George Heriot's School not only chemistry and physics were taught, but natural science, physiography, geology, botany, physiology and zoology, each subject being under a different teacher.

Professor Kennedy remarked upon the rapidity with which the necessity for laboratory work in physics had been taken up by the teachers in these Scottish schools. The physics course in George Heriot's received great praise, but he thought it might be neither possible nor desirable to attempt so much in other schools, and if only one branch of physics could be studied, he recommended mechanics, partly because it was closely associated with everyday life, and it was for the most part quantitative and could be associated

with their geometry and algebra. On the other hand, electricity or magnetism experiments were made with special apparatus kept in a cupboard and never seen outside a laboratory. He remarked upon the difficulty for teachers of science in schools to decide what units (English or Metric) it was most advisable to use, but, for mechanical problems, it appeared essential to work with feet and pounds if boys were to tackle problems in a form that would afterwards be of use to them.

The Committee on the Teaching of Chemistry of the British Association in 1889 reported⁽¹⁾ that generally, chemistry was presented to children in elementary schools in exactly the same way as to undergraduates in the universities, and that this was the principal cause of unsatisfactory results. They considered also that the teaching of qualitative analysis, which constituted the "practical chemistry" of most schools, although interesting to the pupils, was "unsatisfactory and uneducative." In other countries, such as Germany and Switzerland, where science was applied to industry very successfully, only science of a simple and general character was taught in the elementary schools, and the teaching of science of a systematic nature was begun in the higher schools and polytechnics, whereas, in this country, boys were taught chemical analysis although they were unable to do simple

(1) Brit. Assocn. Report 1889. p.257.

arithmetic or to write their own language correctly. The opinion was expressed that the most that could be aimed at in elementary schools was "the training of the faculties of observation and of orderly thinking, and the stimulation of the instinct of inquiry."

Prof. H. E. Armstrong stated that hitherto practical chemistry had consisted mainly of the analysis of simple salts, and he expounded a scheme by which pupils could be trained by the solution of problems presented to them. His course consisted of six stages, (1) lessons on common and familiar objects, (2) lessons in measurement, (3) studies of the effect of heat on things in general; of their behaviour when burnt, (4) the problem stage, (5) the quantitative stage, (6) studies of the physical properties of gases in comparison with those of liquids and solids, Molecular & Atomic theories. His first stage gave rise to object lessons in the primary departments of schools, and his second stage became only too well known in Scotland and lasted longer even than in England, where its relegation to the mathematical staff was recommended in 1908. The studies of the effect of heat on metals, water, sand, clay, chalk, sulphur, were conducted both qualitatively and quantitatively. The outstanding and revolutionary part of his course was the problem stage. The problems were:-

1. To determine what happens when iron rusts.
2. To determine the nature of the changes which take place on burning substances in air.
3. To separate the active from the inactive constituent of air.
4. To determine what happens when chalk is burnt to lime.
5. To determine what happens when organic substances are burnt.
6. To determine what happens when sulphur is burnt.
7. To determine what happens when metals are dissolved in acids.
8. To determine what happens when oxides are acted on by acids.
9. To determine what happens when the gas obtained by dissolving iron or zinc in sulphuric or muriatic acid is burnt.
10. To determine what happens when hydrogen and other combustible substances are heated with oxides.
11. To determine whether oxides such as water and chalk gas may be deprived of oxygen by means of metals.
12. To determine the composition of salt gas, and the manner in which it acts on metals and oxides.
13. To determine the composition of washing soda.

This method of teaching was a great improvement on what had been attempted hitherto, and even caused an alternative

course in chemistry to be introduced into the Science and Art syllabus. Prof. Armstrong's Heuristic Method proved one of the landmarks in the history of science teaching.

In an address to the British Association in 1889,⁽¹⁾ "On Botanical Gardens for elementary schools," details were given of small botanical gardens in connection with Merchiston and other private schools near Edinburgh, and a board school (not named) at Dunfermline.

The University of Edinburgh conducted Local Examinations,⁽²⁾ and the questions asked in chemistry for the Senior Examination were:-

1. Give one method for the preparation of each of the following substances, (a) hydrobromic acid, (b) phosphoretted hydrogen, (c) potassium permanganate.
2. Describe the action of nitric acid on (a) calcium carbonate, (b) copper, (c) tin.
3. What substances are formed when excess of chlorine is passed into a cool dilute solution of caustic potash?"

In the Junior Certificate Local Examinations of the University of Glasgow were asked these questions:-

1. How can it be demonstrated that water is a compound substance? What is the difference between hard and soft water, and how is it ascertained? Which is the softest natural water?

(1) Brit. Assocn. Report 1889. p.648.
(2) Brit. Assocn. Report 1890. p.282.

2. Of the following oxides, which are soluble and which insoluble in water:- CuO , K_2O , SO_2 , Pb_3O_4 , CaO , SO_3 , HgO , Fe_2O_3 , BaO , P_2O_5 , N_2O_2 , SiO_2 ?
How could the insoluble oxides be got into solution?
3. Define "water of crystallisation" and "water of hydration", giving examples.
4. What is combustion? How can it be shown that oxygen will burn with a flame?
5. In chemical nomenclature the terminations -ous, -ic, -gen, -ide, -ate, -ite frequently occur. Give examples of each, and explain their meaning and use."

In the corresponding Senior Certificate Examinations at Glasgow occurred the following questions:-

- "1. Three yellow solids contain iodide, phosphate and arsenite of silver respectively. How could you liberate the acids in each, and identify them?
2. Why is the combining weight of oxygen taken as 16 rather than as 8?
3. What would be the volume in litres of 1 gramme of Nitrogen measured at 100°C and 200 mm. pressure?
4. Write the formulae of ferrous iodide, chromic fluoride, platonic chloride, baric hypophosphite, chloric acid, metaphosphoric acid.
5. What is the difference between the specific gravity and the

density of a body?

In 1891, the Code reintroduced in arithmetic the study of the metric system, which had been dropped in the year 1874.

The teaching of science in George Heriot's Hospital School was specially reported upon by Prof. Archibald Barr and Dr. Alfred Daniell in 1890.⁽¹⁾ A new science building had been opened three years previously, and it contained a chemical laboratory and a physical one. The latter was supervised by Messrs. J. B. Clark and J. T. Morrison. For certain parts of the work manuscript books were provided, in which the pupil could find the object of the experiment he was about to perform, a description of the method to be used, and an indication of how his results should be recorded. For other parts of the work such instructions were placed on the blackboard. These notes were copied into a rough note book, and as the experiment proceeded, the pupil added his own observations and results. When this record was completed it was shown to the teacher, and, if found satisfactory, copied into a final note book. It was found that this method caused little loss of time and that there was a splendid training in scientific method. The experiments carried out were mainly in order to make measurements of quantities, such as lengths, area, volumes, weights and specific gravities. Pupils

(1) Report of Comm. of Council on Educn. in Scotland 1889-1890. pp.167.

in Class V were taught magnetism and electricity by demonstration and laboratory practice, so that they were "as far as may be, led to discover experimentally for themselves the principal physical laws." In Class VI, heat, light and sound were taught in a similar manner. It was found that the pupils had a real knowledge of the subject, not merely cram, and that their written answers were "terse, comprehensive, very much to the point, and illustrated by good diagrams."

Chemistry was taught by Mr. Samuel Walker to the same six classes. First, chemical action was illustrated, then indestructibility of matter, classification of elements, mixture and compounds, acids, bases, and salts, the common gases and their compounds were studied. Afterwards, other gases were prepared and elementary qualitative analysis was begun. The upper classes studied gaseous combination and analysis of mixtures of inorganic salts. The two gentlemen making the report made an important suggestion. The prominence given in the course to qualitative analysis was customary, and the instruction in it was very effective, but they considered that the educational results of the usual course of analysis were not commensurate with the effort put forth, and did not encourage any inventiveness or resource on the part of the pupil. Accordingly, they doubted whether the time devoted to qualitative analysis in the schools might not be more profitably spent. (See

Report of British Association 1889, on p. ~~384~~ of this thesis).

Messrs. Clark and Morrison also taught physiology and physical geography to younger boys, who in later classes learnt geology, which was a strong feature of the school, both geological phenomena and an acquaintance with the commoner minerals and rocks. Mr. Morrison conducted voluntary geological excursions. Boys, of fifteen years of age, also received excellent practical instruction in botany, including dissection and physiology of an elementary nature, but it was intended to extend this course in the following session to include microscopic study of sections, classification, and further physiology. Instruction was supplemented by the use of a small botanic garden.

In 1891,⁽¹⁾ physical geography and physiology ceased as specific subjects. As a class subject, elementary science did not find much favour, only 109 departments studying it as compared with 1,993 in history. The only school in the north studying it was at Keith, where good apparatus was supplied by the Board.

The system of payments by results sometimes led to abuses, and in 1892,⁽²⁾ for personating one of his pupils in the 'Principles of Agriculture' examination held by the Science and Art Department in 1890, also for inaccurate registration, W.M.

(1) Ibid 1891-2. pp. XVIII & 302.

(2) Ibid 1892-3. p.128

Milne, M.A., Alness, had his certificate cancelled.

The Committee appointed to inquire as to the best means of distributing the grant in aid of Secondary Education in Scotland, issued its report⁽¹⁾ in 1892. The evidence given showed that Science and Art examinations were tempting, as grants were large and, in aiming at these, the real educational work of a school might be injured. Statistics were given of the higher subjects taught in schools benefited by endowments, and the number of pupils studying these subjects, viz:-

Monymusk	physiography, agriculture, hygiene.	6 each.
Peterhead	prac.theor.and adv.prac. inorganic chem.	3, 4, 2.
Campbeltown	mech.,physiography, mag. & elec.,light & heat.	40
Darvel	Physiography.	13
Largs,Brisbane Academy.	Mech.,mag. & elec., sound, light, heat.	25
Fordyce	elem. science.	44
Macduff, Murray's Institution.	science.	80
Hutton Hall, Caerlaverock.	agric. chem.	20
Sanquhar	science.	15
Wamphray.	agriculture.	17
Salton.	agriculture.	11
Tranent,Geo.Strell's.	agriculture.	25
Brin (Daviot).	agriculture.	3
Fleetside.	physiology, elem.sc.,agric.	35, 40, 45.
Borgue.	agric.,boty.	44, 75.
Carsphairn.	agriculture.	3
Dalry.	"	25
Kirkmabreck.	"	40

(1) Report published as C.6840 pp.81, 144, 165.

Bo'ness.	Physiography, agric.	50, 12
Hope (Orkney).	mechanics	1
Manor (Peebles)	agriculture	3
Dunkeld.	physiography, agric. & boty.	34, 18
Rosemarkie.	mechanics	1
Selkirk, Knowepark School.	elem. phys.	not stated
Kingussie.	science	25
Tobermory.	navig., mag. & elec.	6, 12

With regard to the teaching of science, it was stated that in Morison's Academy, Crieff, there was no specially fitted laboratory, but one of the rooms was used for science teaching. The apparatus was deficient and the workshop was maintained by the headmaster at his own expense. At the Ewart Institute there was neither a laboratory nor a workshop, and there was very little apparatus for science teaching. Theoretical lectures with experiments were given in Waid Academy, but there was neither laboratory nor workshop, while chemistry was taught in a class room. In Spier's School, Beith, there was a laboratory for practical chemistry, but, owing to lack of funds to pay a science master, it was seldom used, and there was no workshop. A few boys were taught science twice a week. In Falkirk High School there was a science master.

In 1891-2 the Leaving Certificate examination which had previously been restricted to Higher-class Schools, was extended to State-aided Schools also. This resulted in a large increase in certificates awarded. In 1888, 29 schools

obtained 972 certificates, whereas in 1897, 362 schools obtained 16,378 certificates.

By 1895, scientific subjects were decreasing in popularity, (1) only 115 departments studying elementary science as a class subject, as compared with 2,021 in history. As specific subjects, there were 185 presentations in animal physiology, 212 magnetism and electricity, 125 chemistry, 126 botany, 114 mechanics, 64 geology, 14 sound, light and heat. The tide was turned by a payment of 1/- per head for boys who were taught elementary science, and this became a subject frequently taught to boys when the girls were at needlework.

For Standard III upwards, a tripartite course was suggested, animal, vegetable and matter, any one section of which might be studied:-

(a) Animal.

Standard III - General notions of the differences of structure of beast, bird, fish, insect, and reptile.

Standard IV - Classification; with habits and uses.

Standard V (Man) Circulation, respiration, alimentation.

Standard VI (Man) Bones, muscle, brain, nerves, the organs of sight, smell, touch, hearing and taste.

(b) Vegetable.

Standard III - Comparison of animal with vegetable life.
General structure of a plant, root, stem, flower, with specimens.

(1) Report of Comm. of Council on Education in Scotland
1895-6. XVIII.

Standard IV - Plant structure. Wood, bark, pith, cells.
Use of different parts of a plant.

Standard V - Food and growth of plants. Exogens and endogens. Formations of different kinds of fruit.

Standard VI - Principles of classification with a general knowledge of the chief orders. Germination. Ferns, mosses.

(c) Matter.

Standard III - Matter, organic and inorganic, elementary and compound. Its three interchangeable states, solid, liquid and gaseous. The properties of matter.

Standard IV - Energy indestructible. Force, inertia, momentum, gravitation, cohesion, chemical affinity, combination and decomposition. Preparation and properties of oxygen, hydrogen, nitrogen and chlorine.

Standard V - Heat. What it is; effects of; modes of; thermometer. Reflection and refraction of light; dispersion of light by a prism. Microscope; telescope.

Standard VI - Magnets, kinds, structure, uses. Mariner's compass. Electricity, kinds, laws; electroscope, electrophorus, telegraph. Lever, wedge, screw.

By an order of the Committee of Council on Education in Scotland, in 1897, the administration of grants for purposes of science and art instruction in Scotland was transferred from the Science and Art Department to the Scotch Education Department.

In 1897, Dr. Ogilvie stated⁽¹⁾ that, with regard to the teaching of geography in Scotland, "the schools in which mere strings of names and disjointed facts are glibly repeated, are getting few and further between."

(1) Brit. Assocn. Report 1897. p.372.

In 1898 nature knowledge replaced elementary science and served to counterbalance mere book-learning. Higher grade schools were now established by the Code of 1899 for pupils who intended to stay at school until about 16 years of age. The curriculum was predominantly scientific or commercial, though general education was also included. By a liberal grant, practical work in science was fostered, and (by Circular 221) a Leaving Certificate in practical science was also promised. For experimental science a minimum of four hours per week was necessary, and of this at least two hours per week must be spent in practical work. Not more than 25 pupils were to be given practical work at one time, and the period of practical instruction had to be at least one hour and a half in duration. The examination for Leaving Certificate in Science was chiefly oral and practical, conducted at the pupil's school, based on the work actually done and depending, in addition, on the pupils' own records and the teacher's marks.

The transference of the work of the Science and Art Department in Scotland to the Scottish Education Department⁽¹⁾ resulted in the introduction of science into the Leaving Certificate Examination, and at the first examination in 1898, eight schools presented 102 candidates, of whom 58 obtained certificates. In French and English there were 6,551 and

(1) Report of Comm. of Council on Educn. in Scotland, 1898-9.
p. 263, 499 & XXXVIII.

10,325 presentations respectively. The schools which presented candidates in science were Robert Gordon's College, Aberdeen Grammar School, Edinburgh Academy, George Heriot's Hospital School, Perth Academy, Sharp's Institution, Perth, Grange School, Grangemouth, and Leith Academy.

In the Science and Art examinations in science subjects in 1898, 22,000 candidates were presented and 14,000 passed.

In the Western Division it was stated that science was not often made part of the general curriculum of the school, but was reserved for a few pupils who "are either preparing for special examinations in which it is required, or are considered too stupid to bring credit to the school in classics." There was no Training College in that district possessing "even a properly equipped lecture table, far less a laboratory, and in the Universities laboratory work seems to be regarded as a luxury to be reserved for the few, rather than as the sine qua non of a good training in science."

In 1899,⁽¹⁾ there were 13 Schools of Science, of which 10 were Higher Class Schools and 3 were Secondary Departments of State-aided Schools.

Dr. T. A. Stewart, who had even in his reports in 1879 advocated "instead of some of the pretentious 'ologies, the substitution of what Mr. Arnold, H.M.I. designates as Naturkunde,

(1) Ibid. 1899-1900.. pp.32 & 484.

would be very desirable," continued his plea for a development of the powers of observation in the Elementary School by nature knowledge, and hoped it would not share the fate of physiography "which has become a pot pourri of all the subjects on the face of the earth."

In the Special Reports on Educational Subjects issued by the Board of Education in 1898, is one by Prof. Henry E. Armstrong, F.R.S. on "The Heuristic Method of Teaching, or The Art of Making Children discover things for themselves. A Chapter in the History of English Schools."⁽¹⁾ The term "heuristic" was introduced not by Armstrong, but by Prof. Meiklejohn at the International Conference on Education in 1884, when he said, "the heuristic method is the only method to be applied in the pure sciences." In heuristic methods of teaching, the student is placed as far as possible in the attitude of the discoverer, and thus has to find out instead of being merely told about things.

Heuristic experimental studies, he claimed, conduce to the formation of moral and intellectual character and purpose, by exciting interest in common objects and phenomena which are gradually studied, thus encouraging children to be properly inquisitive and enquiring, by measuring and weighing not merely things, but deeds and words, thus producing exactness, by observing correctly the habit of patiently attending

(1) Vol.II, p.389.

to details; by reasoning from observation a logical habit of mind is developed, and by devising and fitting up apparatus handiness is acquired. As he adds, "surely a sufficient list of possibilities."

Appended is a course in elementary physics and chemistry, and on this the Scottish scheme of 1898 appears to be based. It commences with the measurement of length, area and volume. His scheme of instruction in chemistry was described by him at the British Association in 1889. (See page 385 of this thesis).

He also gave a scheme of instruction in botany, viz:-

Description of herbs, shrubs and trees.

Leaves. Diary of leaf-fall and of flowering.

Note situation where different plants and trees grow.

Trees studied. Stems - leaf scars and nodes.

Buds. Bulb. Eyes of potato.

Use of various woods.

Sawdust or chips weighed, loss of water, weight of ash.

Effect of crowding.

Leaves - built up of cells. Veins. Stomata.

Leaves - weight of water lost.

Roots - measurement. Root hairs. Penetration of earth.
Root-caps.

Flowers. Calyx-protective. Corolla-attractive.
Stamens - bear pollen. Pistil.

Fruits and Seeds.

In Vegetable Physiology the work included germination, growth of plants and the study of yeast, moulds and fungi.

The Code issued in 1898⁽¹⁾ did not allow any payment for individual passes, and thus specific subjects died a natural death, mourned by few, as, owing to the way they were taught, they were no loss to education.

In 1899 twelve schools presented candidates for the Leaving Certificate in science, those which had not done so the previous year being Arbroath, Merchiston Castle, Paisley Grammar, Blairlodge School, Polmont, Craighall Road School, Leith.

Mr. Blair reported that an average timetable of an Organised Science School consisted of 30 hours per week, divided among Physics 3, Chemistry 3, Practical Geometry $1\frac{1}{2}$, Drawing $1\frac{1}{2}$, Mathematics 6, French 3, German or Latin 3, English 5, Manual Instruction (or, for girls, Cookery and Needlework) 2, Book-keeping 1, Shorthand 1, and that very few day schools had a biological curriculum, as enthusiasm was wanting and teachers were few. New buildings erected or extensive alterations effected at numerous schools, provided greatly increased laboratory accommodation. In five schools there was a special Girls' course, including biological rather than physical science.

Mr. Ewen, H.M.I. expressed a hope that very soon it will be generally recognised that every student of an experimental

(1) Report of Comm. of Council on Educn. in Scotland 1899-1900.
pp. 502-5 & 582.

science ought to spend at least half as long again in the laboratory as he does in the lecture room."

A very important step in the history of the teaching of science in Scotland was the placing of science on a regular footing by the issue of a syllabus of instruction, which more or less standardised the teaching throughout Scotland.

The "Syllabus of Instruction in Experimental Science"⁽¹⁾ for Higher Grade (Science) Schools, issued in 1898, may be summarised as follows:-

FIRST YEAR'S COURSE

Introduction: Classification. Differences of air, water and solids.

Terms - solid, liquid, gas.

Measurements of lengths, areas, volumes. Units.

Lab. practice is use of yard-stick, metre-stick, measuring-jar and burette.

Relation between British and Metric systems.

"Exercises in measurement of lengths, areas and volumes should not be unduly prolonged; they should cease as soon as the pupils can determine with fair accuracy areas of triangles, quadrilaterals, and circles in sq. cms. and sq. ins. of the lab. tables or class-room walls or floor in sq. m. and sq. ft., the vols. of a cube, a square prism, a cone and a cylinder in cub. cms. and cub. ins., the capacity of a flask in c.c. and of the

(1) Appendix to Circular 234 of 7th Dec. 1898. pp.211 et seq.

class-room in cub.m. and cub.yds. These measurements are merely a means to an end, but interest will be added to them and their usefulness increased if they be employed to find out or to verify certain well-known relations, e.g.circumference of a circle and its diameter."

Verification of well-known propositions.

Area measurements to establish some of Euclid's propositions.

Volume measurements to discover the relation between the volumes of a cone and a cylinder on the same base and altitude.

Relative Densities.

"The use of the balance will follow. The class now able to find weight and volume is ready for the conception of density. Relative densities of solids should be found, also the weight of 1 c.c.of water, the vol.of a small flask (by weighing the water it will hold) and then the R.D's of methylated spirit, milk and sea water with the help of the flask."

Principle of Archimedes.

Expansion. Solids, liquids and air will be submitted to experiment.

The Thermometer. C. and F. thermometers side by side in a mixture of ice and water heated over a slow flame. Temp. recorded every 30 secs. until the water boils. A curve should be plotted.

The Barometer. Mercury barometer. Hare's Apparatus.
Application of the principle in the working of pumps,
and in the use of the syphon.

Evaporation, solution and distillation.

SECOND YEAR'S COURSE.

Effect of heat on bodies. Heat common metals (lead, copper, iron, silver, magnesium, tin) in an iron spoon over a gas flame and record results. Mercury should be heated in a Florence flask furnished with a cork, and a long tube to act as condenser. The effect of heat on sulphur, salt, chalk, coal, bread and lean meat may also be investigated.

Study of the change that occurs when iron rusts.

Increase in weight. In bell jar $1/5$ of air is used up.

Heat iron in air.

Phosphorus - in bell jar, then oxide collected and weighed.

In flask, no increase in weight. Remove cork. Air enters.

Increase.

Combustion of a candle. Similar experiments may be made with coal gas.

"Attention should be called to the general conclusion as to the constitution of the air, the difference between mixture and chemical combination, the non-material nature of heat, etc.

Separation of the active constituent of air.

Heat oxide of mercury.

Oxygen. Preparation. Phosphorus, sulphur, carbon, magnesium

burned in it and the formation noted of products which alter the red or blue colours of flowers (use first the colour extracted by pressing geranium or pansy petals between blotting paper and afterwards litmus). The terms oxygen and oxides may now be explained and the properties of two or three common acids studied.

Quantitative nature of change produced by heating potassium chlorate.

Constitution of Water. Pass steam over metals heated by Ramsay burner. Gas collected over water - hydrogen. Burn magnesium in steam. Synthesis of water by heating. Copper oxide in stream of hydrogen. Explosion of hydrogen and water in eudiometer.

Study of chalk. Effect of heat and of acids on chalk.

Difference in properties between chalk and lime.

Comparison of lime with potash and washing soda.

Study of ammonia. Carbon dioxide.

Effect of burning carbon in oxygen.

Chalk, a typical example of a chemical compound.

Further study of carbon dioxide.

Presence in atmosphere. Taken in by plants.

Formed when carbon burns. Exhaled from lungs.

THIRD YEAR'S COURSES.

Course (A) for Boys.

"Detailed and systematic study in classroom and laboratory

of Charles' Law, Boyle's Law, latent heat, specific heat, melting points, boiling points, and the following treated simply:-

force: gravitational, magnetic, electric, and refraction of light.

The heating, chemical and magnetic effects of the electric current.

Course (B) for girls.

Division I.

Fairly detailed and systematic study in class room and laboratory of the following:-

Water, hard water, soft water, softening of water. Soap, preparation of soap.

Soda; alkaline nature of, etc.

Some food stuffs. Flour, separation of gluten. Starch: conversion into sugar. Fats: presence of carbon. Lean Meats: presence of nitrogen. Classification of foods.

Drinking water: its impurities, sources of contamination, the house supply.

Cookery recipes, health maxims, or dietaries are out of place.

Division II.

The preparation and study of the skeleton of a rabbit; the more important parts to be named, drawn (in different views) and their uses indicated; the digestive, circulatory, respiratory and nervous systems; the form and position of

the chief organs should be drawn in situ and afterwards when dissected out, to show the more important details; venous and arterial blood; the changes undergone in the lungs; the process of digestion; animal heat.

Microscopical study of the tissues is unnecessary, except that it is advisable to show blood corpuscles and the circulation in a frog's foot.

It shall not be considered essential that every, or any, pupil shall personally dissect out all the structures, but it is essential that all the pupils shall make their drawings from observation of the organs themselves.

Comparison with human organs by means of diagrams.

Both divisions should be taken, and the lessons arranged to fit in one with the other as much as possible.

COURSE (C) FOR RURAL SCHOOLS.

The course shall include the following subjects, treated experimentally wherever possible:-

Germination; the young plant; functions of the various parts of the plant, stem, roots, leaves, etc; the sources from which the plant builds up its tissues; composition of the ash or mineral matter contained in plants; presence of potash and phosphoric acid in the ash; the sources of the mineral constituents of the plant; soils, their classification into "heavy" "light", etc; determination of moisture, organic matter, sand and clay in soils; connection between the soil and the rocks

from which it has been formed; action of frost; action of earthworms; action of water containing carbonic acid; distinction between available (soluble) and non-available (insoluble) plant, food; manures; chief sources of potash, phosphoric acid and nitrogen; simple physiology, as in introduction to the study of the animals of a farm.

Attention was drawn to the method of "regional survey" as an aid to the teaching.

By the Code of 1901,⁽¹⁾ a grant of 12/6d. per 100 hours was paid for instruction in Experimental Science under Article 21. In the second year of the High Grade Science Course, not less than 8, and in the third year not less than 10 hours had to be allotted to science. At least half of this time had to be spent by the pupils in individual experimental work. A concession was made that 3 hours of drawing and/or manual instruction would be reckoned equivalent to 2 hours of science.

In 1900, for the first time, group certificates were issued after Leaving Certificate examinations, the group to include at least four subjects, English, a language and mathematics being essential, and a language being replaceable by science. Two Lower Grade passes were reckoned equivalent to a Higher.

In 1900, 158 candidates were presented in science from fifteen schools, (including, for the first time, Dumfries Academy, Dundee High School, George Heriot's, Falkirk High

(1) Report of Comm. of Council on Educn. Scotland. 1900-1901. pp.140.282.539.577.

School, Dalziel High School and Strathbungo School, Govan), as compared with 10,697 candidates in English.

Mr. Young commented on the laboratories in many schools not being kept in the state of cleanliness and good order which was desirable in order to inculcate neatness and precision in the work of the pupils.

Mr. Ewen, who helped greatly to develop the teaching of science, stated "Practical work in science ought not to be regarded in any kind of a way as an "extra" for the few, but rather as a sine qua non of a liberal secondary education.... The valuable mental and manual training obtainable from a course of practical instruction in a science laboratory is not to be gained, or even compensated for, by any amount of 'book study', and the sooner this is recognised and given effect to, the better for the higher education of this country."

The period we have just considered, from 1872-1900, is probably one of the most important in the teaching of science, for during it, science teaching became more systematic and gradually obtained a footing, though rather an insecure one, as a regular subject in higher education in Scotland. Several causes contributed to this progress, such as the numerous commissions that studied Scottish education and drew attention to its defects, the propaganda carried on by the British Association for the Advancement of Science, the missionary efforts of Huxley, Matthew Arnold and Henry E. Armstrong, the

the conversion of several endowed schools into secondary schools with a scientific bias, and last, but probably the greatest cause, and work of the Science and Art Department. In the burgh and parish schools the most popular subjects were physical geography and animal physiology, whereas in the "higher class schools" physical science (including mechanics) was preferred. Chemistry was not much in evidence until popularised by the Science and Art Department. Unfortunately, a great deal of the teaching of science was not experimental, but from manuals prepared specially to cover the syllabus of the "specific subjects" and of Science and Art Department subjects. The introduction of physiography provided a useful scientific subject, which included a smattering of various sciences. In their early days, "Specific subjects" served a useful purpose by encouraging the study of scientific subjects, with a view to obtaining grants, at a time when science was not so popular, but later the system of payment by results was not in the best interests of education. The Science and Art Department developed the teaching of chemistry and the importance of practical work. The Heuristic Method further emphasised practical work, so that it received rather disproportionate attention for many years thereafter.

Progress - 1872-1900.

1. Inclusion of scientific subjects among "specific subjects."
2. Popularity of physical geography.

3. Consideration given to the methods of teaching scientific subjects, principally due to the British Association.
 4. Introduction of physiography by T. H. Huxley.
 5. The advocacy by Matthew Arnold of Natur-kunde as a more suitable subject for elementary schools than smatterings of various sciences.
 6. A wide-spread realisation of the need of science teaching in schools.
 7. The institution of elementary science as a "class subject".
 8. The conversion of several endowed schools into secondary schools with a scientific bias, e.g. Allan Glen's Institution, Glasgow, George Heriot's Hospital, Edinburgh, and Gordon's Hospital, Aberdeen.
 9. Increase in technical education.
 10. Schools of Science and Organised Science Schools under the Science and Art Department (Detailed in Chap.X.).
 11. Transfer of work of Science and Art Department to Scotch Education Department.
 12. Institution of Leaving Certificate Examination in Science.
 13. Issue of Syllabus of Instruction in Experimental Science for Higher Grade (Science) Schools.
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CHAPTER X.

SCIENCE AND ART DEPARTMENT.

When Queen Victoria opened Parliament in 1852 she stated ⁽¹⁾ that "the advancement of the Fine Arts of Practical Science will be readily recognised by you as worthy the attention of a great and enlightened nation", and in 1853 was created the Department of Science and Art, ⁽²⁾ which removed its headquarters in 1857 from Marlborough House to South Kensington, by which name it became popularly known.

When established in 1853 it was placed under the direction of Mr. Cole. ⁽²⁾ It was decided to establish classes for instruction in science, and this duty was given to Dr. Lyon Playfair, well known as Professor of Chemistry at Edinburgh University. After his resignation in 1858, Mr. Cole, in the following year persuaded a young engineer officer, Lieut. Donnelly, to carry on the inspection and organisation of science instruction throughout the country.

In the First Report of the Department of Science and Art in 1854, ⁽⁴⁾ the average attendance of students at the Watt Institution and Edinburgh School of Arts was stated to be 530, and the courses were Mathematics, Natural Philosophy, Chemistry, English, Modelling and French. The numbers of

(1) Calendar of Science and Art Dept. 1896.

(2) Brit. Assn. Report 1903. p.865

(3) By the enlargement of the Department of Practical Art which was already in existence.

(4) Sc. & Art Dept. Report 1854. pp.385, 397, XXV, XXVI & Appendix p.3.

students in these classes were 109, 85, 60, 51, 47 and 111 respectively. The types of students are shown by the lists of those who obtained "attestations of proficiency",

CHEMISTRY.

John J. Scott, clerk
John McLaren, teacher
Thomas Jackson, plumber
George Liddell, baker
Joseph Muir, draper
Henry Wilson, shoemaker
John Sommers, plumber
Peter Stewart, teacher

NATURAL PHILOSOPHY.

James Forrest, clerk
George Liddell, baker
Peter Stewart, teacher
Alex. Ingram, teacher
James Heddle, clerk

The building in Adam Square, which had for a long time been leased by them, had now been purchased, and a statue of James Watt was to be erected in front of the premises.

In the Second Report, 1855, there is mention of a school of science established in connection with the Mechanic's' Institution at Aberdeen. "The classes are designed chiefly for the working population and comprise instruction in natural philosophy, chemistry and mathematics, and the numbers attending them are 36, 46, and 29 respectively, or 111 in all." In 1856 a navigation school was opened at Leith, while in this year the Department of Science and Art was transferred from the Board of Trade and placed under the Education Department.

Dr. Geo. Wilson, Director of the Industrial Museum, Edinburgh, was appointed Professor of Technology at the University, and the Regius Keeper of the Natural History Museum, Edinburgh, was Geo. J. Allman, M.D., F.R.S. Both these posts were under the Science and Art Department.

An overcrowded curriculum was not unknown in 1857.⁽¹⁾ "The introduction of scientific teaching as a separate branch of study to primary schools is attended with considerable difficulties, and can only be carried on gradually and with much caution. Already the claims upon the attention of the pupils are so numerous, that without affecting the main objects of the school, it would be difficult to obtain separate periods for scientific lessons. The first point for success is to enable the schoolmaster to illustrate the common lessons by his own scientific knowledge, and with this view, increased attention has been given to science in Training Schools."

The following passage sums up the position of such science as existed in the schools then:-

"The Training Schools throughout the country have hitherto chiefly cultivated the physical rather than the natural sciences, and when the schoolmaster introduces science into his primary school, he generally selects mechanics, physics or chemistry, as the objects of study.

(1) Sc. & Art Dept. Report. 1857. pp. XXX, XXXI.

But the sciences of observation, such as zoology, botany and physiology are more suitable to the children of primary schools, than the abstract physical sciences referred to, which are better adapted for secondary schools. - - - Some of the physical sciences, such as chemistry and experimental physics are required to explain several of the most common phenomena of life, and in this point of view may be studied with advantage even in a primary school; while, as their abstractions are relieved by illustrations they compel observation, but, as a whole, they do not appear to be so well suited to educe a love of nature in the minds of children as a knowledge of the plants, animals and stones seen in their daily walks."

In the following year, 1858, a navigation school commenced in Glasgow⁽¹⁾ in addition to those already at Leith and Aberdeen, and they, with the science school at Aberdeen and Edinburgh (Technological Museum) comprised the institutions in Scotland under the care of the Science and Art Department.

It was decided⁽²⁾ in 1859 to "assist the industrial classes of this country in supplying themselves with instruction in the rudiments of Practical and Descriptive Geometry, with Mechanical Machine Drawing and Building Construction, Physics, Chemistry, Geology and Mineralogy (applied to

(1) Sc. & Art Dept. Report. 1858. p.18

(2) Sc. & Art Dept. Report. 1859. pp.13, 34.

Mining), and Natural History, by augmenting grants in aid of salary to competent teachers, by payments and prizes on successful results and grants for apparatus". Examinations were to be held annually for the teachers' certificates, which were of three grades, to carry augmentation of salaries, of £20, £15 and £10 respectively per subject, provided that ten or more students passed, e.g. a teacher possessing an Education Department certificate, a Second Grade Certificate in both Inorganic and Organic Chemistry and a Third Grade Certificate in Experimental Physics could receive £15, £7.10, £7.10 and £10 respectively, making £40 altogether. Another condition was that each student must have received 40 lessons from him in that year. At the first examination there were 104 entries and 65 certificates were awarded,⁽¹⁾ the only Scottish teacher being John Mayer, Carlton Place School, Glasgow, who received a third grade in Inorganic Chemistry and a second grade in Organic Chemistry. His class was the first in Scotland opened under the new system,⁽²⁾ and it was reported upon in the 1861 Report by the Science Inspector, Capt. J.F.D. Donnelly, Royal Engineers. The officers of this corps had a considerable share in the later administration of the department and were paid fees for the work done in addition to their military duties. From this

(1) Report 1860. p.30

(2) Report 1861. p.23

school of about 200 boys and girls, 12 boys went up for examination and only 3 failed. In this same year, instead of Natural History as a subject for examination were substituted two separate subjects, "Animal Physiology and Zoology" and "Vegetable Physiology and Systematic Botany."

In the 1862 Report,⁽¹⁾ we find mention of further successes in the examinations for teachers' certificates, David Maver, Mechanics' Institute, Aberdeen - mechanical physics (2nd. grade), then in Inorganic Chemistry, John Mayer, Glasgow and Daniel C. Orkney, Free Church School, Jamestown, both second grade, and Mr. Orkney also in Organic Chemistry (3rd. grade). In addition John Mayer obtained a 1st. grade in Animal Physiology and Vegetable Physiology, while Robert Beveridge, School of Science and Art, Aberdeen, obtained a 1st. grade in Animal Physiology, Zoology, Vegetable Physiology and Systematic Botany, so that now there were four certificated science teachers in Scotland.

Reports were made on the various schools of science under the department. At the Mechanics' Institution, Aberdeen, under Beveridge and Maver were 60 students, 7 in botany, zoology, etc, 10 physics and 36 chemistry. In the Canongate Burgh School, Edinburgh, Alex. McIvor taught physics to 52 students, while in the Carlton Place Secular School, Glasgow, John Mayer taught 117 students, 27 chemistry, 103 animal physiology and 30 botany. The Andersonian

(1) Report 1862. pp.5, 13

University, Glasgow, had 721 students, 411 physics and geology, 183 chemistry, and 121 zoology.

In November 1862, ⁽¹⁾ John Mayer added Metallurgy and Botany to his certificates, while John Robertson, Milton Established Church Session School, Glasgow and James Farmer, Glasgow, passed in Physics and Chemistry. An interesting person in the history of this department now appeared in Margaret Mac~~o~~mish, Glasgow, who passed in Animal Physiology.

The syllabus for these examinations is interesting, ⁽²⁾ both as regards the wording and the content. In Voltaic Electricity, "The candidate ought to be able to state precisely how voltaic electricity may be generated; to describe Volta's pile, and his crown of cups; also the batteries of Daniell, Grove and Bunsen - - -

He must be able to measure the strength of an electric current and he is strongly recommended to master thoroughly the law of Ohm, regarding the mutual relations of electro-motive force, resistance, and strength of current.

He ought to be acquainted with the so-called polarisation of metallic plates between which a current passes through a liquid and to show how this is avoided in Grove's battery.

He ought to be able to give a clear description of

(1) Report 1863 p.13

(2) Science Directory 1861. p.34.

some one form of the electric telegraph.

He ought to be acquainted with the physiological effects, and with those of light and heat produced by the voltaic current; and to show the dependence of the heat on the strength of the current, and on the resistance which it encounters.

It would also be well to master as much of the phenomena of induced currents as would enable the candidate to explain the action of the galvanizing apparatus used by medical men."

The subject of Botany contained one portion on Vegetable Physiology and Economic Botany e.g.

"The forms of leaves. Exhalation - - -

The flower. Calycine, Corollal, Staminal and Carpellary leaves. - - - Ovules or seed buds. Vegetable Impregnation. Embryo. Seed. - - -

Properties of vegetable substances used in the arts and manufactures. Vegetable secretions used as dyes.

Materials used in the manufacture of textile fabrics.

Principal forms of timber trees and their uses.

Nature of tanning principles and plants yielding tannic acid.

Gums, oils and resins used in arts.

Substances obtained from the vegetable kingdom and used as medicines."

The other portion was on Systematic Botany and included Algae, Lichens, Fungi, Mosses, Ferns, Graminaceae, Cyperaceae, on to Ranunculaceae and twenty-two natural orders.

In 1863, ⁽¹⁾ there were 66 students at the Mechanics' Institution, Aberdeen, under Professor Brazier, Mr. Maver, and Dr. Beveridge, in chemistry, mechanics and botany, while Mr. John Mayer at Glasgow Secular School taught chemistry, metallurgy, animal physiology and botany to 102 pupils, and 721 students were in the scientific classes at the Andersonian University, Glasgow.

It was decided, ⁽¹⁾ in 1864, to make payments to teachers, according to results, £1 for every student who passed in a subject, £2 if honourably mentioned, £3 if third class, £4 if second class, and £5 if first class, with half these amounts if a student were successful in any further subjects, and a diminished amount when the grant exceeded £60. A grant towards the purchase of apparatus up to 50% of the cost could also be obtained. In this year Dr. Beveridge passed in Geology, Thos. Edwards, Alex. Finlay, and Margaret Macomish in vegetable physiology, and Mrs. Elizabeth Mayer in zoology. As each teacher added to his qualifications, we find that subject added to those taught in his school, and consequently payments received by him for such instruction.

In Britain there had been 9 classes with 500 pupils

(1) Report 1864. pp. 4, 17.

under this department in 1860 and in 1864 there were 91 classes with 4,666 pupils while the number of teachers had increased to 70.⁽¹⁾ In Scotland two other schools had been established, the Athenaeum, in Glasgow, where A.T.Machattie taught inorganic chemistry, and the Girls' School, Corsock, where Miss Macomish taught 24 pupils animal physiology. We find the relative popularity of the various subjects in Great Britain from the number of persons examined in 1865, viz. theoretical mechanics 43, applied mechanics 26, acoustics light and heat 253, magnetism and electricity 269, inorganic chemistry 851, organic chemistry 142, geology 164, mineralogy 28, animal physiology 479, zoology 174, vegetable physiology and economic botany 121, systematic botany 70, physical geog^{raph}y 70. New subjects added in 1865 were Navigation, Nautical Astronomy, Steam and Physical Geography.

That the Science and Art classes were a good source of income to their teachers is shown by the payments made in 1866.⁽²⁾ At the Glasgow Secular School, John Mayer received £64.10. and Mrs.Mayer £34, at Aberdeen David Maver obtained £18.10. and at Corsock, Miss Macomish, with about 25 pupils, earned £14.

It was stated in 1868⁽³⁾ that payments would be made to teachers only "for instruction of students of the artizan or

(1) Report 1865. pp.VI. 33

(2) Science & Art Dept. Report. 1867

(3) Report 1868. pp. 4, 6.

weekly wages class and whose incomes are less than £100 per annum", also that grants could be earned for the teaching of scientific subjects in elementary schools, provided that instruction was outside the ordinary teaching hours which were already earning grants from the Committee of Privy Council on Education. The teachers' certificate examinations had been abolished in 1867, and the necessary qualification became the obtaining of a first or second class prize. This was not received favourably by the teachers who disliked sitting the same examination as the ordinary students.

New science schools established in Scotland were Lady Burnett's school at Banchory, where 8 pupils were taught magnetism and electricity, and the Burgh Academy, Dumbarton, where there were 50 pupils each taught geology, animal physiology, zoology, and vegetable physiology.

In the following year, 1869, more science classes commenced under this department, ⁽¹⁾ at Aboyne Parish school room, Alexandria Mechanics' Institution, Beith, New Street School, Brechin School room, Cults school room, Cupar Madras Academy, Kilmarnock Fould's Street, New Academy, Kirkwall Grammar School, and Tarbat Parochial School. In only two centres was Physical Geography studied, at Kilmarnock Academy and at Tarbat where Rev. Daniel Fraser carried on the classes and earned a grant of £58, of a total of £871.10 for Scotland.

(1) Report 1869. pp. 8, 9, 122, 129

The number of classes of passes was cut down to three, and two stages of examination were established, elementary and advanced. Building grants were now given in aid of a new building or for the adaption of an existing building. An extra inducement was offered to teachers, that those who had taught two consecutive years and passed not less than thirty students each year would be allowed second class railway fare to London and £3 towards expenses there, so that they might visit South Kensington Museum and other institutions in order that their students might obtain from them a knowledge of the latest progress of those educational subjects which affect the schools.

During the year 1868, honorary science certificates were granted to over twenty Scottish teachers, mostly experienced graduates, to enable them to claim payments on results without having previously passed the examination of this department. Among these gentlemen were Wm. Lees, and Dr. Macadam of Watt Institution, Dr. Penny of Anderson's University, and Dr. Crum Brown. In 1870 it was decided ⁽¹⁾ to dispense with examination as a qualification for teachers who were university graduates.

In 1871, ⁽²⁾ in addition to the aid given towards purchase of apparatus, extra payments were made on account of the practical work done by students, in order to encourage such

(1) Report 1870. p.12.

(2) Report 1871. pp. X, 12.

work, as it had been found that the teaching had been mostly confined to lectures and book work. To test knowledge of laboratory practice, questions on chemical analysis were set in the ordinary examination paper, and extra payments of 10/- and £1 were made for a first class in the elementary and advanced grades respectively. A grant of £1 was made towards the laboratory expenses of each student, provided that the school was furnished with a suitable laboratory which was fitted up with all the apparatus contained in the official list, and that the student carried out $37\frac{1}{2}$ hours laboratory work.

The Syllabus for Physical Geography, First Stage, ⁽¹⁾
was:-

1. Form and motions of earth. Division into land and water. Size and shape of continents. Low lands, their position and the names by which they are known. High lands or plateaux. Hills. Mountains and mountainous systems. Valleys.
2. The ocean and its extent. The names given to different parts. Its depth where known. Its saltness. The movements of the ocean. Marine currents. Waves.
3. Rivers and river systems. Lakes.
4. The air, its nature, extent and principal uses. Permanent winds. Periodical winds. Storms.

(1) Science Directory, 1871.

5. Dew. Clouds and rain. Snow and hail. Nature of climate.
6. The nature of earthquakes. The nature of a volcano. Earthquake bands and bands of volcanic action. The simple phenomena of a volcanic eruption.
7. The mode in which plants and animals are distributed on the earth. The mutual relations of horizontal and vertical distribution. The meaning of representative species and the principal groups of plants and animals that represent others in different continents and large islands.
8. The different races of men. The mode in which they are now distributed on the earth.

Officers of the Royal Engineers acted as District Inspectors ⁽¹⁾ for the Science and Art Department, both at the May examinations, and at a preliminary general inspection made between November and April to see how the instruction was being carried on, those employed in Scotland being Col. White, Capts. Smith, Twigge, White, Gordon and Bollard.

Many new schools were opened this session, at Auchinblae, Bervie, Burntisland, Dalkeith, Fraserburgh, Gartsherrie, Johnshaven, Langholme, Lasswade, Linlithgow, Montrose, Musselburgh, and Torphins. Corsock now ceased to present pupils, as the teacher, Miss Macomish, had trans-

(1) Report 1871. p.64

ferred to Kirk Wynd School, Burntisland. From 1876 she carried on science classes in London. At a special course of instruction in biology to science teachers by Prof.Huxley, held in 1871 at London, ⁽¹⁾ 39 teachers attended and Margaret Macomish, on obtaining first place, was rewarded with a prize of books and a microscope, valued at £2 and £5 respectively.

Owing to the large extension of science classes and the increase in the number of candidates, many cheap text books of inferior quality were produced, mainly with the object of enabling the student to cram his memory with as many facts as possible. Schools begun this year were Dollar Academy, Dundee Y.M.C.A., Largs Brisbane School, Rathven, Saltcoats, Slains, Stonehaven, Tarland and Tillicoultry.

In 1872 there were 948 science schools in Britain ⁽²⁾ and 36,783 pupils, while more schools were established in Scotland, at Buckie, Cluny, Darvel, Daviot, Dunkeld, Fettercairn, Forfar Academy, Inch, Keith Grammar School, Llanbryde, Sharp's Institution, Perth, West Church School, Perth, and Stirling High School. In Scotland the number of students was now 4,264.

In 1874 it was reported ⁽³⁾ by J.F.D.Donnelly, now Major R.E., that a new subject, Biology, had been formed by combining the subjects of Zoology, Vegetable Anatomy and

(1) Report 1872. pp. 22, 54.

(2) Report 1873

(3) Report 1874. p.27.

Physiology, while Elementary Botany was a modification of the former Systematic and Economic Botany.

Collections of apparatus for teaching various branches of science had been formed in 1872 and circulated to various schools. This system had been extended and the apparatus for teaching theoretical mechanics had been sent to Alloa and Dundee.

Among the Queen's Medallists in Inorganic Chemistry was Frank W. Young, an assistant chemist, aged 21, trained at Dundee Y.M.C.A., who was later to take a leading part in the development of science in Scotland.

New schools opened were ⁽¹⁾ Alloa Academy, Crieff Morrison's Academy, Stirling School of Science and Art, Perth School of Art, North William Street.

In 1876 statistics were published ⁽²⁾ showing the relation between success and the age of students:-

⁽³⁾

Age 12	-	44%	successful	-	61	candidates.
" 13	-	70%	"	-	184	"
" 14	-	68%	"	-	544	"
" 15	-	72%	"	-	788	"
" 16	-	73%	"	-	845	"
" 17	-	75%	"	-	1044	"

As a result of a memorial from the Highland and Agricultural

(1) Report 1875. Append. 1.

(2) Report 1876. pp. 2, 10.

(3) These statistics refer to Great Britain, not merely Scotland.

Society of Scotland, in 1875, Principles of Agriculture was adopted as another subject, and in the first examinations in 1876 there were 122 Scottish candidates from eight classes at Aboyne, King Edward, Monymusk, Rhynie, Rothiemay, Torphins, Watten and North of Scotland School of Chemistry and Agriculture, Aberdeen.

In 1876 it was decided ⁽¹⁾ to discontinue aid in instruction in Physical Geography, but a new subject was recognised in Physiography which would "embrace those external relations and conditions of the earth which form the common basis of the Sciences of Nautical Astronomy, Geology and Biology as treated in the Science Directory."

In 1878 conditions were made ⁽²⁾ for the receipt of grants for instruction in practical chemistry, e.g. a separate working place for each student, who must be supplied with a complete set of apparatus. A teacher might be called upon by the inspector of the Department to show his ability to use any apparatus. Each year showed a steady increase in the number of schools and students in Scotland, those for the various subjects in 1880 ⁽³⁾ being:-

Theoretical Mechanics	641
Applied Mechanics	585
Sound, Light and Heat	354
Magnetism & Electricity	1,123

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- (1) Report 1877. p.2.
(2) Report 1878. Append. p.2.
(3) Report 1881. p.202.

Inorganic Chemistry	1,379
Organic Chemistry	96
Geology	398
Mineralogy	16
Animal Physiology	589
Elementary Botany	296
General Biology	50
Navigation	172
Steam	539
Physiography	709
Agriculture	548

Agriculture was still very popular in the north east, but had been taught elsewhere e.g. Inveraray, Kilmarnock, Maybole, Mousland, Veterinary and Agricultural College, Glasgow, Newton Stewart and Stirling.

The director of science of the department after various promotions became in 1882 Col. Donnelly, R.E., though he had been in the full time employment of the Department since its inception, and in 1883 he issued instructions ⁽¹⁾ that payments would not be made in more than three subjects per pupil each year. Previously five subjects comprised the maximum. In 1883, Hygiene was added ⁽²⁾ to the list of subjects.

The Department sent representatives to the Electrical Units Conference held at the first International Electrical

(1) Report 1883. Appendix p.1.

(2) Report 1884. pp. 1, 9.

Exhibition held in Paris in 1881, at which were adopted the c.g.s. system, and the units ohm, volt, ampere, etc.

Agriculture had been looked on with favour as a subject of examination ⁽¹⁾ not only by country schools but by city schools which had had continued and striking success, e.g. in London, Stepney 50, Kentish Town 60, Limehouse 60, Goswell Road, Finsbury, 130, Bethnal Green 24, 30 and 40, Bishopgate 24, Peckham 60 pupils. Consequently the Department intimated in 1884 that they might "refuse to make payments for subjects of applied science, instruction in which is manifestly inappropriate and useless in the locality, as, for instance agriculture in town schools, unless it can be shown that the students intend to remove to localities where such instruction could be applied."

In order to render the instruction more thorough, practical examinations were introduced in 1886 ⁽²⁾ for the honours examination in Sound, Light and Heat, Magnetism and Electricity, and Animal Physiology. Such examinations had been held for several years in Chemistry and Botany.

In 1872 had been established Organised Science Schools ⁽³⁾ in order that a more methodical instruction in scientific subjects might be given. In 1886 the curriculum consisted of:-

(1) Report 1885. Appendix p.2.

(2) Report 1886. p.

(3) Science and Art Directory, 1886. p.41.

First Year - Mathematics, Freehand Drawing, Practical Plane Geometry, Inorganic Chemistry with one branch of Physics (Sound Light and Heat, or Magnetism and Electricity, or Physiography).

Second Year - Mathematics, Practical Geometry, Elementary Mechanics, Inorganic Chemistry, Animal Physiology, with one branch of Physics.

Third Year - Mathematics with specialisation in science.

It is of interest to examine the syllabus ⁽¹⁾ in use at 1886 in the subject General Biology, first stage:-

1. Form, size, growth - Torula, Protococcus, Amoeba, Bacterium.
2. Mucor, Penicillium.
3. Chara.
4. Fern.
5. Anatomy and physiology of flowering plant.
6. Frog.
7. Lobster or Cray fish.
8. Fresh Water Mussel.
9. Sea Anemone.
10. Fresh water Polype.
11. Bell Animalcule.

It certainly does not seem to bring out general biological principles to the same extent as most modern schemes, and is

(1) Science and Art Directory 1886. p.216.

more a collection of detached examples.

The scheme in Botany had now developed to include chemical preliminaries, histology, general anatomy and physiology of plant, special morphology and physiology of the angiospermous flowering plant. This last section embraced the description in technical language of fresh plants, and the characteristics of various natural orders.

To the Science and Art examinations can be traced the prolonged popularity of qualitative analysis in practical Chemistry, almost to the exclusion of other forms of practical work. There was a written examination of one hour in Practical Inorganic Chemistry and a practical examination of $2\frac{1}{4}$ hours. In the syllabus in Theoretical Inorganic Chemistry is mention of "French and English weights and measures" not the term "metric" as is used now, also the preparation of "Hydrogen Dioxide." In Magnetism and Electricity we find Frictional Electricity, Voltaic Electricity, "Electro-magnetism and Magneto electricity".

A subject which attained great popularity under the Science and Art Department, as being a species of general science, was Physiography, so the detailed syllabus ⁽¹⁾ is given here:-

"First Stage.

1. Elementary ideas of the various conditions of matter as regards energy, embracing heated states and electric and

(1) Directory 1886. p.242.

magnetic states.

2. Elementary Notions of Chemical Action. The formation of binary compounds. Breaking up of compound matter into simple forms. The chemical elements.
3. Water, its composition and different states.
4. Chemical and physical character of the crust of the Earth. Rocks, stratified and unstratified. Inorganic materials - the more frequent simple minerals and rocks formed of them - granite, volcanic products; sedimentary rocks, conglomerate, sandstone, shale; limestone, gneiss, slate, marble, sand, mud, surface soil. Materials partly produced by organisms - coal, peat, chalk, coal, limestone.

Bodies of which these are compounds.

The chemical elements of which the crust is chiefly composed.
5. Internal Terrestrial Phenomena. Observations indicating an increased temperature in the interior of the earth. Volcanic phenomena and distribution of volcanoes. Earthquakes and slow upheavals and subsidences of the Earth's crust.
6. The Sea. Salts dissolved in sea water, depth and form of sea bottom, remarkable inequalities. The chief currents. Distribution of temperature and density. Phenomena of

arctic and antarctic regions. Floes, pack ice, icebergs etc. Action of the sea upon the Earth's crust. Influence of the sea in the distribution of climate.

7. The Atmosphere. Height and composition; atmospheric pressure, use of the barometer. Distribution of temperature, horizontal and vertical. Use of the Thermometer.

Evaporation and condensation. Aqueous vapour, rainfall, ice and snow. Regions of extreme dryness and of great rainfalls.

The prevailing air currents: cyclones. General conditions of climate.

Action of rain, springs, rivers and glaciers upon the Earth's crust. General ideas of the changes which the Earth's surface has undergone in the past.

8. Electricity and Magnetism. Elementary notions as to the effects of terrestrial electricity and magnetism.

Thunderstorms; aurora; the mariner's compass.

9. Light and Heat. Distribution of light and heat on the Earth's surface. Day and night. The Seasons." (1)

Mr. Chas. Buckmaster, M.A., one of the inspectors, reported (2) that a little hamlet in Caithness "supports and has supported more than one science class for several years. In fact, in the village to which I refer, that of Watten, I

(1) Science & Art Dept. Directory 1886. p.242

(2) Science & Art Dept. Report, 1887. p.49.

was informed that the majority of the inhabitants had at one time or another passed one or more of the Department's examinations. Such an instance is probably unique, but if this can be done in a remote village in the north of Scotland, the same is possible elsewhere."

In 1888, arrangements were made ⁽¹⁾ to defray part of the fees of teachers who wished to improve themselves by attending classes and laboratories at various institutions, including University College, Dundee.

An idea of the work done is obtained by studying the examination paper set for the First Stage of Inorganic Chemistry in 1887 by the Science and Art Department:-

1. Classify the following substances as elements and compounds:
chalk, graphite, water, sulphur, iron, ammonia, oil of vitriol, chlorine, diamond, ozone. (8)
2. How would you distinguish hydrochloric acid from nitric acid? Give the formulae of the two acids and describe the preparation of a salt of each acid. (13)
3. Express in the form of equations the action of:-
 - (a) heat upon mercuric oxide.
 - (b) sulphuric acid upon common salt.
 - (c) hydrochloric acid upon marble.
 - (d) nitric acid upon copper.
 - (e) steam upon red-hot iron. (13)

(1) Report 1888. p.XVI.

4. By what experiments can you prove that the air contains $\frac{4}{5}$ of its volume of nitrogen? (9)
5. How could you convert sulphur dioxide into sulphuric acid and sulphuric acid into sulphur dioxide? (13)
6. 100 cb.c. of air are passed over red-hot charcoal. How would you ascertain if the air was altered in volume, or had experienced any alteration in properties? (13)
7. How many litres of oxygen gas, measured at 10° C. and 755 mm. can be obtained from 1 kilogram of potassium chlorate?
(1 litre of oxygen at 0° and 760 mm. = 1.43 gm) (15)
8. What is meant by the term allotropy? Describe the various allotropic modifications of sulphur, oxygen and carbon. (10)
9. How would you prepare nitrous and nitric oxides? Give equations for the reactions and state how you would recognise these bodies. (11)
10. Explain what is implied by the following terminations, -ous, -ic, -ite, -ate, and -ide and give examples of their use. (11)
11. How are the two oxides of carbon prepared and by what tests may they be recognised? (12)
12. Why is the flame of a taper extinguished in nitrogen gas, and why does it continue to burn in air? (9)

There was an Alternative First Stage Examination in Chemistry based on a wider syllabus:-

1. A glass of water is exposed to the air. In time the water disappears into the air. How do you account for this?
How could you prove that there is moisture in air? (13)
2. Air is passed over red-hot iron. What change does this cause in the air and in the iron? (9)
3. How could you show that the gas obtained by dissolving marble in hydrochloric acid is also obtained in the breath? (10)
4. Two samples of water are given to you. One is a hard water, and the other is distilled water. Describe two methods of distinguishing between them. (13)
5. What is vinegar? How is it prepared? Vinegar is poured upon washing soda: what happens? (9)
6. Ammonia is classed as an alkali. Why? Name some of the sources from which it can be obtained, and give its composition. (15)
7. A piece of lead, a piece of copper, and some mercury are separately heated in a crucible over a lamp. Describe what occurs in each case. (11)
8. From what substances can starch be obtained? Of what is it composed, and how does it behave when boiled with water? (13)

9. Name some commonly occurring compounds of sodium. How can you show that chlorine is a constituent of common salt? (10)
10. What substances are contained in flour? How can they be separated and what essential difference is there in their composition? (12)
11. What is meant by saying that a solution is saturated? How would you prove that no loss of weight occurs when a substance is dissolved in water? (8)
12. What are the distinguishing characters of cast iron, wrought iron and steel? What is iron-rust? (13)

It causes one to remember the conditions under which the work was carried on when one reads ⁽¹⁾ in a report that little progress had been made in the artificial lighting of classrooms and often "antiquated gas rings with flat reflectors still survive. Some of the best modern systems of lighting such as the Wenham burner, the Welsbach incandescent lamp, and Bray's patent burners are well worthy of trial where an intense concentrated illumination is required."

In 1888, an alternative subject of Elementary Physics was established ⁽²⁾ to include some portions of the syllabus of the two subjects Sound Light and Heat and Magnetism and Electricity. In this year it was ordered ⁽³⁾ that a certificate

(1) Report 1888 p.11
(2) Report 1889 p.2
(3) Directory 1888 p.37

must be furnished that candidates in mining, navigation, nautical astronomy, and principles of agriculture were; or were going to be, employed in the trade or industry to which the subject applied, or were to be teachers of it.

By 1891 science instruction had undergone a change of conditions. ⁽¹⁾ The isolated science class or classes under teachers, each directly and financially interested in the success of his own class was being gradually replaced by centres on definite educational lines where the teachers were remunerated usually by fixed salaries.

Owing to the financial assistance provided for technical instruction by the Local Taxation (Customs and Excise) Act, 1890, grants for apparatus and fittings were suspended. ⁽²⁾ By 1892 the scheme of science instruction had developed to such an extent that it was rather unwieldy, e.g. there were 190,000 papers corrected and over 14,000 practical examinations. Grants on account of examination passes were diminished, but an increased grant was given for attendance at an Organised Science School, £1 in day school and 10/- in the night school.

By this time Col. Donnelly had become Major General and finally Sir John F. D. Donnelly, K.C.B., late R.E., Secretary of the Science and Art Department.

(1) Report 1891. p.34.

(2) Report 1892. p.XX & Appendix. p.1.

Various Organised Science Schools were established in Scotland, ⁽¹⁾ those in 1893 being Robt. Gordon's College, Aberdeen with 1005 students, School of Science and Art, High School, Dundee 295, Glasgow and West of Scotland Technical College, Allan Glen's Institution 492, Sharp's Educational Institution, Perth 123, High School of Science and Art, Stirling 310. In the following year ⁽²⁾ there began at Leith Academy 388, School of Science and Art, Academy, Perth 300, School of Science and Art, High School, Falkirk, 164 students. In these schools not only science and art, but literary and commercial subjects were taught in varying amounts, and in 1895 it was ordered ⁽³⁾ that these latter subjects must form a definite part of the curriculum. New syllabuses were issued and in practical chemistry, "analysis should occupy a secondary position". As we have seen it had hitherto held rather too prominent a position in the course. Practical work was to include the setting up of apparatus, weighing and other chemical manipulations, the preparation of gases, and the estimation of volume. "The experimental work in physics and the principles of mechanics should be as far as possible quantitative in character and should lead to numerical results." Unfortunately the quantitative side of physics has predominated in

(1) Report 1893. p.126

(2) Report 1894. p.148

(3) Report 1895. Appendix p.5 & pp. 38, 39.

schools up to comparatively recent years, even in junior classes, and only recently has much qualitative physics been introduced, when it was found that the simpler parts of various branches were suitable for instruction there, while the quantitative parts could be taught later on.

Mr.R.Blair, the Inspector for the North Scotland Division, reported that chemical (and in some cases physical) laboratories and science lecture rooms had been built and were being equipped with the new schools at Inverness Academy, Arbroath High School, Kirkcaldy High School, and Bruntfield Public School. Laboratories had also been improved or enlarged at Thurso, Fochabers, Aberdeen (Grammar School) and Alva. He pointed out that secondary education was still principally literary and that the universities stood in the way of science becoming an integral part of the secondary school curriculum as science subjects were not even optional subjects in the Bursary Competitions, and as yet, they were not included in the Leaving Certificate Examinations.

In 1895, the number of individual students in Scotland under the Science and Art Department was 27,503.⁽¹⁾ The numbers of those who passed the examinations in various subjects is shown in the following list:-

Theoretical mechanics, solids	-	1,084
Applied	"	- 1,795

(1) Science and Art Dept. Directory, 1896. p.414.

Sound, Light, and Heat	521
Alternative Physics	1,504
Magnetism and Electricity	2,537
Inorganic Chem. (Theor.)	4,493
" " (Prac.)	2,127
Organic Chem. (Theor.)	180
" " (Prac.)	170
Geology	297
Physiology	679
General Biology	40
Zoology	40
Botany	443
Physiography	3,742
Principles of Agriculture	1,300
Hygiene	919

The various Organized Science Schools in Scotland with the dates they were established, and numbers of students are given below:-

		Students
Aberdeen, Gordon's College	1880	350
Arbroath High School	1895	38
Falkirk High School	1890	25
Glasgow Technical College	1886	242
" Allen Glen's	1895	406
Inverness, Royal Academy	1893	27
Kilmarnock Academy	1894	240

Leith	1894	135
Paisley, Gram.School & Acady.	1894	37
Perth, Academy	1892	160
" Sharp's Institn.	1885	110

In 1896, Mr.Buckmaster stated ⁽¹⁾ that only a few years before, a physical laboratory was a rarity but soon it would be found in every school where science occupied a proper place in the curriculum. Physics was now experiencing the same development of practical work which, in application to Chemistry, had already covered the country with chemical laboratories. ⁽²⁾ Mr.Blair commented on the improvement in the quality of the teaching in consequence of the summer and winter courses for teachers at South Kensington, at Edinburgh and at county council centres. There was, however, need of more experimental work and less text book work.

The Report of 1897 ⁽³⁾ stated that there were 12 Organised Science Schools in Scotland and that 337 schools in Scotland presented candidates for science examinations. Mr.Buckmaster reported that he found chemical laboratories "generally overcrowded with benches, dating both in plan and arrangement from the just departed era when analysis and practical chemistry were identical."

(1) Science & Art Dept. Report, 1896. pp. 17, 22.

(2) Mr.Ewen has informed us that the development of practical work in physics occurred only after cheap German-made balances were obtainable.

(3) Report 1897 p.49

In 1898 the work of the Science and Art Department in Scotland was transferred to the Scotch Education Department.

The work of the Science and Art Department has frequently been criticised unfavourably owing to the undue prominence given to certain parts of scientific subjects e.g. qualitative chemical analysis. Unfortunately, it was only near the end of the regime of this Department that this matter was remedied. The system of payment by results led to much teaching being done with only this end in view, and to the selection of easy first-stage subjects, instead of the study of subjects being continued to advanced stages. The nature of the examinations led to much cramming and to the publication of manuals for this purpose. Due credit must however be given to the beneficial work of the "South Kensington" regime, and without the encouragement given by it, science would not have been taught in Scotland to the extent that it was. Many Scotsmen today can still show with pride the boxes of instruments or books received as prizes in these examinations, as for some decades practically every Scotsman engaged in industry passed through these classes. The popularity of the classes really brought the activities of this Department to an end, as the whole system became too unwieldy. The examination system applied equally to day and to evening classes, to schoolboys and to artisans. The Organised Science Schools were really secondary schools, but literary and commercial studies were discouraged, so that

the resulting curriculum was unbalanced. The Mechanics' Institute movement of the first half of the Nineteenth Century paved the way for the Science and Art Department, and the desire for technical and scientific education assisted it. Scientists such as Huxley and Armstrong exerted a guiding influence. The best possible outcome of this system was its absorption in 1898 into the normal education system of Scotland.

Progress - Science and Art Department.

1. Department of Science and Art created, 1853.
2. Schools of Science and Schools of Navigation instituted.
3. Grants in augmentation of salary of teachers, 1859.
4. Teachers' certificates instituted, 1859.
5. Payment by results, 1864.
6. Grant towards purchase of apparatus, 1864.
7. Abolition of teachers' certificate examinations, 1867.
8. Building grants, 1869.
9. Exemption from examination of teachers who were university graduates, 1870.
10. Payments made on account of practical work, 1871.
11. Extra grants made dependent on suitable laboratory, 1871.
12. Courses for teachers held at South Kensington.
13. Collections of teaching apparatus formed, 1872.

14. Inclusion of new subjects in syllabus,
Biology 1874, Principles of Agriculture 1875, Physio-
Graphy 1876, Hygiene 1883.
15. Electrical Units Conference, 1881.
16. Restriction on grants for unsuitable applied science,
1885.
17. Organised Science Schools established, 1872.
18. Prominence given to chemical analysis diminished, 1895.
19. Literary and commercial subjects to form a definite part
of curriculum of Organised Science Schools, 1895.
20. Transfer of work of Science and Art Department in Scot-
land to Scotch Education Department, 1898.

CHAPTER XI.

SCHOOLS SINCE 1901.

Regulations regarding instruction in Science in Higher Class Schools were issued in Circular 296 in 1900, and it was stated "My Lords have thought it well to lay down a minimum of three hours a week as the least in which it can be expected that satisfactory results will be obtained." Either Physical or Natural Science might be professed, but each should include some study of the fundamental facts of Physics and Chemistry. It was suggested that pupils might be initiated into the study of Natural Science by devoting part of the time in the summer term to field excursions and discussions regarding the observations made there.

The policy regarding theoretical instruction in science differed in Scotland from that of England. In the former country it was stipulated that the theoretical instruction "should consist merely in the discussion, explanation and summarising of the results obtained and should have no separate period expressly allotted to it. In other words, the practical work should not be regarded as illustrative of a parallel course of systematic instruction in theory, but contrariwise, the theoretical instruction should be explanatory to such extent as may be necessary, and that only of the results arrived at in the practical work."

In 1903 a Minute was issued amending the regulations issued in 1900. Practical instruction had to be given in lessons of at least two periods (1 hour 20 minutes) duration, and "the time table of the school must be arranged to leave sufficient time to the Science teacher for laboratory preparation." Of the minimum time of three hours per week, not less than two were to be occupied in practical work on the part of the pupils. For theoretical instruction not more than 40 pupils might be taken by one teacher, nor more than 20 for practical instruction unless a laboratory assistant were provided, in which case the number might be increased to 30.

By the Code of 1902 for Day Schools, a science lesson must be not less than $1\frac{1}{2}$ hours in duration, and not more than 18 pupils ought to be taken for practical work at a time. The minimum ages stipulated for candidates for the Leaving and Intermediate Certificates were 17 and 15 respectively.

Dr. Macnair, even in 1901, was deploring the want of official recognition of experimental science in the preliminary examination for admission to the universities.

The Teaching of Botany in Schools was reported upon by a committee of the British Association in 1903.⁽¹⁾ It was stated that, at one time, instruction in botany consisted merely of getting the classes and orders of the Linnaean system committed

(1) Brit. Assn. Report 1903 p.420

to memory. Later, it aimed at the description of a plant in correct technical language, and in fact some text books were merely glossaries of terms. The nutrition of green plants was almost ignored in schools and colleges, even as late as 1870, and little had been done by British botanists in this branch. Only recently had it been realised that plants must be studied alive and experimentally.

A good idea of science teaching of that time is contained in a book entitled Science in the School, a course of experimental science and nature study with teaching hints, by W.J.Gibson, Headmaster of Nicolson Institute, Stornoway, published in 1905. In addition to the experimental science customary in schools, the special feature of the course is the attempt made "to connect with the experimental work of the laboratory a simple region survey of the school district." The details of the survey relate to Lewis. This book was first printed for the members of a teachers' science class held at Stornoway.

Supplementary Courses were established in Day Schools in 1903,⁽¹⁾ to place on a more systematic basis the instruction given beyond Standard V, the courses suggested being Commercial, Industrial, Rural and Household Management. The Industrial Course included some instruction in the simple principles of mechanics, and the Rural Course included the study of soils

(1) Report 1902-3. pp. 287, 405, 698. Circular 374.

rocks in the neighbourhood, wind and insect pollination, life histories of weeds and of insect pests also "a few well illustrated lessons in the rudiments of chemistry".

At this time a minimum of 480 hours instruction in Science was required for presentation of a candidate for the Leaving Certificate, and for a pass in Lower Grade Science instruction during 320 hours in Experimental Science with Drawing was required.

Dr. McNair stated that as yet the Leaving Certificate examination in Science was not recognised in any way by the Scotch Universities, and in 1904 he commented on pupils in the lower classes working in groups at science, whereas individual work should be the rule, while the time devoted to science (10 hours) in the third year of Higher Grade Schools he considered excessive. The number of pupils following this course was 1,314 (963 boys and 351 girls).

The Scotch Code (1905) stated ⁽¹⁾ that a course in science should be in accordance with an approved scheme, and this practice is still in use.

There were now in existence three types of instruction subsequent to the primary grade (which ended about the age of 12), namely, the Higher Class School for pupils who remained to University age, the Higher Grade School for pupils who

(1) Report 1904-5. pp. 116, 375, 432-3.

remained at school until 16 years of age, and the Supplementary Course for those who left school at 14.

In 1905 it was reported that experimental science had not been taken up as a separate subject, but rather as a continuation and development of the new mathematical syllabus of which it was the natural outcome. "Accurate measurement which forms the basis of such branches of the mathematics syllabus as scale drawing, mensuration and experimental geometry, is continued in the laboratory by the use of the metre stick, burette, balance, thermometer, and other instruments of precision. Habits of careful observation are engendered by the use of such instruments, and the pupils are trained to form logical deductions from their observations and measurements, and to set forth their descriptions and results with clearness and accuracy." Unfortunately, the first year course in science was for many years merely a course of practical mathematics, and it frequently killed any natural interest that the pupil might have in science. About twenty years elapsed before this uninteresting series of measurements was discarded.

Mr. Philip, H.M.I., suggested that these measurements might be carried out in the ordinary class room by pupils of ten or eleven years of age in the senior division, so that

time might be saved in the laboratory and a resultant enlargement of the science syllabus obtained. This was done in Ellon School. The same method has been suggested recently for the teaching of biology.

There was difficulty in obtaining teachers with satisfactory training in experimental science. Dr. Macnair stated that most of the science masters in the Higher Grade schools were learning what they had to teach in the process of teaching it. Summer courses were held e.g. at Glasgow Technical College to remedy this state of affairs.

In 1906, Dr. Macnair rejoiced ⁽¹⁾ in the fact that in most H.G. schools the science teacher also taught mathematics, "for much of the work of the first years' Science course can be brought into very close connection with that in Mathematics, and almost every experiment can be made the basis of interesting problems in Arithmetic and Algebra."

Alterations were made in the certification of teachers in 1907, with the passing of the pupil teacher, and under Chapter V, recognition in Science was given to graduates in pure science, who must also have undergone an adequate discipline in the methods of experimental science, e.g. by a pass in Science at the Leaving Certificate Examinations, a qualification required also for recognition in Mathematics.

It seems rather curious for us to read ⁽²⁾ that in

(1) Report 1905-6. p.263

(2) Report 1907-8. p.384

1908, woodwork was not the only form of practical instruction in boys' Supplementary Courses, as "in some of the schools Experimental Science takes its place - a perfectly legitimate development e.g. in mining districts", so that science was evidently not as yet a common subject.

The Scotch Education Department, in 1906, issued Rules to be Observed in Planning and Fitting up Public Schools. In these, it was stated⁽¹⁾ that the area of a science room should contain not less than 600 sq.ft. of floor space. In Higher Grade Schools the "laboratory accommodation must be sufficient to provide at one time for the largest class in the school", separate laboratories being provided for physics and for chemistry, wherever possible. For each pupil, 30 sq.ft. of floor space must be allotted, i.e. a minimum of 600 sq.ft. in a laboratory. The laboratories had to be supplied with gas and water, while in addition, there might be a lecture room, with an area of about 750 sq.ft., supplied with a demonstration table and gas and water supply in addition to a sink and fume closet. A further necessity was a preparation room fitted with shelves, cupboard, bench, sink and a supply of gas.

The gradual development of science even in schools of classical tradition⁽²⁾ is reflected by the statement in 1908 at the Royal High School, Edinburgh that "the greatly enlarged

(1) pp. 10,11

(2) W.C.A.Ross. Royal High School. pp. 69, 146

scope of teaching in Science and in Drawing made it imperative to secure the continuous and exclusive services of specially appointed masters in these two departments". Part-time instruction had been given successfully by Dr. Andrew Wilson in Physics for 33 years and by Dr. Drinkwater in Chemistry for 22 years. The chemistry laboratory had been fitted up in 1887 and the new physics laboratory and workshop in 1891.

In 1908 was issued by the Scotch Education Department ⁽¹⁾ a Memorandum on Nature Study and the Teaching of Science in Scottish Schools. This standardised the syllabus more or less throughout the country. It will be remembered that in 1898 a syllabus had been issued in the same way. This 1908 syllabus is the last one officially drawn up by the Department, the policy since then being to leave the schemes to be drawn up by the various schools and to be approved by the Department, except in the case of post intermediate work, where a syllabus was issued for the Leaving Certificate course in 1932 and annually thereafter in Circular 30, also in 1937 in Circular III.

It is stated in this Memorandum that the aim and purpose of "assigning to Nature Study a prominent place in the school curriculum is that it brings the pupils into direct contact with actualities and occurrences, as distinguished from descriptions and illustrations, that it develops

(1) Report. 1907-8. pp. 313 et seq.

in their growing minds habits of observing and discriminating, of noting resemblances and differences, and of thinking independently, and that it is calculated to foster their natural interest in all that surrounds them, and thus to afford a gentle and unobtrusive guiding of their out-of-school employment so that their every-day activities may open up to them endless sources of relaxation and delight. Looked at in this way, the subject may be regarded as a most valuable instrument for overcoming that divorce between school life and home life which is, in the opinion of many, a serious defect in our system of education."

The correlation with other subjects such as science, geography and drawing is advised while the nature study group is contrasted with the didactic group. English, however can find in nature study a useful ally providing material for oral composition and essays, while arithmetic, mathematics and manual instruction can all cooperate with nature study. Reading should not replace observation, and dependence on reading for information, it is pointed out, is altogether foreign to the spirit of Nature Study. The difficulties of teaching nature study in the larger towns is realised, but they are easily overcome. The studies should be seasonal and might include weather observations and the phenomena of plant and animal growth. The value of school gardens is stressed while nature study excursions should be frequent and might be

combined with map reading. A nature calendar would prove of interest and in some cases a regional survey might be attempted. A vivarium, an aquarium, nesting boxes, feeding tables, and observation bee hives might all be utilised in the study of living animals. No attempt is made to formulate a universal, rigidly defined scheme, each school being asked to draw up a scheme suitable for its own circumstances and the facilities available. Suggestions are then given for the treatment of nature study in the Infant, Junior, and Senior Divisions and in Advanced Classes.

The Memorandum on the Teaching of Science explains that "the main object of a course of Experimental Science is to implant in the minds of the pupils the habit and spirit of accurate investigation - a process which may be made a means of mental discipline of the highest order. It follows from this that the first-hand investigation by each pupil of a definite problem in the laboratory should be the keynote of the work, and that demonstrations by the teacher must take a secondary place."

A text-book is not advised at the Intermediate stage, as, in the laboratory, the pupil should be concerned chiefly with the observation of the facts and phenomena themselves, and in this, individual investigation is desirable. The records of experiments and tabulation of results in a note book are required, together with a description of apparatus,

illustrations, and graphs plotted from results. Unfortunately, the stressing of carefully detailed note books has led to rather an undue proportion of the science teaching time being occupied with this work, until a comparatively recent date, when, with a more limited allotment of time to science in schools, it has been realised that less time may quite well be devoted to this purpose.

It is stated that the early lessons of the course will be chiefly devoted to elementary exercises in measurement, but that this work should not be unduly protracted. After this, most of the work during the first two years should be physical and should precede studies in elementary chemistry, since chemical phenomena are usually of a higher order of difficulty than those in elementary physics, and the proper interpretation of chemical changes and laws depends on physical principles.

An outline of a suitable course in Experimental Science for an Intermediate School devoting three hours per week to the subject is then given, viz.,

Physical Measurements: Lengths, Areas, Volumes. Lever Moments. Beam Balance, Spring Balance. Mass, Density.

Physics of Air and Water : Pressure. Barometer.

Boyle's Law. V and W tubes. Syphon. Hydrometers.

Specific Gravity. Principle of Archimedes.

Tune and its Measurement: Pendulum.

Heat: Thermometer. M.P. B.P. Transfer of Heat.

Newton's Law of Cooling. Calorimeter. Specific Heat. Latent Heat.

Coefficients of Expansion of Solids, Liquids and Gases. Charles' Law.

Hygrometry.

Introductory Chemistry: Mixtures and Compounds.

Separation. Filtering. Solution, Crystallization, Distillation etc.

Chemistry of Air, Water and Combustion. The indestructibility of Matter. Acids, Bases and Salts.

Chemical Studies of Common Substances, e.g. Chalk, Carbon, Salt, Nitre, Ammonia, Sulphur and their derivatives.

Law of Constant Proportion.

Study of the Equivalentents of Common Elements.

Law of Equivalent Proportions.

This scheme, however, was not obligatory but merely suggested, and it was hoped that where a teacher was so qualified he might continue on more intensive lines in addition, the Nature Studies commenced in the Senior Division.

In the Post Intermediate stage there was a choice of work which might be professed, depending on the time available, and the aim of the pupil, e.g. Chemistry, Light, Sound, Experimental Mechanics, Magnetism, Electricity (Statical and Voltaic), Biological Studies (Botany and Vegetable Physiology, or Experimental Physiology and Hygiene). It will be noticed

that there was no mention of Zoology or of Geography. The former was scarcely considered suitable for school instruction at this time, and even now it is taught in very few schools. Where Geography was taught in the upper classes the treatment at this time was scarcely scientific. In time, it lay between the period of physical geography and the modern scientific period. In Scotland, geography and history have usually been closely allied, owing it is said, to their being correlated thus in the German Gymnasien in the early part of last century, when such curricula were adopted as models in this country.

It was hoped that the lessons in science would be applied to the explanation of natural phenomena, to manufacturing processes and the concerns of everyday life, e.g. fluid pressure in gas and water mains, use of barometer and thermometer in meteorology, formation of dew, fog, rain and snow. The studies were to be synthetical only, and not at all analytical, a method "common not so long ago in schools". Simplicity of apparatus was recommended and it was suggested that some apparatus might be made in the school workshop. The main purpose of the course was as a means of mental discipline.

An excellent appendix of suggestions to teachers for seasonal Nature study in schools was provided by Professor J. Arthur Thomson, and an appendix containing a list of apparatus required for the physical part of the course.

The British Association in 1908 published an excellent report on the teaching of science.⁽¹⁾ Test tube work and the analysis of salts were, by this time, things of the past, and the balance was made the basis of the first years of experimental work. It was recommended that science instruction in schools should be less academic than it had been. Text books, it was stated, were not used and should not be used in the youngest classes, but when the pupils were nearly sixteen years of age, text books could be usefully introduced. Improvements which were really required were the teaching of mensuration and elementary physical measurement as part of mathematics and the inclusion of nature study and biology where this was not already done. It is of interest to study the science scheme issued in Scotland in this same year, to find whether these suggestions were enacted there. As a matter of fact it was only about 1923 that the first suggestion regarding mathematics bore fruit, and about 1936 that biology was included in Scottish schemes. The report also suggested that though quantitative work was important, qualitative work deserved encouragement and respect. This would avoid producing the student described by Prof. J. J. Thomson (at the B.A. meeting in 1896) in the words, "he commences his career by knowing how to measure or weigh every physical quantity under the sun, but with little desire or

1) Brit. Assn. Report 1908. pp.501, 530, 531, 534

enthusiasm to have anything to do with them." The report also endorsed the opinion expressed by Prof. Mier to the Public School Science Masters Assn. (Jany. 1908) that all science work should be brought into closer touch with everyday experience.

In an official educational pamphlet⁽¹⁾ it was stated in 1909 that, from the first, the advocates of science have had to struggle, if not to fight against the firmly established position of the classics as instruments of education, and that the contest had not been rendered less arduous by the vested interests and lack of sympathy of many of those entrusted with classical teaching. It was also stated that in Edinburgh Academy 150 boys studied science in one chemistry room and one physics room, in each case the room being laboratory and class room combined. In Hutcheson's Grammar School, Glasgow 220 boys received instruction in science in a combined laboratory and classroom for Chemistry and for Physics. Instruction extended over at least three hours per week and no text books were used. The apparatus was kept as simple and plain as possible to avoid heavy expense.

The Report of the Board of Education (in England) for 1909-10 emphasised⁽²⁾ the fact that since 1902 there had been a gradual transformation from curricula which were predominantly scientific and mathematical to curricula in

(1) Educnl. Pamphlet No.7. Report on Science Teaching in Public Schools represented in the Assn. of Public School Science Masters.

which a more even balance of studies was secured. In addition, the whole period of growth and transition, it was pointed out, had been characterised by considerable changes in the methods and to some extent also in the aims of Science teaching.

In Botany, the time devoted to the purely descriptive work connected with the classification of plants in their natural orders had been greatly curtailed and now there was frequently included in the course an experimental treatment of plant physiology and some consideration of habitat.

During this period in Scotland some popular text-books were A First Year's Course in Practical Physics by James Sinclair, which reached a second edition in 1907 and a seventh edition in 1916, and was followed by similar courses for Second and Third Years, An Introduction to Chemistry by Dr.D.S.Macnair and A First Year's Course of Chemistry by James Sinclair and G.W.McAllister, published in 1912. It will be noticed that these books contain practically nothing but descriptions of experiments, and are decidedly quantitative, whereas during the post-war period, text-books became less quantitative in their treatment and more qualitative, as exemplified in A New Experimental Science by J.G.Frewin in 1926 and this tendency became more pronounced in subsequent books such as Experimental Science for Schools by D.B.Duncanson in 1926, and A School Course of Science by James Hunter in 1934. The "quantitative

period" of science teaching also necessitated and rendered popular among teachers such books as Questions and Numerical Exercises in Physics and Chemistry by David Baird, in 1915, a book which is still well-known. Illustrations have also changed in text-books, and instead of mere diagrams there are now reproductions of photographs.

A new type of school, 'an Intermediate School, was defined ⁽¹⁾ in 1910 as "a school providing at least a three years' course of instruction in Languages, Mathematics, Science and such other subjects as may from time to time be deemed suitable."

Mr. Ewen reported that in one or two schools, increased attention was being given to biological work, chiefly botany, and that steps should be taken to link up the Nature Study of the Primary School with the Lower Science course of the Intermediate Curriculum. Today this desire is being repeated with respect to biology in the secondary school.

In most of the H.G. Schools, stated Dr. Macnair, the time given to science had been reduced to 3 hours per week, the minimum required by the Code, but this reduction of time had not been accompanied in these schools by any corresponding reduction in the syllabus. In fact this reduction should have been proportionately greater, he pointed out, as, in practical work, with shorter lessons, a greater proportion of time was wasted in the necessary preliminaries. A similar position

arose about 1936, when biology became essential in post primary science, and the time allotted to science was in most cases reduced owing to increase in time devoted to Physical Exercises and Music. This led to much of the practical work being dropped and being replaced by demonstrations. In 1910 Sir John Struthers deprecated ⁽¹⁾ the tendency to neglect the teaching of scientific method the principal aim of school science teaching in favour of the teaching of facts, and traced this, in part to the too frequent recourse to demonstration where individual experiment was both feasible and desirable.

A closer relation was recommended by Mr. Ewen, between the experimental work done in the laboratory and the experiences of everyday life, and that measurement be not confined to c.g.s. system of units to the exclusion of the familiar British weights and measures.

Higher Grade Science was now put on another footing, the minimum instruction being increased to that required for mathematics or a foreign language. There was consequently a smaller number of presentations.

There was also recommended the teaching of the historical development of the branch of science studied intensely for the Higher Certificate. Instead of a single subject, a closely related group of subjects might be selected.

After 1912, the Commercial, Technical, Army and Special

(1) Report 1910-11. pp. J. 36-7. D31.

Group Leaving Certificates were merged into the Group Leaving Certificate⁽¹⁾.

The Intermediate course was largely a uniform course, at this time, dealing with fundamental ideas and units, thus forming the foundation of all sciences.

For Junior Students, i.e. those intending to enter the teaching profession, there was an obligatory science course which should include studies of plant and animal life.

At Golspie H.G. School,⁽²⁾ the teachers of science and gardening cooperated in the supervision of work done in the experimental plot.

It was pointed out in 1913 that a course in science would achieve its purpose if it produced in the pupils a habit of patient, self-reliant striving after the best results and the elimination of possible sources of error, and that this could be produced by constant watchfulness and guidance by the teacher during experimental work.

Little attempt had been made to illustrate the ordinary science course for girls by experiments taken from the every-day life of the home.

Sir John Struthers in 1914 replied⁽³⁾ to critics who alleged that Science was not a suitable subject for inclusion in a curriculum of general education. The Intermediate

(1) Report 1911-12. pp. L 6 & 42

(2) Report 1912-13. pp. D 51. K 49.

(3) Report 1913-14. pp. K 7 & 54.

schedules of a number of schools were scrutinised, and it was found that the highest marks in Science were usually gained by those who were among the best in Languages and Mathematics, and that general ability was the governing factor in educational results, one-sided talent being comparatively rare.

Again, there was complaint that the units used in everyday affairs were being neglected in favour of the decimal system and that the Fahrenheit thermometer was seldom used, the Centigrade one being usually used in the laboratory.

In 1915 it was stated ⁽¹⁾ that the microscope should be used to answer questions which arose naturally and which could not be answered without it, but with younger pupils, its use should be extremely limited, while much valuable work could be done without it.

A circular (No.470), was issued, advising economy in the use of laboratory glassware (owing to most of this having been imported previously from Germany and Austria), the substitution of ordinary bottles for flasks in the preparation of gases such as hydrogen and carbon dioxide which are evolved without the application of heat, and the replacement of beakers by tumblers and enamelled mugs in weighing objects in water. It was also recommended that smaller quantities of chemicals be used in experiments, so hastening the experiment and encouraging "neat manipulation and accurate observation."

(1) Report 1914-15. p. K 51.

A course was suggested (M 241) of specialised instruction for boys in supplementary classes of schools in mining districts, and this included Experimental Science - (practical measurements and the elements of mechanics, heat and chemistry), and Geological Nature Studies.

In the Science Departments, ⁽¹⁾ especially of Intermediate and Secondary Schools, there was found difficulty in staffing owing to the enlistment of teachers in H.M. forces. Vacancies had been filled by the employment of retired teachers, of married women who had previously been teachers, also of one or two ministers. Many schools were requisitioned by the military authorities, and in some cases this resulted in the use of one building by two separate schools, each occupying it for part of the day. In other cases halls and even churches were utilised.

A letter which appeared in The Times of 2nd. February 1916 had a considerable effect later in the teaching of science. It was signed by many famous scientists including Dr. Henry E. Armstrong, Sir Wm. Crookes, Sir Wm. Ramsay, Lord Rayleigh, Professors Gregory, Perkins, J. Arthur Thomson, and Ewart, and it was entitled "Neglect of Science".

"It is admitted on all sides that we have suffered checks since the war begun, due directly as well as indirectly to a lack of knowledge on the part of our legislators and

(1) Report 1915-16. pp. 4-6.

administrative officials of what is called science or physical science. By these terms we mean the ascertained facts and principles of mechanics, chemistry, physics, biology, geography, and geology. Not only are our highest Ministers of State ignorant of science, but the same defect runs through almost all the public departments of the Civil Service. It is nearly universal in the House of Commons and is shared by the general public including a large proportion of those engaged in industrial and commercial enterprise. - - - - - This grave defect in our national organization is no new thing. It has been constantly pressed upon public attention during the past fifty years as a cause of danger and weakness."

The writers stated that they were convinced that the matter required immediate attention and drastic action. They recommended an extension of science teaching in schools and colleges and that it be given its rightful place in civil service examinations.

Little attention was paid to this letter in the newspaper, interest being centred in a ship, S.S. Appam being brought into New York under a German prize crew, but two days later a gentleman in Godalming replied in The Times:-

"We have no time for controversy or disputing. We have to win this war or perish. To win it is our sole business and to discuss new schemes of education and whether

a boy is to be nurtured on Greek or Chemistry is, just now, --- sheer folly."

This was the only immediate response, but this letter led to the Prime Minister appointing a Commission to investigate the teaching of Science.

The Scottish Education Reform Committee, which consisted of representative Scottish teachers, issued a report⁽¹⁾ in 1917, and recommended that the science syllabus followed in schools should be remodelled. It was suggested that the present course took "an inordinate time to teach very little" and that better results might be secured by a combination of the experimental and the demonstration methods of teaching, also that steps should be taken to open up vistas of the field of science to the pupils. Another possible branch of study would be the stories of the heroes of science and their discoveries, and a course "should include a study of the elements of social and personal hygiene, and possibly also of the elements of biology." It was also considered that much less time might be devoted to measuring and weighing in the Intermediate School if more practical work were done at the primary stage.

Dealing with Scottish education in Problems of National Education in 1919, D. MacGillivray stated that the science syllabus required remodelling on the lines suggested by the recent Committee on Science teaching in schools.

(1) Reform in Scottish Education. 1917. p.41.

"Too much time is at present spent in measuring and weighing, valuable as these are in their place, and there is a serious loss of time through failure to make any use of the demonstration method of teaching."

A committee of the British Association issued a report⁽¹⁾ in 1917 on The Teaching of Science in Secondary Schools. It recalled the fact that about 1870 most apparatus for physics was not designed for individual pupils but for demonstration purposes and that Prof. Worthington was largely responsible for introducing courses of practical work in school physical laboratories with simple apparatus. In 1886 he published his "Physical Laboratory Practice" containing the physical laboratory course carried on successfully at Clifton College. At that time practical chemistry consisted mainly of qualitative analysis, but in 1884 Prof. Armstrong had outlined, and in 1889 and 1890 detailed, a more suitable method of teaching chemistry by presenting the pupil with problems to be solved by him experimentally, in order to develop the faculties of independent inquiry, accurate observation and intelligent reasoning. These British Association schemes completely changed the teaching of chemistry and physics in schools. In the same manner as Prof. Armstrong had revolutionised the teaching of chemistry and physics, Prof. L.C. Miall, had altered the teaching of experimental natural history.

(1) Brit. Assn. Report. 1917. pp. 126 et seq.

Consideration was given to the changes in science teaching since the B.A. Report of 1908, and it was found that in England less attention was paid to elementary practical measurements, mechanics was frequently being omitted from the science schemes, to be treated only theoretically by the mathematical staff, while biology was receiving some attention in schools. None of these conclusions were statements of the position in Scotland.

It was considered that three conspicuous motives prompting men to make attempts to understand science were (1) a delight in the intrinsic beauty and charm of natural phenomena e.g. delight in the forms and ways of plants and animals, and in the splendour of the heavens; (2) that man can exploit the forces of nature only if he is prepared to take the trouble to understand them i.e. the motive which has created applied science; (3) the craving for theoretical completeness and unity, i.e. the motive prompting men to seek 'fundamental principles' or to organise their ideas into logical systems. It was investigated whether these three motives, the 'wonder motive', the 'utility motive' and the 'systematising motive' were present and active in children, and it was decided that up to about 11 years, the 'wonder motive' was predominant, then from 11 or 12 to 15 or 16 years the 'utility motive' assumed mastery, while only at adolescence,

and even then not in all cases did the 'systematising motive' appear.

In accordance with these facts, the most suitable study up to age 11 is nature study to awaken or to profit by the interest of the pupils. In many schools it had been found most effective for pupils of 12 to 16 years to discover the principles involved in examples of applied science e.g. to study electricity is to analyse the working of the electric bell and the dynamo, so that these topics are not regarded as applications of scientific principles but "as the force of interest from whose study the pupil's knowledge of the scientific principles is to emerge". The committee also recommended the introduction into the teaching of some account of the main achievements of science and of the methods by which they have been attained. This could be done by means of general lectures, discussions or by reading. Every pupil should learn something about the lives and work of such pioneers of science as Galileo and Newton, Faraday and Kelvin, Pasteur and Lister, Darwin and Mendel and something about the useful applications of science. Various excellent schemes of science instruction were appended, probably the best one by T.Percy Nunn, being on the lines of what would now be called 'General Science'. Scientific knowledge and scientific method were not considered as separate things as in the B.A. Report of 1867, and it was felt that scientific training would be

acquired with suitable scientific knowledge.

The Committee on the position of Natural Science in the Educational System of Great Britain was appointed by the Prime Minister in 1916, and issued its report in 1918. It was found that science courses were carried on in Scotland⁽¹⁾ in 106 intermediate schools, 146 secondary schools, 46 schools not in receipt of grants and in certain primary schools, 15 of whom had presented candidates for the Intermediate Certificate. At that time Science was compulsory during the Intermediate course and consisted mainly of physics and chemistry, taught principally in the laboratory, the minimum accepted by the Department being three hours (four periods) per week. Science occupied one-seventh to one tenth of the school week. The report states, "this seems to us an inadequate amount of time in view of the fact that the minimum very generally comes to be regarded as a maximum and that the course in Science ceases for the majority of boys at the Intermediate Certificate stage." Nevertheless, conditions then were ahead of those prevailing at the present time, when many post-primary pupils receive no instruction whatsoever in science.

It was pointed out in the evidence that excessive attention was devoted to practical work to the neglect of lectures with illustrative experiments, and that "many teachers have become so dominated by the idea of the supreme value of

(1) Natural Science in Education. p.102 et seq.

experimental work that they have left on one side and neglected those sciences which do not lend themselves to experimental treatment in school," the tendency being to limit the work to portions of chemistry and physics in which pupils could perform experiments for themselves. In addition, it was found that, "in many schools laboratory practice among junior pupils has degenerated into a routine of quantitative measurements which belong rather to practical Mathematics than to Natural Science." In many schools more time was spent in laboratory work than the results obtained could justify. It was felt that the usual course which was a growth of the past twenty years had become too narrow, and that a school science course should include some knowledge of the main facts of the life of plants and animals. "Systematic work in zoology, including dissection of animals and the use of the compound microscope, belong to a later stage of school life, but the main facts as to the relation of plants and animals to their surroundings, the changes in material and in energy involved in their life and growth should form part of a well-balanced school course."

It was recommended that, in girls' schools, hygiene should be taught "after a course of systematic work in the sciences on which it depends", that more consideration should be given to "those aspects of the sciences which bear directly on the objects and experience of every-day life." Too often the human interest had been neglected in science teaching, and no attempt had been made to show the pupils the relation

between their experiments and the general principles of the Sciences or the relative facts of everyday life. Few pupils obtained an intelligent conception of Science as a whole.

Some of the other conclusions reached by this committee were:-

"That Natural Science should be included in the general course of education of all up to the age of about sixteen.

That increased attention should be given to the provision of suitable instruction in Science in the Upper Standards of elementary schools.

That there should be in every elementary school a room in addition to the ordinary class-room accommodation available for work in Science and other practical subjects.

That specific instruction in agriculture or agricultural science should not be given in elementary or secondary schools, though under favourable circumstances a rural bias may be given to the work of a secondary school."

Although the recommendations of this report applied equally to England and Scotland, one which interested Scotland only was that steps should be taken to remove the limitations which confined a large proportion of the old established bursaries in the universities to the Faculty of Arts. This may have had an influence on the position of science in post-intermediate courses, where science was not compulsory, (and where six hours per week for two years was the time required),

as in 1916, only 87 out of 146 schools presented any candidate in Science for the Leaving Certificate examination, and the candidates in Science numbered 571 (out of 2098), while the candidates in Science for the Intermediate Certificate numbered 7,756. It was suggested by the Committee that a written test in Science be held for the Leaving Certificate, and eight years later, this was established.

The war had awakened in the public mind an interest in Science, and the Ministry of Reconstruction issued in 1919 a publication entitled Natural Science in British Education. It was recommended that a broader view of the position of Science in education be taken and that in addition to practical work, there should be lectures and class teaching. In these, Science should be treated "as one of the Humanities, or as a record of the progress of human thought applied to the solutions of the problems of nature, and illustrated on the one hand by the biographies of the pioneers of Science, and on the other by descriptions of the applications of Science to industry."

It was stated ⁽¹⁾ in 1917 that "for 10 to 15 years past, Experimental Science has formed a regular portion of the intellectual discipline of all Intermediate and Secondary School pupils in Scotland, with results that must be described as distinctly gratifying."

(1) Report 1916-17. p.14.

In 1918 it was felt ⁽¹⁾ that the limit had been reached in depletion of the ranks of science teachers owing to the ever increasing needs of the army, and there was great difficulty in filling their places.

Experimental Science had come steadily into favour as a subject in Supplementary Courses. ⁽²⁾ in the ten or dozen years prior to 1921, and it was now nearly as popular as woodwork.

Mr. Forbes reported ⁽³⁾ in 1922 that in Forfarshire, a rural district, an attempt had been made to provide an education in supplementary classes so that the pupils would be enabled to follow intelligently scientific progress in agriculture. The course of science taught was planned to be fundamental to rural industry, and introduced by simple experiments in pure chemistry leading on to agricultural chemistry, simple geology, biology, and botany.

In 1923 as the Medical Preliminary Examination had been raised in standard to the Higher Leaving Certificate, the Intermediate Certificate was abolished, and the last examination for this took place in 1924. At the same time the Universities established a Medical Pre-registration Examination in physics and chemistry. Other alterations took place, the Supplementary Courses of Primary Schools being replaced by

(1) Report 1917-18. p.13.

(2) Report 1920-21. p. B. 37.

(3) Report 1921-22. pp. D.71. G.3.

Advanced Divisions, and the Day School (Higher) Certificate being established ⁽¹⁾ to mark the successful completion of a three year course of post primary education while the Day School (Lower) Certificate ⁽²⁾ might be obtained by pupils leaving after a two year course.

By the Code of Regulations for Day Schools in Scotland (1923) science was rendered necessary in advanced division instruction, and by the Secondary Schools (Scotland) Regulations, 1923, provision must be made during the earlier years of the secondary course for the inclusion of science.

At the British Association meeting in 1922, Sir Richard Gregory stated ⁽³⁾ that the teaching of science in schools was not intended to prepare for vocations, but to equip pupils for life, and that it was as necessary for intelligent general reading as it was for everyday practical needs, so that no education could be complete or liberal without some knowledge of its aims, methods, and results. In consequence, the science taught should be "science for all" and not for embryonic chemists, biologists or engineers. In his opinion, the principal claim of science to a place in the school curriculum is based upon the intellectual value of the subject matter and its application to life. Herbert Spencer suggested the conception of education through science as the best preparation

(1) Circular 60. 8th.Dec., 1923.

(2) Circular 63. 21st.Jan., 1924.

(3) Brit. Assn. Report. 1922. pp. 206 et seq.

for complete living and this led to the introduction of science into many schools. "Spencer's doctrine agreed with the principles of Pestalozzi with regard to the sequence in which the facts and ideas should be presented and be related to stages of development in order to be effective in creating or fostering natural interests in the mind of the child."

The Board of Education issued in 1922 a circular (No.1294) entitled Curricula of Secondary Schools in England and in this circular, the minimum time required to be devoted to the teaching of science is six periods per week of 35 to 37 periods.

In 1923 the Board of Education issued a report on Differentiation of Curricula between the Sexes in Secondary Schools, and found⁽¹⁾ that girls were inferior to boys in the branches of science for which a knowledge of mathematics is essential. In girls there was found the lack of an attitude of scepticism and curiosity, which form the best approach to the Natural Sciences, but girls were really superior in the Biological Sciences owing to their neatness and diligence, their descriptive power, and an ability for understanding elaborate classification. Boys were superior in experimental work, in initiative, and in reasoning.

An advance was made⁽²⁾ in the training of potential science teachers in 1923 by the introduction of courses of

(1) pp. 101-4

(2) Report 1922-3. p. C.23.

instruction in Laboratory Arts including the bending, blowing and general manipulation of glass and the construction and care of apparatus.

As a result, in part, of the changes in organisation of post primary education, ⁽¹⁾ there was a growing tendency to depart from the schemes of science which had held sway for so long, in fact since 1898, the principal changes being stated thus:-

- " 1. There appears to be a general consensus of opinion that the purely mathematical part of the former syllabus should be transferred to the teacher of mathematics.
2. A certain amount of the quantitative experimental work, such as the determination of specific and latent heats hitherto attempted somewhat prematurely, and often with dubious success in the earlier years of the course, is now being postponed to the later.
3. The time thus set free is being employed in the widening of the field and adding lessons on the other branches of Science, such as botany and electricity, with occasional suggestive peeps into the history of scientific discovery at some of the points of cardinal importance. These changes seem calculated to add fresh interest to the instruction by giving it a wider outlook and a more direct bearing on the phenomena of everyday life, and further indicate a liberal and adaptable attitude among

(1) Report 1924-5. p. D.46.

the teachers of Science that is entirely praiseworthy."

The official report in 1925 quoted above marks one of the most important steps in the teaching of science in Scotland.

During the session 1924-5, much useful work was done by the Inspectorate in proposing to the schools visited that the amount of time devoted to measurement might be greatly curtailed. A reaction had set in against the science courses which had been in operation for many years. Various schools considered an unofficial suggested course to cover the first three years of science instruction, and which introduced the study of magnetism and electricity in the second year, also experimental mechanics in the third year, with many simple but effective experiments. A text book exemplifying the new tendencies made its appearance in 1926 and was entitled A New Experimental Science by J.G.Frewin. As the author, an Inspector, states in the preface, the scheme was not an untried one, "it represents what may be termed the standard course for the large majority of schools in south-east and south-west Scotland and is put into book form in response to oft-repeated request."

The teaching of science was now completely revolutionised, much more qualitative work was performed, whereas previously practically all work in physics was qualitative, the scope was now much broader, more branches of physics were considered, much more interest was created among the pupils,

and as Mr. Frewin states, "the numerical conundrums that inevitably followed experiments, as if science had been brought into schools to provide practical material for Arithmetic, have had their day."

By the time that these new ideas had been adopted in the schools, there was a movement to add botany to physics and chemistry, but before it was adopted to any extent, the biology movement had taken its place in Scottish education, with the plea for General Science. Each of these movements has taken time to become firmly established, but the post-war period of science teaching has been a time of continual progress. It will be noted however, that there are points of similarity between General Science and the Physiography of a previous period.

Provision made in 1924 for instruction in science for the Leaving Certificate stated ⁽¹⁾ that schemes must include a suitable combination selected from physics, chemistry, botany, zoology, geology and geography. To satisfy the requirements of the Universities' Entrance Board, in 1926, written papers were introduced for the first time in the Higher Grade examination of all these subjects except geology, also in Lower Geography. These papers were to test not only the work done in the laboratory but also the collateral reading of the candidates. In addition, the oral and practical tests by which

(1) Circular 62. 1924.

alone the subject had previously been examined were continued, in addition to the teacher's assessment of the candidate.

In Advanced Divisions ⁽¹⁾ there was a striking advance in the number of schools in which science was taught, the figures being 412 schools and 33,370 pupils in 1924 and 751 schools and 56,095 pupils in 1925. There was a corresponding improvement in both staffing and equipment, but there was a scarcity of teachers properly qualified to give this instruction.

Inspectors in 1926 reported that the teaching of science in Advanced Division Schools followed too closely that of Secondary Schools whereas the time available was shorter and the capacity and outlook of Advanced Division pupils differed from those of Secondary pupils. It was recommended therefore that for the former, the teaching should be simple and be kept as close as possible to everyday life. Dr. Stokes deprecated the amount of attention given to quantitative measurements such as density, the accuracy aimed at being frequently excessive.

In 1927 questions in Human Physiology were introduced ⁽²⁾ into the Zoology paper of the L.C. examination. In the Physics paper was a compulsory question from a section on Mechanics, while the other sections were on Sound, Heat, Light, Electricity and Magnetism.

(1) Report 1925-6. pp. A.11, 15. C. 24, 46

(2) Circular 30. (1926)

The Scottish Education Department, in 1925 issued Recommendations to be followed in the Planning and Fitting up of Schools. As in 1906 the area of a laboratory had to be at least 600 sq. ft., but it was now suggested (1) that sinks might conveniently be placed along one of the outside walls in order to simplify plumbing and to avoid cutting expensive tables. It was also suggested that a science store room was desirable and that it might be used as an optical laboratory. The area of a lecture room where such was provided should be 750 sq. ft. in area, just as was stipulated in 1906. In small schools, a practical room might be available for both science and benchwork. These recommendations were reprinted without alteration in 1931.

Much more detailed suggestions were issued in 1936 in England by the Board of Education, (2) who recommended an area of 960 sq. ft. for a class of 40 pupils of a public elementary school. It is of interest to learn that difference of opinion still exists there with regard to the question whether science instruction should be given to a full class of 40 children or to half classes, consequently a

(1) p. 19.

(2) Education Pamphlet No. 107 Elementary School Buildings.

large science room makes possible a choice of policy by the school. It is recommended that a carpenter's bench be placed in a laboratory and that a first aid cabinet be placed in a suitable position. There is mention of provision of electric points carefully situated for experimental work. Primarily the science room should be equipped for General Science but the increased importance of instruction in Biology renders necessary some additional provision for such items as glass houses, aquaria, vivaria and Wardian cases.

Somewhat similar proposals were issued for secondary schools by the Board of Education in 1931 in a pamphlet entitled "Suggestions for the Planning of New Buildings for Secondary Schools."

In 1926 was issued a report of the Consultative Committee of the Board of Education on The Education of the Adolescent. The chairman of the committee was Sir W.H. Hadow, C.B.E. As mentioned in the report, (1) science was at that time a prescribed subject in the Advanced Division curriculum as well as in the first three years of the Secondary curriculum in Scotland.

The Report states, (2)

(1) p. 40.

(2) pp. 221-4.

"It is, however safe to say that most schemes for courses in elementary science in Modern school and Senior classes might be grouped round a simple syllabus consisting of:-

- I. The chemical and physical properties of air, water and some of the commoner elements and their compounds, the elements of meteorology and astronomy, based on simple observations, and the extraction of metals from their ores.
- II. A carefully graduated course of instruction in elementary physics and simple mechanics, abundantly illustrated by means of easy experiments in light, heat, sound and the various methods for the production and application of electricity.
- III. A broad outline of the fundamental principles of biology describing the properties of living matter, including food, the processes of reproduction and respiration, methods of assimilation in plants, the action of Bacterial organisms and the like.
- IV. Instruction in elementary physiology and hygiene based on lessons in Biology.

We regard it as extremely important that instruction in elementary physiology and hygiene, developing out of the lessons in elementary biology, should be given to all boys

and girls in Modern schools and Senior classes."

Unfortunately, this recommendation has not been adopted in Scotland, and many pupils receive no instruction in biology.

In the Preliminary Examination of the Scottish Universities, the only scientific subjects until 1927 were Mathematics and Dynamics. In 1927 was commenced a new subject, Physical Science, which was examined by means of two papers, the first being entirely Dynamics, while the second paper the candidate was allowed to select from the following four sections, viz: Heat, Magnetism and Electricity, Sound and Light, Chemistry. It was felt to be a hardship that a pass in Higher Science for the leaving Certificate was accepted only as a Lower pass by the Universities Entrance Board unless it included Physics, and this tended to restrict the study of the biological sciences in schools. Some ten years later, the attitude of the Universities Entrance Board towards geography caused many pupils to be reluctant to study this subject. The inter-relation of university and school is thus an important factor in the study of scientific subjects.

A Report on Animal Biology in the School Curriculum
was published by the British Association in 1928,

and it contained the following guiding principles:-

1. The general aim of school studies in Biology should be to inculcate a sound appreciation of the natural laws which govern the lives of human beings no less truly than they do those of other animals and of plants.
2. The basis of the study should be close observation of plants and animals in relation to their natural environment, and not as self-contained entities.
3. Morphological study should be undertaken less for its own sake than for that of its fundamental importance in the study of organic function."

The report stressed the experimental study of function as well as of form and showed that biology (including human physiology and hygiene) was studied in all the countries of Western Europe much more than in Britain. Biology and Zoology were studied to a very small extent in English schools and botany was practically confined to girl's schools in England. The Board of Education in England was, however, advising the broadening of the science curriculum with greater prominence being given to the teaching of biology. Though Scotland was not devoting much attention to biological subjects at this time, it was not worse than England in this respect.

It was stated by the British Association that "biological education must be 'biological' in the fullest sense - must take as field the whole range of life, plant and animal alike and man in his own place-but must not, however elementary the instruction ever sacrifice its breadth of view ----- Even parallel courses in Botany and Zoology, run on separate lines, do not constitute truly 'biological study' and will not, unless unified by the philosophic approach, contribute greatly to the end in view, if that end be cultural."

The official attitude towards the actual science taught was altering, and in 1928 it was even stated (1) with regard to the teaching of girls that "the subject of specific gravity including Archimede's Principle should be touched on very lightly and more time should be spent on elementary heat and chemistry."

(2)

The progress of science in advanced divisions schools is shown by a comparison of the statistics of 1923-24 and 1927-28. In the former sessions there were 412 schools with 33,370 pupils studying science and in the latter session 828 schools with 68,539 pupils. Both the number of schools and the number of pupils had been more than doubled.

(1) Report 1927-8 p. C 48.

(2) Report 1928-9 pp A 14 C 19, C 73.

Suitably equipped laboratories were now provided in most schools and courses based mainly on experimental exercises were developed. Mr. Frewin drew attention to the fact that biology appeared to be losing ground.

In the first three years of science instruction it was stated,

"The chief aims are to interest the children from the beginning in the various phenomena with which they have an every-day acquaintance, to lead them by simple yet striking and convincing experiments to investigate the why and wherefore of these phenomena, and to cultivate in them ability to record their observations and conclusions with accuracy and lucidity. Very properly at this stage the elements of physics and chemistry form the basis of the course of study. Due regard is being paid to logical treatment and sequence, and emphasis is laid not so much on the gaining of quantitative results - many of which mean little or nothing to young pupils - as on knowledge of principles and their application." It was suggested that the personal or human aspect might be increased by more acquaintance with the lives and work of the great men of science.

An important post-war development of the Educational Institute of Scotland has been the establishment of Science Sections in the four Secondary Districts (Edinburgh, Glasgow, St. Andrews, Aberdeen) and a Central Science Committee formed of representatives from these Sections. The last has done much useful work in drawing up schemes of work based on the opinions of teachers of science, and in co-operating with the Department in the interests of science teaching.

The Central Science Committee published in 1928 Suggested Schemes of Work for the Written Examination for the Leaving Certificate in Higher Science.

The need for a wider study of science in schools resulted in the issue, in 1929, of Schemes of Work in Science for Advanced Divisions by the Western Secondary District. Separate schemes were provided for an academic course, an industrial course and a domestic course and the schemes included only physics, chemistry, with the addition of a little botany. Biology had not yet made its appearance as a branch of science taught in Scottish schools.

In 1930, the Central Science Committee drew up a Memorandum re Schemes of Work in Science for the Higher Leaving Certificate, and while stressing the freedom of the teacher to frame his own syllabus for the first three

years of the course, it indicated in outline a scheme which might be covered during that period, and for the first time, biology was included in a Scottish scheme.

"It should not be regarded merely as a catalogue of topics in Natural History, but rather as a connected series of studies to be developed on broad observational and experimental lines which will lead the pupil to realise a deeper meaning in his outlook upon Physics and Chemistry, to appreciate more clearly the social and economic interdependence of all forms of life, and to learn something of the infinite variety and wonderful harmony of Nature."

In 1931, the Consultative Committee of the Board of Education, under the chairmanship of Sir W.H. Hadow, C.B.E., issued a report on The Primary School. Mr. Andrew, H.M.I.S. gave evidence regarding conditions in Scotland. The report states ⁽¹⁾ that Nature Study should form an integral part of the curriculum of every school, and, since physical facts play so large and obvious a part in modern life they cannot be neglected entirely in the school. In consequence, even young children should be introduced to those outstanding facts which come within their everyday experience, e.g. the lever in its practical uses, the

(1) pp. 182-6.

magnet and the mariner's compass, the effect of heat on water. "No attempt should be made to build up an organised body of science at this stage; the aim should be to interest children in just those physical phenomena which they meet in their ordinary experience. There is also recommended ⁽¹⁾ some first hand study of the apparent movements of the sun, moon and a few stars, taken in conjunction with the sequence of day and night and the seasons. It is doubtful whether much attention has been paid in Scotland to the conclusions reached by this committee.

The Scottish Council for Research in Education published in 1931, as the results of the deliberations of it's members, Curriculum for pupils of twelve to fifteen years (Advanced Division). In the section dealing with the teaching of science it is stated, "Science is taught because a general education is not complete if it does not include some knowledge of natural phenomena, of the physical laws and properties of matter, and of the application of scientific principles met with in everyday life." A scheme of work is suggested, and this includes the study of astronomy, geology, biology, physics and chemistry. The minimum time required for the teaching

(1) p. 100.

of this scheme consists of six periods per week, of which two periods should be devoted to biology, which it is considered should be an essential part of the science instruction in all schools.

In 1932, the Scottish Education Department issued a circular (No. 62), containing new regulations for the leaving Certificate. Science must consist of an approved combination of physics, chemistry, botany, zoology, geography, or an applied science e.g. engineering, agriculture. Candidates in cookery, laundry work, and housewifery must have had appropriate instruction in science, and must include elementary lessons in hygiene. A syllabus was also issued (in Circular 30) for the examination for the leaving Certificate in Science. Normally candidates would be presented in two branches only, but it is stated that "in the earlier stages, physics, chemistry and biology should form the basis of the instruction."

The Board of Education, in 1932, published a Memorandum on the Teaching of Science in Senior Schools.

(1) The values to be expected from a training in Science are stated, and may be summarised thus:-

(1) Educational Pamphlet No. 89. pp.12,17,18,23,29,34,47,
49, 51.

1. A more rational mode of life resulting from a knowledge of the facts and principles gained by scientific works, hence a healthier and therefore happier community.
2. Labour saving devices have resulted from laws of Science, so a knowledge of the principles involved and manual dexterity acquired in the laboratory may be useful to the pupil in later life.
3. Knowledge of some of the secrets and processes in Nature may create an absorbing interest in later life.
4. An increased interest in the "riddle of the Universe."
5. Pupils may obtain some training in Scientific method, i.e. observation, experiment, grouping of significant facts, and deduction, and may learn how accurate knowledge is won, the need of caution in forming judgments and the necessity for carefully weighing evidence.

It is pointed out that there is a short age range in which the work must be accomplished, and that "there is a pedantry of the laboratory, no less than of the class room on the study." Many science courses were too academic, too remote from the natural interests and everyday experience of the children.

The teaching of biology must play an important part, not only in supplying a knowledge not only of the

open book of Nature, but of the principles of biology and their applications. The calculating of areas, and volumes should be dealt with by the mathematician not the science teacher, "nor need much time be given to the subject of density or specific gravity," and "the principle of Archimedes usually confuses the less acute children." The neglect of biology is pointed out, and in teaching this subject, "the best introduction is through direct study of life histories and habits."

In considering the methods of teaching, it is pointed out that demonstrations are not merely desirable but essential, that practical work however is equally necessary, though the disadvantage of practical work is that it consumes much time, and "many schools are in danger of falling into superstition and treating practical work as a ritual, in itself productive of scientific or educational salvation." Practical work must play its part in conjunction with demonstrations, discussions, field work and the use of books.

Probably the most revolutionary changes proposed are in equipment and apparatus. Fume cupboards and balance benches are not recommended, the former because they are usually used for a variety of purposes other than

their proper use, and the latter because the place of beam balances should be taken, for the most part, by spring balances, thus saving much valuable time. Another piece of apparatus which should not be used is the specific gravity bottle, while it is very pleasant to learn that "Nicholson's hydrometer has no place in a school course. It is merely a scientific curiosity and no child should be troubled to use it."

In electricity, astatic and tangent galvanometers should not be used as "their day of usefulness has passed" and measuring instruments should be direct reading. For some biological work a micro-projector may prove useful. The memorandum also recommends that a bench for woodwork and metalwork be in the laboratories, and that the science teacher should be given authority to purchase equipment "as he sees his opportunity to do so," and not be dependent merely on the periodical requisitions.

The British Association published, in 1933, the report of the Committee on the Teaching of General Science in Schools, with Special Reference to the Teaching of Biology.

It was found that the chief causes of the neglect of biology in schools were said to be:-

- "(a) The apparent absence of any strongly expressed demand from parents and others interested in education.
- (b) Inertia and lack of initiative in the face of established custom in schools in which only chemistry and physics are taught.
- (c) A shortage of teachers who have studied biology during their University career."

This committee suggested that General Science should be taught in all secondary schools and that it should provide a coordinated study of physics, chemistry and biology.

It was reported in 1934 (1) that in many schools some form of biological instruction was now included as a definite part of the curriculum in the first three years. In the years 1930-33 a change of outlook had taken place. The work of these years had become "more extensive and less intensive, it has become qualitative rather than quantitative, while more branches of physics are studied than was formerly the case, and biology is added to the physics and chemistry

(1) Report 1933-4 pp. C 22+85.

of the past. It would appear, however, that biology is not making such rapid headway as is desired."

The position of biology in the school curriculum was considered at a conference held in Edinburgh in 1934 under the auspices of the British Social Hygiene Council, and the Department, in the Report of 1934-5, investigated how it could obtain a more adequate measure of recognition in competition with various other subjects. It was decided (1) that, instead of creating an additional school subject, biology, it should be incorporated with the existing science course. "We believe that this can be done without detriment to the other branches of science included in the curriculum and with real advantage to the general education of the pupils."

As Professor Peacock pointed out at this conference, "If Biology is to form part of the school science curriculum and examinations, such cannot be done without some modification in the treatment of Mathematics, Physics, and Chemistry. This point is crucial." Unfortunately this was not realised by many, also, no additional time was allotted to science in schools, although frequently the previous course in physics and chemistry was continued as well as biology.

(1) Report 1934-5 p. 18.

In 1932, the number of subjects required in the examinations for the Day School (Higher) Certificate was decreased from five to four (by Circular 86) a choice being given of Science, French, Art or Crafts. This led to a rapid diminution in the number of pupils professing Science in this examination, e.g.

1925-6	96%
1926-7	96%
1927-8	96%
1928-9	97%
1930-31	96%
1931-2	95%
1932-3	- (not published)
1933-4	82%
1934-5	79%

Statistics of sessions subsequent to these have not yet been published.

This alteration in the regulations occurred at a time when economy was of paramount national importance and it provided an opportunity for economy in both staffing and accommodation, as a class or form of 40 pupils required only one teacher and one room for French, Art or Crafts, but, by regulations, it required to be divided into two classes of 20 pupils for Experimental Science, and this necessitated

two teachers and two rooms. The great and rapid decrease in the percentage of post primary pupils studying science as an independent subject in Scottish schools is shown by the following statistics:-

1928	95.3%
1929	95.3%
1930	95.1%
1931	94.1%
1932	78.4%
1933	76.0%
1934	72.1%
1935	71.9%

The year 1929 can thus be reckoned the time of high tide of instruction in science in Scotland; from 5% in 1868 the percentage had risen to 95.3% , but since 1929 the tide has ebbed steadily.

Even more striking are the statistics of the percentage of pupils in Advanced Division Schools studying science as an independent subject and those are shown here in comparison with the corresponding figures for Secondary Schools. ^x

x The basis of calculation is exemplified by 1929:-					
Advanced Divisions	$\frac{67,352}{71,609}$	= 94.1%	Secondary	$\frac{76,573}{79,714}$	= 96.1%
All post primary, as in previous table,				$\frac{144,125}{151,323}$	= 95.3%

	Advanced Division Schools Pupils.	Secondary Schools Pupils.
1928	94.4%	96.0%
1929	94.1%	96.1%
1930	93.4%	96.6%
1931	94.7%	93.7%
1932	71.2%	84.5%
1933	70.0%	81.5%
1934	63.6%	80.7%
1935	62.7%	81.0%

In addition, some pupils have studied science as a subsidiary subject, i.e. subsidiary to some practical subject, (but these numbers are evidently not mutually exclusive with those for science as an independent subject):-

	All Post Primary Schools.	Advanced Division Schools.	Secondary Schools.
1928	5.9%	10.7%	1.7%
1929	6.2%	10.7%	2.1%
1930	6.3%	11.4%	1.8%
1931	7.1%	12.1%	2.9%
1932	5.5%	9.8%	1.8%
1933	6.5%	9.9%	3.5%
1934	7.6%	13.0%	2.3%
1935	8.9%	15.0%	2.8%

In contrast to these statistics in Scottish schools is the position in England, and I am informed by the Board of Education that "one branch at least of Science will normally be included in the curriculum for post-primary pupils in nearly all Elementary Schools in this country and that it will be taken by pupils in all Secondary Schools for some part at least of their courses of study" (letter dated 19th. May, 1938.)

Science as a subsidiary subject frequently consists of only two periods per week being devoted to it.

It will thus be seen that a great number of pupils in Advanced Divisions receive no instruction whatsoever in Science. In 1935 about 22.3%, actually 20,169 out of a roll of 90,185 as shown by statistical tables, or even considerably more, as has been stated already owing to the figures given not being mutually exclusive.

It appears very unfortunate that so many Advanced Division pupils should learn nothing about Science, although it affects their everyday life to such a great extent, and probably even worse is their lack of instruction in biology.

Many important changes resulted from the Education (Scotland) Act, 1936. This act authorises the raising of the school leaving age to fifteen in 1939, and gives a wider definition of the term "secondary education", which is now, "instruction approved by the Department in such subjects as may from time to time be recognised by them as suitable for pupils who have reached the stage recognised in accordance with the regulations of the Department for the time being in force as marking the conclusion of the primary course." This alteration broke down the barriers between advanced division and secondary departments, and later regulations welded them together. In 1936 also was issued a circular (No. 98) on "Physical Education and Physical Well-being", which contains the following statement:-

" 29. Hygiene is the science which treats of the preservation and promotion of health, but the teaching can only be successful if it is based on some knowledge of the fundamental science, biology, which deals with the normal processes of life itself."

In consequence, to judge from the statistics of pupils undergoing instruction in science, the teaching of hygiene is evidently not very successful at present, especially in advanced divisions.

The Central Science Committee of The Educational Institute of Scotland published in 1936 A Course in Biology, which is intended for the first three years of secondary and advanced division schools. The amount of time devoted to biology during that course amounts to about 52 double periods and forms $\frac{8}{9}$ of the course.

Within recent years there has been a tendency to increase the amount of applied science taught in schools. It will be remembered that this is not in accordance with the recommendations of the Prime Minister's Committee. Agriculture was, in 1934, included among courses approved in applied science, (1) and in the following year navigation was added. Previously engineering had been recognised as a

(1) Report 1934-5 p. 16.

course. The course in navigation ⁽¹⁾ approved as an applied science consists of spherical geometry and trigonometry, navigation, nautical knowledge, weather science and economic geography. This return of vocational training is noteworthy as representing the return to the subjects taught in the first academies of Scotland. The first presentation in agriculture for the Leaving Certificate was in 1936. It is interesting to notice the decline of some country schools which were renowned last century, when most of the pupils at them were boarders e.g. Hutton Hall, and how one such school, Wallace Hall, has retained a position as a secondary school by becoming a centre of agriculture instruction.

In continuation classes, most of the scientific training is of a technical nature, and national certificates authorised in the Code of Regulations for Continuation Classes in Scotland, 1936, are for Mechanical Engineering, Electrical Engineering, Naval Architecture, Plumbing, Gas Engineering, and Gas Supply, and Chemistry. In addition, classes were conducted for the Preliminary Scientific Examination of the Pharmaceutical Society until attendance was made compulsory at full time day courses held in various colleges in 1937. Agriculture has also formed the basis of courses at some centres, e.g. Cupar.

The Scottish Education Department issued in 1937 a report as to The Position of Technical Education in the Day School System of Scotland. In this report it is stated that

(1) Report 1935-6.

in technical courses some form of art work should be carried on in addition to, and not as alternative to science and that some of the work in science which appears unreal to many of the pupils in advanced division schools, owing to its remoteness from the practical affairs of life, could be dispensed with. It is recommended that apparatus and working models for simple demonstrations "in the principles and use of electricity, wireless, steam and internal combustion engines should be available, either in a science laboratory or technical room," also that scientific films be employed for demonstrations which are impossible with school apparatus. In rural schools should be provided a special scheme of instruction in biological science related to the work and requirements of the district. Science is included in the curriculum of the day continuation classes conducted by the Ayrshire Education Committee at Kilmarnock for boys in the engineering industry.

An important part in the teaching of science is now played by the lessons broadcast by the B.B.C. The first experiments in Scottish school broadcasting took place at Garnetbank Public School, Glasgow, in 1924 and included a violin recital, a lesson in music, a talk on ballads and a short lecture in French, but no scientific lesson. In the following year, weekly talks were given during the summer term on Science from Aberdeen, and on Travel and Natural History from Glasgow, while a monthly talk on Nature Study was given from Edinburgh.

The evolution of school broadcasting is interesting. These first talks were on Friday afternoons, but gradually the talks came further into the school week and took a more definite form.

During the next session, 1925-6, Aberdeen provided talks on Nature Study by T.A. Morrison, from Glasgow came Science Course by Rev. E. Bruce Kirk, the subject during the summer term being The Sun, Planets and their Satellites, from Dundee were radiated talks on Natural History, and from Edinburgh, talks on Natural History, Science and Hygiene.

There was an increase in the number of talks during session 1926-7. During the Autumn Term, Edinburgh provided a fortnightly talk by H. Mortimer Batten on The Woods and the Wild Folk, then in the Spring Term, Glasgow on different days, had three series of lessons, The Story of the Earth by G.W. Tyrrell, Science in Everyday Life by J.P. McHutchison, and Natural History, by Seton Gordon and H. Mortimer Batten. Glasgow and Edinburgh, during the Summer Term radiated three series of talks, Nature Study for Rural Schools by R. Stewart McDougall and H. Mortimer Batten, Science in Everyday Life by W.M. Gregory, and In the Sea by Richard Elmhirst, while Aberdeen had talks on Animal Nature Study by T.A. Morrison, and both Aberdeen and Dundee relayed lessons from London, How Things Grow by E. Kay Robinson and The Shadows of the Stars by Professor H.H. Turner.

In the Autumn Term of session 1927-8, Glasgow provided talks on Wild Birds and their Homes by G.W. McAllister, and

Seabirds and their Homes by Evelyn V. Baxter, from Edinburgh came talks on Nature Study, and from London, relayed by Aberdeen and Dundee, were lessons by Anthony Collett on Out-of-Doors (Nature Study and Biology). This last talk was continued the following term by Eric Parker, and from Edinburgh R. Stewart McDougall spoke of The Natural History of the Sea. Nature Talks were given from Glasgow, British Wild Animals by Professor L.A.L. King and Wild Animal Stories by H. Mortimer Batten. During the Summer Term the talks from Glasgow were by W.M. Gregory on Pioneers of Progress: Scientists and Inventors, and by A.E. Miller on Butterflies, Insects and Creatures of the Seashore. Edinburgh continued its previous lessons, Aberdeen broadcast talks by T.A. Morrison, Out and About with Nature, and Rev. John A. Lees spoke from Dundee on New Nature Myths (Nature Study).

From 1928, all the Science Courses for Scottish schools originated in Scotland because atmospheric inter-fered with the radiation of courses originating in England. At that time a land line was not utilised for relaying programmes to various transmitters, but they were received from Daventry and radiated then. Definite courses, instead of sporadic talks were now instituted, namely in session 1928-9, Natural History round the Year by J. Arthur Thomson, and in

the following year the same subject by R.S. Macdougall, then in session 1930-1 there was a variety, Astronomy; Behold the Heavens! by D.B. Duncanson, Geology: The Face of Scotland by G.W. Tyrrell, Nature Study, Nature and her Ways by Professor James Ritchie, and Science Talks for Advanced Divisions: Great Experiments in Science by Professor A.D. Peacock.

The Scottish Sub-Council for School Broadcasting originated in 1929, and the first meeting of the Science Programme Sub-Committee was held in March, 1930. This committee was able to represent the views of teachers on the matter.

In session 1931-2 there were two courses in science, Ourselves and the living world (Elementary Comparative Physiology) by A.D. Peacock and The Story of the Earth by James Ritchie and D.E. Innes, then in the following session the courses were Adventures in Science (Famous men of Science) by A.D. Peacock, also Homes and Haunts of Wild Life by Ritchie. During session 1933-4, Duncanson gave a course on The Science of Familiar Things and an interesting experiment commenced, a two years' course of Biology in which Professor Peacock, Dr. Garry and Dr. Kidd dealt with biology, physiology and hygiene respectively. It was felt that the

B.B.C. could best help the teacher by paying attention to biological teaching, which was just commencing in many schools, and in 1935 another course lasting two years began. It was entitled Biology, and was given by Prof. Peacock and Dr. (later Prof.) Garry. Statistics regarding listening in schools were collected by the Scottish Education Department for the session 1935-6, and it was found that 3,787 pupils listened in 119 schools, while in session 1936-7 there were 4,060 pupils in 149 schools. These same professors, in session 1937-8 gave another series of talks entitled Biology - A History of Living Things, which dealt with evolution, and in session 1938-9 they are to break new ground with a course entitled Our Daily Life, which gives special emphasis to Human Physiology. The Biology talks are for pupils aged thirteen to fifteen years, but there are also Nature Study talks for pupils aged nine to twelve years. It has been found that of the pupils listening to the Nature Study lessons, 39% are urban and 61% are rural; in 1935-6 there were 15,872 pupils listening in 303 schools and in 1936-7 were 22,658 pupils in 437 schools.

There has been no dearth of experimental work in the teaching of science in Scotland. The Dalton Plan was used with success for teaching chemistry at Kent Road H.C. School, Glasgow, from about 1921.

The cinematograph and the film-strip projector have been introduced in many schools as visual aids in teaching geography, nature study and biology. The formation of the Scottish Educational Film Association with specialist panels for reviewing films has been of the utmost advantage.

As part of the instruction in biology at Morgan Academy, Dundee, (1) phenological observations have been made since 1921, and these are incorporated in the annual Phenological Report issued by the Royal Meteorological Society.

In the Royal Scottish Museum, Edinburgh, a Children's Gallery was opened in 1935 to provide a suitable display of material for study by children, and it has proved extremely popular and successful. Co-operation between school and museum was advocated by the Department in Circular 87 - Museums and Galleries and the Schools - published in 1932. A further experiment in co-operation was undertaken in Perth Museum (2) during sessions 1935-6-7, when a class from Caledonian Road School listened in the museum to the broadcast lessons in biology (given by Professors Peacock and Garry) as part of the

(1) J. Garrick, Scot. Educnl. Jnl. 1936 p. 573.

(2) D. J. S. Sutherland, Scot. Educnl. Jnl, 1937, p. 982.

science course professed.

Alterations in the regulations governing the issue of the Leaving Certificate were contained in Circular 111, which was issued in 1937. Among these changes, which take effect in 1940, is the position of geography, which ceases to be one of the branches of Science and becomes an independent subject, that must be professed on at least the lower standard, unless the candidate chooses history as an alternative. The branches of science now recognised are physics, chemistry, botany, zoology and engineering. The examination of candidates for Science on the lower grade will include a written paper containing a compulsory section on General Science and optional sections containing questions on physics, chemistry, botany and zoology. This decision marks an important step, for by it the teaching of "General Science" is now made essential, the teaching of only physics and chemistry is no longer sufficient, and to these must be added biology.

In Circular 62, as issued originally in 1924, applied science was not included among the branches of Science (a subject which had to be included in every curriculum), but when this curriculum was reissued in 1932, it was stated that Science might include in any approved combination an applied science, e.g. engineering, agriculture. From 1940, however, although engineering is retained among the branches of Science, agriculture ceases to be one of these branches, and becomes an independent

subject. Just as in 1932 (by Circular 86), Science ceased to be a compulsory subject in advanced divisions, similarly from 1940 it will no longer be obligatory for pupils in secondary departments, the concession given in Circular 111 being stated thus, "while it will remain a requirement that Mathematics and Science ought to find a place in every curriculum, although they need not always be studied throughout, the Department will be prepared to approve beforehand courses which do not require presentation in either Mathematics or Science."

In 1937 the Department issued a circular entitled "Accidents in School Laboratories and in Rooms used for Practical Work" (No. 107), in which warning is given regarding various experiments in which accidents may occur, and which states various precautions which should be taken.

The Memorandum Explanatory of the Draft Day Schools (Scotland) Code, 1939, envisages a Junior and a Senior Leaving Certificate, also a secondary division in schools, with alternative courses for pupils leaving at 15 years of age and those remaining till 17 or 18. The advanced division thus ceases, and "it is generally recognised that it is desirable to give such three-year courses a status and opportunity equal to that of the classes following the older and more academic types of three-year post primary course." In every course, hygiene teaching must be an important feature, In Science must be

studied both in physical and natural science, also elementary physiology in relation to hygiene, the teaching including in all cases the applications of science to matters of everyday life, and the work being both qualitative and quantitative. It is not clear whether science is again restored in status to being an obligatory subject, (although not necessarily a subject for presentation for a Leaving Certificate). This would be a very welcome change however, especially as we are living in an extremely scientific age, and as will be shown presently from statistics, there are tens of thousands of pupils in post-primary departments of Scottish schools who receive no instruction whatsoever in Science. In some schools only about 25% of the advanced division pupils are taught Science.

A great obstacle to the teaching of science in Scottish schools today is the difficulty of finding time for this subject in an already overcrowded curriculum. This problem is far from new, and was encountered by the Royal Commission on Scientific Instruction and the Advancement of Science. The opinion of this Commission, as stated in its Sixth Report, (1) in 1875, is worthy of consideration at the present day:-

"While we cannot deny the reality of this difficulty, it seems to us to offer no justification whatever for the

(1) p.8.

total or almost total exclusion from Education of any great branch of Human Knowledge. The difficulty is one which can only be met by carefully economising time, by employing the best methods of teaching and by discarding superfluous subjects of study. To meet it by making education one sided and incomplete, cannot be for the interest of the pupil. Nor does it appear to us impossible to make a fair adjustment between the claims of the different branches of Instruction."

"Progress - Schools - since 1901."

1. Supplementary courses established. 1903.
2. Memorandum on Nature Study and the Teaching of Science in Scottish Schools. 1908.
3. Intermediate departments established. 1910.
4. Plea by Scottish Education Reform Committee for remodelling of science syllabus. 1917.
5. British Association Report on The Teaching of Science in Secondary Schools. 1917.
6. Report of Committee on the position of Natural Science . 1918.
7. Advanced Divisions established. 1923.
8. Abolition of Intermediate Certificate. 1924.
9. Decrease of (i) mensuration, (ii) quantitative work.
10. Extension of teaching of Botany.
11. Introduction of written papers in Leaving Certificate Examination in Science. 1926.
12. Introduction of Physical Science in Preliminary Examination of Universities. 1927.
13. Introduction of (i) Biology (ii) General Science. 1934.
14. Introduction of Applied Sciences.
15. Broadcast lessons in Science.
16. Use of visual aids.
17. Abolition of Advanced Divisions. 1939.

RETROSPECT.

For fully four centuries science has been taught in some form or other to the youth of Scotland, but it is only during the last two hundred years that it has actually found a place in schools. Science teaching is under a deep obligation to John Mair, who introduced the subject into Ayr Grammar School then into the first Scottish academy, Perth Academy. Undoubtedly the development of science in schools was due to the establishment of academies throughout the length and breadth of Scotland. The teaching of science has passed through many phases, and not the least interesting are the lectures given by peripatetic teachers, a feature confined chiefly to the Edinburgh district, the use of scientific reading books by English or Classical Masters, and the most common method, the use of demonstration lessons. Practical work is of comparatively recent introduction, becoming customary only towards the end of last century, and to a great extent due to the efforts of the Science and Art Department, which exerted a great influence on science teaching in Scotland.

Science, as a school subject, has passed through a process of evolution, from being more or less a branch of practical mathematics, to the science taught in school laboratories at the present day, while with the progress of science, there has been a corresponding progress in science

teaching. In consequence, the science taught in school today may best be described as "a living body of knowledge which is interwoven into everything around us, whether machines or manufactured articles or the play of natural forces, whether the life of the fields or the mysteries of the laboratory".

APPENDIX I.

(1)

REID'S CHEMICAL ABACUS

for facilitating the study of the
Atomic Theory of Dalton and Berzelian Symbols
constructed and described in
Dr. Reid's Text-book and in his Elements of Chemistry.

Edinburgh: Sold by John Dunn, Optician, 52 Hanover Street,
Maclachlan, Stewart & Co., Booksellers, opposite the College;
and E.M. Clark, Philosophical Instrument Maker.

HER. Arcade, London.

(At top of Abacus, left and right).

In using the Abacus on this side, place the beads
on the other side in the first place, and then arrange them
on this side according to the composition of the compounds to
be represented, placing them perpendicularly above each other
which represent particles of different bodies in combination.

(1.) Dimensions 10 ins. x $7\frac{3}{4}$ ins.

(At left side)		(At right side)	
<u>ELEMENTS.</u>		<u>ACIDS.</u>	
Nitrogen	N	:: N	Nitric
Hydrogen	H	: S	Sulphuric
Carbon	C	:: P ²	Phosphoric
Oxygen	O	: C	Carbonic
Sulphur	S	H Cl	Hydrochloric
Phosphorus	P	HS	Hydrosulphuric
Chlorine	Cl		<u>BASES.</u>
Iodine	I	. K	Potassa
Potassium (NH ³	Ammonia
or	K		
Kalium (. Ca	Lime
Calcium	Ca		
Iron	Fe	. Fe	Oxide of Iron
Mercury	Hg	. Pb	Oxide of Lead
		. Cu	Oxide of Copper

(At Foot of Abacus)

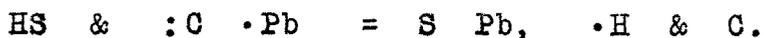
MEMORANDA - Move the beads with a pin, a pointed wire, a pencil, or a small slip of wood.

II. In using the Abacus, any provisional series of symbols may be substituted for those represented on this side, writing them with a pencil, or on slips of paper which may be placed in a temporary manner above the others.

III. When compounds containing oxygen and hydrogen mutually decompose each other, the oxygen from the one usually combines with the hydrogen of the other,

producing water, and the remaining substances combine, or are separated.

Thus, Nitric Acid and Hydrochloric Acid produce Nitrous Acid, Water and Chlorine $::N \ \& \ H \ Cl = \cdot:N, \cdot H, \ \& \ Cl.$
 Again Hydrosulphuric Acid and Carbonate of Lead produce Sulphuret of Lead, Water and Carbonic Acid.

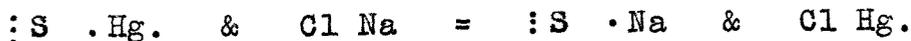


IV. But when compounds containing Metals decompose Water, the Metal takes the Oxygen, and the other ingredients combine or are separated.

Thus Sulphuret of Iron, Water and Sulphuric Acid, give Sulphate of Iron and Hydrosulphuric Acid.



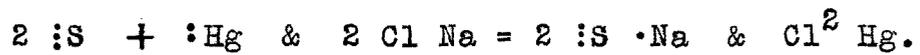
V. Compounds containing one equivalent of each ingredient, usually decompose one equivalent of any compound which they may affect. Thus, Sulphate of Mercury and Chloride of Sodium produce Sulphate of Soda and Chloride of Mercury.



VI. But if two equivalents of any substance be combined with one of another, and if this compound decompose a second containing two ingredients and only one particle of each, one of the former usually affects two of the latter.

Thus, one of Bisulphate of the Binoxide of Mercury

and two of Chloride of Sodium produce two of
Sulphate of Soda and one of Bichloride of Mercury.



APPENDIX II.

STATISTICS.

(i) Scholars taught Experimental Science
in Primary and Higher Grade Schools.

<u>Session.</u>	<u>Schools.</u>	<u>Scholars taught</u> <u>Science.</u>
1901-2	60	3,756.
1902-3	62	4,636.
1903-4	89	7,731.
1904-5	130	15,036.
1905-6	169	21,517.
1906-7	188	25,863.
1907-8	249	29,379.
1908-9	298	32,991.
1909-10	345	36,642.
1910-11	387	39,232.
1911-12	438	42,549.
1912-13	465	46,258.
1913-14	529	50,622.
1914-15	571	55,457.
1915-16	590	58,645.
1916-17	588	61,178.
1917-18	591	62,344.
1918-19	586	64,967.

No corresponding statistics are available for Higher Class and Secondary Schools, and no statistics are available of possible number of scholars i.e. total roll of Supplementary and Higher Grade pupils, only of the latter.

(ii) Scholars taught Experimental Science. (X)

Session.	Schools.			Pupils taught science.			Roll.		
	Advanced Division	Secondary	Total	Advanced Division	Secondary	Total	Advanced Division	Secondary	Total
1919-20	378	292	666	21,873	63,402	85,275	60,392	58,661	119,053
1920-21	356	250	606	21,774	65,907	87,681	63,447	60,693	124,140
1921-22	367	248	615	24,628	69,985	94,613	66,586	65,769	132,355
1922-23	370	248	618	26,206	73,742	99,948	66,793	69,778	136,571
1923-24	412	248	660	33,370	74,061	107,431	61,162	76,342	137,504
1924-25	751	249	1,000	56,095	75,871	131,966	69,970	76,153	146,123
(X) 1925-26	783	248	1,031	60,624	74,057	134,681	71,816	78,086	149,902
1926-27	793	249	1,042	63,129	76,765	139,894	74,060	80,506	154,566
1927-28	828	248	1,076	67,631	77,898	145,529	73,145	81,122	154,267
1928-29	827	248	1,075	67,352	76,573	143,925	71,609	79,714	151,323
1929-30	795	247	1,042	65,531	76,945	142,476	70,150	79,687	149,837
1930-31	778	245	1,023	65,999	76,234	142,233	69,676	81,388	151,064
1931-32	735	249	984	53,097	72,841	125,938	74,607	86,188	160,795
1932-33	718	247	965	59,985	74,193	134,178	85,733	91,012	176,745
1933-34	722	249	971	59,116	75,488	134,604	93,027	93,536	186,563
1934-35	707	250	957	56,455	75,012	131,467	90,185	92,654	182,839

(X) Commencing with 1925-6, Science taught as an independent subject. In addition there are small numbers of pupils taught Science in the Primary Department, in 1925-6 in the two types of schools 854 and 1456 respectively and in 1934-5, 1,693 and 1,472 respectively.

* To 1923 called Supplementary Classes.

† From 1919 to 1923 both Intermediate and Secondary Schools.

‡ This is average attendance as average roll was not published then.

(iii) Scholars taught Science approved as subsidiary to a practical subject.

Session	Schools.			Scholars.		
	Adv. Div.	Secondary.	Total.	Adv. Div.	Secondary.	Total.
1925-6	212	18	230	5,870	1,311	7,181
1926-7	237	21	258	7,915	1,046	8,961
1927-8	254	26	280	7,663	1,405	9,068
1928-9	254	26	280	7,687	1,641	9,328
1929-30	294	30	324	7,965	1,436	9,401
1930-31	310	40	350	8,394	2,379	10,773
1931-32	337	54	391	7,296	1,518	8,814
1932-33	356	62	418	8,447	3,078	11,525
1933-34	361	61	422	12,063	2,107	14,170
1934-35	376	72	448	13,561	2,638	16,199

In addition there are small numbers of pupils taught Science in the Primary Department, in 1925-6 in the two types of schools 400 and 206 respectively, and in 1934-5, 864 and 220 respectively.

(iv) Leaving Certificate Examinations. (X)

(a) Schools.

Year.	No. of Schools presenting Candidates.	Botany.	Pure Zoology.	Zoology + Human Physi- ology.	Physics.	Chem- istry.	Geography.	
							Low- er.	High- er.
1930	219	35	5	2	156	164	20	18
1931	215	40	5	3	162	172	19	18
1932	214	38	5	4	158	166	22	20
1933	220	36	4	4	171	178	26	19
1934	227	38	4	2	168	177	24	21
1935	229	45	7	3	175	184	21	24
1936	226	39	7	3	173	181	21	24
1937	230	45	10	3	177	185	27	28
1938	232	46	11	1	180	188	27	33

(b) Candidates.

Year.	Botany.	Pure Zoology.	Zoology + Human Physi- ology.	Physics.	Chem- istry.	Geography.	
						Low- er.	High- er.
1930	244	20	11	1206	1324	134	76
1931	227	18	17	1244	1359	125	84
1932	246	19	18	1319	1412	113	104
1933	231	19	21	1439	1526	115	87
1934	232	24	8	1436	1540	76	92
1935	246	31	15	1477	1573	81	108
1936	231	25	11	1662	1765	89	126
1937	288	63	10	1662	1788	108	148
1938	324	82	5	1773	1912	91	165

(X) Statistics issued to me by courtesy of the Scottish Education Department.

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