

Mabel's normalcy: Mabel Purefoy FitzGerald and the study of man at altitude

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The Physiological Society was started on the evening of 31 March 1876 at 48 Queen Anne Street, London, the home of John Burdon-Sanderson, and it celebrated its centenary in 1976 over dinner in the great halls of Trinity College, King's College and St Catharine's College during its meeting in July of that year in Cambridge. Three years before its centenary, the Society elected an ordinary member who was born on 3 August 1872, four years before it was founded. Her name was Mabel Purefoy FitzGerald.

Physiologists remember Mabel FitzGerald (1872–1973) principally for one important paper in which she described the observations she made in Colorado when she was a member of an Anglo-American expedition of 1911 to study the effects of high altitude on breathing. She showed that breathing is increased at altitude and so CO_2 is blown off. The reduction in the amount or tension of CO_2 in the lung air (the alveolar partial pressure of CO_2 , P_{ACO_2}) that this increase in breathing brings about is related to the barometric pressure and so to the amount of O_2 in the air. These findings were reported under her name alone in the *Philosophical Transactions of the Royal Society* in 1913 and that is her best-known paper¹.

In 1914 she published a second paper on the same subject, this time in the *Proceedings of the Royal Society*². It also dealt with the alveolar P_{ACO_2} but at more modest altitudes, up to 4000 feet, in the Appalachians. She concluded that the signs and symptoms of the response of man to high altitude are set off by the low tension or partial pressure of oxygen (P_{O_2}) in the arterial blood and not by a low total concentration of oxygen in it, for the amount of oxygen is in fact greater at altitude because of the increase in the concentration of haemoglobin that develops in the blood at high altitude.

Mabel rediscovered

These two papers were known in Oxford – J S Haldane (1860–1936) had trained her there to do

experiments on respiration – but they seem to have been little known to physiologists elsewhere. She personally was forgotten even in Oxford and it was only when Haldane's successor in the Oxford laboratory, Dan Cunningham, happened to be looking up a number in the Oxford telephone directory in 1961 at the time he was organizing a symposium to celebrate the centenary of Haldane's birth that he came upon her name by chance. She was living in North Oxford at 12 Crick Road, just to the north of the Laboratory of Physiology across the University parks. She was invited to the



Figure 1. Mabel FitzGerald at the Haldane centenary celebrations, Oxford, 1961, pictured with C G Douglas and J B S Haldane. (Reproduced from ref. 3, with permission.)

*Deceased

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symposium and the proceedings³ contain a photograph of her with C G Douglas and Haldane's son, J B S Haldane (Figure 1).

A story then started to emerge of her coming to Oxford to live at 12 Crick Road. Haldane had been her neighbour at Number 11, another typical large North Oxford house, and so we supposed that it was Haldane who had drawn Mabel into physiology, for, in addition to her papers alone on high altitude, she was known for an earlier one with Haldane on the normal values of alveolar P_{CO_2} at sea level in adults, both men and women, and in children⁴. That paper came out in 1905, the same year as Haldane's more famous paper with Priestley on CO_2 in the control of breathing⁵.

Roger Elliott, the theoretical physicist, lived in Crick Road in Haldane's old house, and he was then a Fellow of St John's, so from time to time I heard from him or Olga, his wife, about their next door neighbour, Mabel. For example, I had to brief Roger when Mabel wanted to know, imperiously and urgently as always, what it meant that she had been made an honorary member of the Undergraduate Osler Medical Society. The Elliotts helped Mabel a lot in her late eighties and in her nineties.

The centenarian

When she reached 100, in 1972, she received a telegram of congratulations from the Queen. She was interviewed and photographed and she was reported in the *Oxford Mail*. More details of her life emerged. She spoke of studying physiology in the Oxford laboratory in the late 1890s but she could only do that unofficially and with the collusion of the laboratory because the University would not then allow women to take physiology officially. She got on so well in the examination papers of the Final Honour School in Physiology that Francis Gotch, the professor, soon had the regulations altered. She also talked of her scientific work with Haldane and of her later association with William Osler (1849–1919).

Out of all this, Roger Elliott, who had become a member of the University's highest body, its Hebdomadal Council, and the Regius Professor of Medicine, Richard Doll, also on Council, got Mabel put up for an honorary MA of the University and she received it at a special congregation held in the Old Congregation House on 14 December 1972. She was taken there in an ambulance and before she went into the ceremony, she was asked whether she would like a little brandy. "Not now, afterwards perhaps." The public orator, Colin Hardie, introduced her in Latin as: "Amabilem Purae Fidei et filiis Gerald, physiologam, viridis senectutis exemplum." Then this model of lively old age (Figure 2) was admitted by the Vice Chancellor, Alan Bullock. With the degree she made *The Times* and she became famous nationally – the first centenarian to be given an Oxford MA.



Figure 2. Mabel FitzGerald after the degree ceremony in 1972, holding her degree certificate. (With permission of the *Oxford Mail*.)

The national publicity produced a response even from the committee of the Physiological Society. We all turned up to our next meeting clutching a copy of *The Times* with Mabel's photograph in it. She was elected an ordinary member of the Society at the annual general meeting a few weeks later.

She was already a member of the American Physiological Society: indeed, she had been since 1913 – 60 years earlier (Figure 3). She was the second woman they elected and was now their oldest member. Oxford and England felt rather guilty about her: they had ignored her.

I got more involved because Charles Michel and I were the examiners in respiration in the Final Honour School of Physiological Sciences in 1973, and we decided to honour a centenarian by asking the candidates to comment on a quotation from her principal paper. I immediately took a copy of the question paper to Olga Elliott and she gave it to Mabel that day, while the candidates were still writing the paper. It had the best wishes of the examiners written upon it (Figure 4). The next day Roger called upon her and found her immensely pleased. As for the honorary MA and the membership of the Physiological Society, she felt that she had those of right. But to be quoted in a paper of a Final Honour School, which she had not been allowed to take properly herself, was a judgement on the value of her work that she highly treasured.

The American Physiological Society

Chicago June 3 1964

Dr. Mabel P. FitzGerald
416 E. 65th St. N.Y. City.

My dear Madam -

I have the honor of informing you that at the recent meeting in Philadelphia you were elected a member of the American Physiological Society.

Please send me at your earliest convenience the necessary data for an list of members, such as address, degrees, position etc.

Yours truly
A J Carlson Sec

Figure 3. A J Carlson, Treasurer of the American Physiological Society, writes to Mabel FitzGerald to tell her of her election to that Society in late 1913. He asks for details of her degrees and her position, but she still had neither.

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HONOUR SCHOOL OF NATURAL SCIENCE
Final Examination
PHYSIOLOGICAL SCIENCES VI
Respiration
Saturday, 23 June 1973, 9.30 p.m. - 4.30 p.m.

1. In spite of the diminished alveolar oxygen pressure and consequently slightly reduced saturation with oxygen of the arterial haemoglobin, the arterial blood contains considerably more oxygen at high altitudes than at sea level. The symptoms (and signs) of oxygen deficiency at high altitude are therefore due to the deficiency not in amount, but in the partial pressure of oxygen in the arterial blood' (Mabel Purefoy FitzGerald, 1913). Discuss.
2. Discuss the properties and importance of the surface active substance in the alveolar lining layer of the lung.
3. 'Neurophysiology has advanced to a stage at which the term "centre" is no longer a useful one.' Discuss this statement in relation to the control of respiration.
4. Discuss in relation to exercise hyperpnoea or anything else, the significance of those components of physiological control systems which do not in themselves possess an element of feedback.
5. Is pulmonary diffusing capacity an inadequate concept for describing pulmonary diffusion?
6. Discuss the significance of the different speeds of response to changes in their stimuli of the various receptors which affect respiration.
7. Discuss the metabolic and physiological problems to be overcome in designing an artificial lung.
8. What is the use of mathematics in the study of respiration?
9. Discuss the recognition of gas transport that takes place in the animal at birth.
10. 'Hence, in order to measure the real effect of any increase or diminution in the alveolar CO₂ percentage, it is necessary to maintain the percentage constant for some time' (Haldane & Priestley, 1926). Discuss.
11. What lessons in respiratory physiology have been learnt from studies on breath-holding?

To: Miss FitzGerald,

With the best wishes of the Examiners who set this paper,
Clare Michael
B.D. Louane

Figure 4. Examination paper in respiration in Oxford physiology finals, 1973, quoting from the summary of the paper of 1913, and with greetings upon it from the examiners.

The examiners, all of us, hoped to call on her but she was already bedridden and she could not see us. She died about two months later, on 24 August 1973, aged 101.

The things she left

I became more involved in her affairs at the beginning of October 1973, when I was asked to look at her scientific apparatus and papers in 12 Crick Road. The house was being sorted by her niece, Mrs Purefoy, the daughter of her naval brother, and Mr Cannon, a retired nurse who had helped her in her later years and acted as her secretary. The house had been an extraordinary jumble: no papers had been thrown out in half a century. The wallpapers seemed to be the originals of the mid-1870s, when the house was first lived in. There was a mass of books and decrepit furniture, but some very good things too. The papers I then received were principally scientific and are now in the Bodleian Library, together with papers relating to her Purefoy grandmother's acquaintance with the poet Browning.

The scientific papers included notebooks of her observations, many drafts of her papers, letters from scientists (Figure 5) and applications for jobs and studentships. The originals of most of the letters from William Osler that she had annotated went to the Osler Library at McGill in Montreal and some other Osler material had already been taken into his small collection of Osleriana by the Regius Professor of Medicine, but there are copies of the Osler letters in the Bodleian. There were books and

4 STAMFORD SQUARE ROAD
OXFORD

July 18 05

Dear Miss FitzGerald,
New O'Osler today about the clinical experiments. He seems very keen about them, and has promised to give you all the help he can. He had to go to Town tonight, but was to write to make an appointment with you, so you will probably hear from him tomorrow.

Sincerely yours
J. J. Haldane

Figure 5. Letter from Haldane, telling of his progress towards having her make physiological measurements in the Radcliffe Infirmary.

some apparatus: microscopes, one quite old, her haemoglobinometer (Figure 6) and haemocytometer. The two gas analysis apparatuses were of the type Haldane devised for measuring small concentrations of CO_2 in vitiated air of poorly ventilated rooms but they had been fitted with a wider burette so that they would measure the higher CO_2 of alveolar air.

The apparatus formed the tools of her trade as a student of acclimatization to high altitude. It even included an altimeter, an explorer's set and a battered metal brandy flask inscribed "Quand vous avez froid, Pensez á moi".

There were two fascinating diaries, one, 1892, of Mabel's own and the other, 1895, of her eldest sister, Geraldine. Many more of the family diaries went into the Bodleian. That library now has the scientific letters and many more personal and family ones; among the latter by accident are a few of the scientific ones. These are from Haldane, Douglas, Gotch, Mann, Dreyer and Henderson. There was a collection of Haldane's offprints and also one of Henderson's and there were copies of all her own papers. The offprints went to the library of St Anne's College, which the old Society of Home Students has now become. In its early period it would have been an entirely appropriate college for an Oxford resident such as Mabel to have belonged to.

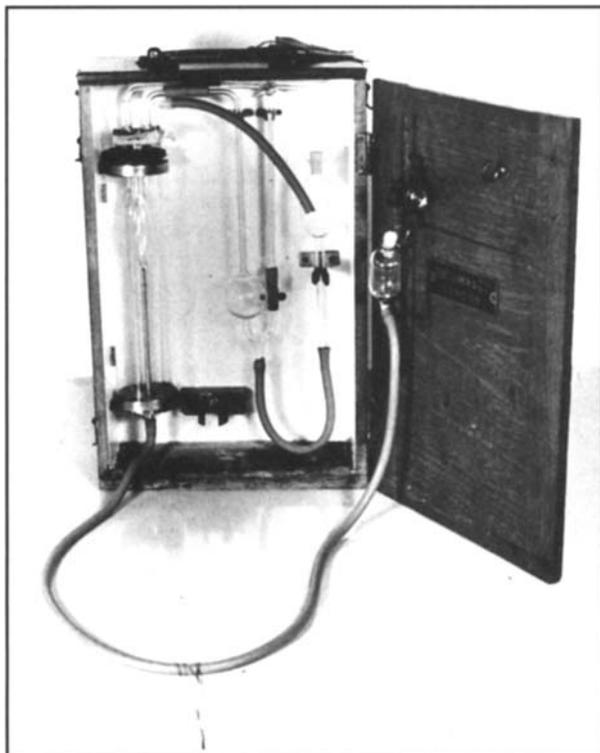


Figure 6. A Haldane gas analysis apparatus for measuring CO_2 in a gas sample. The sample is drawn into the bulb of the water-jacketed pipette on the left, and the CO_2 is absorbed by potash when the gas is driven over into the tubing on the right by raising the mercury, seen here hanging from a rack and pinion on the door of the apparatus.

It seemed to me that Mabel herself had selected the material in the hope that someone sometime would find it interesting to work upon. The two diaries, for example, and a postcard date-stamped "August 15, 1908 Colorado Springs" were not included by chance.

Mabel's family background

Mabel was born on 3 August 1872 at North Hall in Preston Candover, Hampshire. She was proud of her ancestry and she tried to work out some of the details of it in her later years.

Her mother was Henrietta Mary Chester, the daughter of a country clergyman, and her father, Richard Purefoy FitzGerald (1837–1895), belonged to an old family of country gentry which appears in Burke's *Landed Gentry* as the "Purefoys of Shalstone", a small village about 20 miles north of Oxford.

Mabel's Purefoy grandmother held the Shalstone property for the whole of the second half of the nineteenth century and it helps to trace the family back and forwards from her. She was born Sarah Anne Elizabeth Purefoy Jervoise (1809–1898). Her mother was the daughter of an archdeacon and her father, Richard Purefoy Jervoise (died 1811), a third son, was a major in the 1st Royal Dragoon Guards in 1811 when he was killed in the Peninsular War. In 1832, Sarah married Thos FitzGerald JP DL (1777–1860). His mother was Anna McNeale, the daughter of a West Indian planter, and his father was Captain Edward FitzGerald of the 22nd Regiment, who died in Jamaica when his son was young.

Sarah inherited the Shalstone property from an uncle, her father's elder brother, Jane Austen's dancing partner, George Purefoy Jervoise (1770–1847), when he died childless, and under his will the property had to pass from Sarah to the third of her six sons, Mabel's father, and anyone succeeding to Shalstone after Sarah had to take the name Purefoy. Thus when Sarah died in 1898, and Mabel's father had already died in 1895, Shalstone went directly to his son, Mabel's elder naval brother, Richard Purefoy (1862–1942), and he left Shalstone to his only child, Mrs Purefoy.

George Purefoy Jervoise left his other property, the Jervoise property at Herriard not far from Preston Candover, to his sister Mary and she and her husband adopted the name Jervoise. North Hall went to the Purefoys and that is why Mabel's parents were living there when she was born. After their parents' death it went to their elder, naval, son but he sold it in 1905.

The family was not insignificant: it contributed to the life of the country. George Purefoy Jervoise, the gentleman commoner of Corpus, who danced with Jane Austen, was set up financially by his rich uncle, who then held the family property, and he did this so that George could afford to enter politics. He was elected one of the two MPs for

Salisbury in 1813 at a by-election, but the electors of Salisbury found their pair of MPs too keen on reform for their liking and at the next full election, in 1818, George was dropped even as a candidate. In 1820 he became MP for Hampshire, nearer to his home.

Life at Preston Candover

For her first 22 years, Mabel (Figure 7) lived with her parents at North Hall. Richard Purefoy FitzGerald (1837–1895) had been in the forces, the navy first and then the army. He managed land, farmed, shot, hunted, stood for election to the county council as a Conservative, sat on the bench of magistrates and travelled around the country to meetings of the National Agricultural Union. He attended rent audit dinners for farm tenants and the church bells were rung in honour of his birthday.

He had two sons and five daughters. His eldest child, Richard (1861–1942), was in the navy and had been since 1875, when he was 13. he was a midshipman on a corvette with the future King George V. The fifth child and younger son, Henry (1867–1948), went to Keble College, Oxford, in 1892 to read chemistry. He got a first in 1893 and he also got a hockey blue. A pamphlet of his, *The Liver Fluke*, is dated 1886. After Oxford he went to teach science at Wellington College. He was ordained in Christ Church, Oxford, in 1894 and later gave up



Figure 7. Mabel FitzGerald aged perhaps 10. (With permission of the Bodleian Library.)

teaching to work in a parish. C G Douglas (1881–1963), of whom more anon, was a boarder at Wellington from about 1894 until 1897, when he left to go as a day boy to Wyggeston School in Leicester, where his father was a doctor. Douglas said that he moved because science was badly taught at Wellington, but some thought that it was because he was ragged at the boarding school.

Life for the five girls seems to have been less interesting. They had been educated at home. They read widely and went to lectures on literature and health. They walked, painted, made music, played tennis, cycled, met captains and majors and acted in amateur theatricals. They visited their grandmother at Shalstone and went to stay with friends and relatives at Tunbridge Wells and at Portland Place, London. Geraldine (1863–1900) was the eldest of the sisters and she adored her naval brother. She was given to headaches and at any crisis she took to her bed. Mabel was the youngest and was of a more vigorous personality and of a sharper judgement on other people. In 1892 she was aged 20 and was having French lessons and learning to play the violin (Figure 8). She describes a holiday in France near Le Havre, lasting about 10 weeks. Mabel was there throughout but the rest of the family, apart from her naval brother, came and went. She wrote in her diary with affection of Henry, the scientist. He took her to the Natural History Museum in 1889 and she found it "quite lovely". Of her sisters, she was closest to Laura, who was seven years older than herself.

Sudden change

Then the whole picture suddenly changed in 1895. Her mother was sent by the local doctor to London to consult a physician and then a surgeon, and she went into a London nursing home for an operation on 16 February. While she was recovering in London, Mabel's father, who was then standing for election to the Hampshire county council, caught pneumonia and died on 28 February. Her mother returned home to Preston Candover but on 14 May she too died.

The children put a stained glass window in the south aisle of Preston Candover New Church as a memorial to their parents but in truth their deaths may have been a liberation. Certainly they were for Mabel. She was free to build a career for herself. The girls soon had left the country to live in Oxford and both boys were married.

Immediately, though, the girls left Preston Candover and went to live with their grandmother in Shalstone for about a year. Mabel wrote on 9 February 1896 of reading T H Huxley in the garden there. "Digestion," she says, "is very interesting." She later worked on the secretion of acid by the stomach.



Figure 8. Mabel FitzGerald holding a violin, photographed in her late teens. (With permission of the Bodleian Library.)

Choice of a career

It was while she was at Shalstone in early 1896 that Mabel decided on a career in laboratory medical science and she worked at that career in three places: Oxford (1896–1907), first studying and then in research; New York (1908–15), doing research; and finally, in Edinburgh from 1915, in routine pathology until she retired back to Oxford in about 1937.

Up until 1896 she had long gone to nursing lectures. While at Shalstone she attended more strictly physiological lectures, for example one on the heart and another on digestion. She talked a lot with G H De'ath, the local doctor, and went around with him to visit his patients. Dr De'ath also was the medical officer of health for the nearby town of Buckingham and Mabel read a pamphlet of advice about cholera that he had written because cholera was then threatening to reach England from the Continent: she did not think that the pamphlet would advance his reputation. He stressed to her that she should first get some training in basic science and he warned her against supervisors who

simply use their subordinates. Mabel wrote of G H De'ath, "He [is] a real good friend to me." He seems to have introduced her to bacteriology and infectious diseases and among the subjects she worked on during her career were bacterial, fungal and viral infections. She began her work at the time the micro-organisms of disease were being discovered.

At that stage she rejected a career in clinical medicine. She had a medical objective in much of what she did but she seems not to have been prepared for the intense commitment that medicine would have required of a woman, initially in its study and then in its practice. She did, of course, work hard when studying physiology and, in one of her bursts of research, she would get to a high standard in a subject in a short time, but she enjoyed travel and some of the social life she had led while her parents were alive.

Old medical books replaced research as an interest after she came back from the USA. Nevertheless, she did long have a hankering after qualifying in medicine. She even kept an Oxford medical student's *Grey Book* record of studies with the things she had done signed up in it, extending from basic science in 1896 to anatomy in 1927, and she used it to gain entry to a part of the London Royal Colleges Conjoint Examination. But she did not take up a challenge made to her in 1905 by Osler that if she really wanted to qualify in medicine she would have to leave Oxford and move to Edinburgh or to London where women were allowed to study medicine full time.

When she was living in New York after the high altitude expedition of 1911, she came back to the idea of medicine. She studied part time at New York University and by 1915 she had just qualified to enter a New York medical school but she had yet to get a place. That all collapsed when she left the USA finally in 1915. She was then 42.

The move to Oxford

Mabel wrote her name in a copy of T H Huxley's *Lessons in Elementary Physiology* and dated it "Oxford, October 1896". By that time Mabel had started studying premedical sciences in Oxford, and the sisters had all moved there. At first, in 1896, they lived at 26 Norham Road, presumably renting it, and then later in the year they moved to 12 Crick Road nearby, buying the rest of a 99-year lease which would fall in 1971, 75 years later. J S Haldane was then next door in Number 11, but by 1900 he had moved to 4 St Margaret's Road and a few years later he built "Cherwell" at the end of Linton Road where Wolfson College now stands. So Mabel and Haldane (and many of the other actors in our play) were early residents of what is now famous as "North Oxford". Their houses were all part of the St John's College North Oxford leasehold estate.

Study

In 1896–7 Mabel took chemistry and biology. By autumn 1897 she had started on the full physiology course. Many of her notebooks survive of lectures she attended. Most of them were given by Gotch, the professor, and they ranged widely over circulation, respiration, the kidney and the nervous system. Gustav Mann taught histology and Mabel was to do her first research with him.

There is no evidence that she attended lectures by Haldane, though he was then working in the laboratory and he usually did a lot of teaching. He had come to Oxford from Dundee when his uncle, Sir John Burdon-Sanderson, had moved from University College London to be the first Waynflete Professor of Physiology in Oxford and he stayed on when his uncle became Regius Professor of Medicine in 1895 and was succeeded in physiology by Francis Gotch.

First research

The story now becomes fuller. In 1898 Mabel started to work with Gustav Mann. He had become the histologist in the laboratory when Burdon-Sanderson fired Dixey from the job for voting for the retention of compulsory Greek as well as compulsory Latin in Responsions, the examination for admission to the University. Dixey then became a distinguished zoologist in Oxford.

First Mabel studied the skin during vaccination and then she measured how the relative areas of white and grey matter vary with segmental level in the spinal cord, a substantial work that appeared under her name alone in the *Proceedings of the Royal Society* in 1906⁶.

We do not know whether she was paid to do any of this work, but she does seem to have accepted responsibilities as an assistant to Mann. For example, she seems to have helped him during examinations: one of her slide boxes contains slides stained, most of them badly, by candidates in the Final Honour School, including J G Priestley, A McNalty, H E Gibson and H S Souttar. Mann thanked her in 1902 for her help with his book on histological technique.

Before the work on the spinal cord was written up, she had already extended her interest in more clinical problems. She went to lectures on pathology given in Oxford by James Ritchie, then Professor of Pathology, and to pathology lectures given in London by Almroth Wright. There were clinical lectures and demonstrations by Osler. She spent eight months in Salamonsen's laboratory in Copenhagen working on pathology with George Dreyer. She had met Dreyer, a near contemporary of hers, in 1900 when he was working under Burdon-Sanderson in the Oxford physiological laboratory and, in 1907, Dreyer, helped by her, succeeded as the Pathology Professor when Ritchie

moved to Edinburgh. Also she worked on the opsonic index in Cambridge with Strangeways.

So the papers for which she had done the main experimental work (Figure 9) before she started with Haldane dealt with much that was relevant to medicine.

Work with Haldane

Her work that is best-known today was inspired by Haldane and it is the work she herself recalled when she was interviewed as a centenarian. The first part was on the normal value of alveolar CO₂ in men and women and in children at sea level. The gas tension of the CO₂ in the mixture of gases in the alveoli in the depth of the lung is called the alveolar partial pressure of CO₂ (P_{ACO2}). Her notebooks have the names of the children in full instead of just their initials as in the published paper⁴. Jack (JBS) Haldane was then aged 12½, 5 foot 2½ inches tall and he weighed 8 stone 13 lb. He was at the Dragon School, so-called because they beat St George's at rugby. His seven-year-old sister, Naomi, was also a subject then; she later became a novelist (Naomi Mitchison). Jack, of course, became the very distinguished scientist and left-wing propagandist, whom Peter Medawar found "in some ways the



Figure 9. Mabel FitzGerald aged about 28 years, in the Oxford Physiological Laboratory. (With permission of the Bodleian Library.)

cleverest and in others the silliest man I have ever known". When she was aged 90, Mabel recalled the fun when her subjects were small boys from the Dragon.

The joint paper with Haldane came out in 1905, the same year as the more famous one of Haldane and Priestley on the stability of alveolar P_{CO_2} ⁵. This work of hers, like more of the rest of her work on respiration, is a survey of alveolar P_{CO_2} in groups of subjects at rest.

Haldane's two papers from 1905 stand together. With Mabel he established the normal values of P_{ACO_2} and with Priestley he described its control. This relationship was repeated in the mountains of Colorado in 1911.

But again, in respiration, Mabel had a medical interest. On 18 July 1905, Haldane wrote that Osler was willing for her to study alveolar P_{CO_2} in patients in the Radcliffe Infirmary (see Figure 5). Some of them had anaemia and others had respiratory and circulatory disease. Mabel's eldest sister, Geraldine, had died from this disease in 1900. She measured the patients' P_{ACO_2} and their haemoglobin and she counted their red cells. Iron-deficient hypochromic microcytic anaemia was then called chlorosis and, as the old books tell us they should be, the patients with chlorosis were maids. Their haemoglobin as a percentage of normal was very low.

Ellen Talmadge, 21, kitchen maid	Hb 40%
Florence Morten, 18, housemaid at that grand hotel, The Randolph	Hb 31%
Elizabeth Weston, 18, housemaid at the undergraduate sportsmen's club, Vincents	Hb 34%

P_{ACO_2} was little different from normal in anaemia and that observation was to be drawn together with her Colorado observations to reach the conclusion that we had set for comment in the examination paper in 1973.

It was not all that long before she began to work in Oxford with Haldane that Mabel got to know him. Haldane says that they did not meet until she had finished her course in physiology and had started on research with Gustav Mann, and then Haldane was no longer her neighbour in Crick Road. Haldane cannot have had any part in drawing Mabel into physiology: she had chosen it before she reached Oxford.

We do not know how Mabel set up her informal arrangement to study in Oxford. Perhaps her brother, Henry, helped for he was a scientist. He had only recently left Oxford and, as a schoolmaster, he would have maintained contact with his old University.

Off to New York

Mabel applied twice, in 1904 and 1910, for the Philip Walker Studentship in Pathology, but she

never held it, even though her referees were Salamonsen, Mann and Sherrington in 1904, and McCallum, Haldane and Mann in 1910. Sherrington commended her "thoroughness, untiring zeal and truly critical spirit", and he wrote her a long letter about her work on the spinal cord.

But in 1907 she won a Rockefeller Travelling Fellowship. Osler had encouraged her to apply and he cabled her from the USA to tell her that she had got it. She sailed for New York at the end of December 1907 to work at the Rockefeller Institute for the year 1908.

The 1908 visit was not her first to the USA. She had spent two months there in the autumn of 1900 with friends of her family at Pojac Point in Rhode Island. She was there when Geraldine died.

In 1908 she was first with Hideyo Noguchi in bacteriology for about eight months studying sporulation in bacilli of the *Aerogenes capsulatus* group, but during that time at Rockefeller she had some sort of a clash with Simon Flexner. The difficulty seems to have arisen because Mabel firmly believed that she would return to Oxford after the year at Rockefeller and would work in pathology under George Dreyer, her friend who had just become the professor, and she told Simon Flexner that she would. But Dreyer did not come up with any specific proposal for work or even a general invitation to his laboratory. Flexner got to know of this. Mabel wrote to her sisters: "Dr. Flexner must think I am the most awful liar." She was furious with Dreyer – "not a gentleman" – but perhaps he was being prudent in not wanting a personal friend as his assistant, particularly a friend who had some part in getting him his chair.

All this fed on her distaste for the authoritarian atmosphere of Rockefeller and she decided that she had to leave. She thought of resigning her fellowship and wrote to Osler about it, but instead she went on to Toronto in Canada in September 1908 to be with A B McCallum in the physiology department until July 1909, studying secretion in the stomach with a histological technique for judging where an acid first appears: it is in the canaliculi of the oxyntic cells. Again, the paper appeared under her name alone in *Proceedings of the Royal Society*⁷.

Gustav Mann, her mentor in histology, also left Oxford in 1908 for the USA to become Professor of Physiology at Tulane University in New Orleans and he and Mabel met unexpectedly just after Christmas 1908 at the annual meeting of the American Physiological Society in Baltimore. She had come from Toronto with McCallum and he spoke well of the work she had already done in his laboratory in but a few months. "The Rockefeller men there were exceedingly kind and pleased with the paper that Professor McCallum gave with me on my recent work," she told her sisters. Flexner was also there. Mabel wrote, "He seemed embarrassed at meeting either of us."

Out west

Between her times in New York and in Toronto, she spent August 1908 travelling by herself in the west of the USA. A postcard date-stamped "August 15, 1908 Colorado Springs"; and addressed to her sister Laura, who was staying with the Dreyers in Denmark, says:

Oh, I am having a glorious time. The Rockies are all I anticipated. Today I have been riding up a lovely canyon, riding true western fashion, cross saddle. Washington beautiful city, Chicago appalling. Denver good trip from there up Mt. McClellan, 14 000 ft. exquisite. Going to New Mexico tonight.

She went out west again in 1909. She was joined in May by Laura in Toronto, and when she had finished her experiments in July the sisters spent three months travelling in Canada and the USA. It was on this trip west that Mabel first went to the top of Pikes Peak. The sisters left their hotel room in Colorado Springs at night and arrived at the top of Pikes Peak just in time to see the glorious sunrise over the plains to the east. They timed it this way to avoid the mountain sickness that develops in most people who go up to the top on the previous evening and wait there overnight for the sun to rise.

Mabel and Laura got back to New York in the autumn of 1909 and they stayed on until mid-1910, with Mabel writing up her research and Laura keeping house in 416 E 65th St, to the east of the south end of Central Park. This was always Mabel's address when she was in New York between 1908 and 1915 but perhaps she did not retain an apartment there during all her trips away.

The sisters had been together for a year when they arrived back in Oxford in June 1910. Mabel did not return to New York until January 1911, so while she was in Oxford for the second half of 1910 she must surely have heard from Haldane of his plan to study acclimatization to altitude in the hotel on the top of Pikes Peak in Colorado, a plan which had arisen that August during a discussion that Haldane and Douglas had with Henderson of Yale at the International Physiological Congress in Munich.

By that time, of course, Mabel was an old Colorado hand – she had twice been out there – and she knew the hotel on Pikes Peak. This may have encouraged Haldane to invite her to join his expedition to Colorado in the summer of 1911 and to do another of her surveys of P_{ACO_2} . He did not want her to join in the work on the top of Pikes Peak but rather to carry out a quite distinct study of her own, lower down. She was to study the state of full acclimatization in subjects who had long lived at altitude while the summit party studied the process by which full acclimatization developed. However, she could not finally agree until a very few weeks before she did set off, early in July. She had money problems and the Royal Society grant to Haldane would pay only her rail fares.

The money problems arose because she no longer had the Rockefeller Fellowship. She must have had some private income, as presumably each of the sisters had, but she needed more. There are some hints of where it came from.

A Colorado newspaper said that she represented a private scientific school in New York. She may have been teaching at that time. She was taken on part time by the US Navy Ventilation Commission at \$50 a month: she believed that would help but she did not know how part time it was to be and Haldane told her that she was not being paid enough. Henderson had her study the effects of acidosis on breath holding and Yale paid her \$125 for helping him.

Her 1915 passport (Figure 10) calls her a clinical pathologist. That was what she was returning to do in Edinburgh, but she may already have done it in a New York hospital. Certainly she was already well respected in the subject, for in 1915, when she had just returned to work in Edinburgh, she was invited to London to set up a collection of type cultures at the Lister Institute. She was already a very capable laboratory worker in a wide range of subjects. It is true that she got the job in Edinburgh in 1915 because a man had gone off to the war but



Figure 10. Mabel FitzGerald's passport of 1915, which says "Aged 42, height 5ft 5½ ins, forehead medium, eyes blue, mouth medium, nose long, chin square, hair light brown." (With permission of the Bodleian Library.)

she got it against the disadvantage that she had no formal qualification.

Pikes Peak

A few months after Mabel returned to New York in early 1911, she did the study around Pikes Peak which has become her most famous work. The basic story of the expedition itself can be built up from the scientific papers on the expedition but a long series of letters from Haldane to Mabel adds a more personal flavour. They deal mostly with the planning and the writing up. The earliest of the letters (Figure 5) have to do with Osler providing patients in 1905 and with getting Mabel's observations on them published.

Haldane's first letter (23 March 1911) about Pikes Peak thanks her for her advice and "for all the information you are sending and have sent . . . a base of operations at Colorado Springs will be a great help". A letter dated 14 May reads: "Schneider has been working at Yale and we have now arranged for him to join the expedition and to make his laboratory at Colorado College, Colorado Springs our local base." Schneider was Professor of Biology at Colorado College and had taken his doctorate at Yale in about 1900 but not on respiration. Before 1911 he had done little more on altitude than measure a few blood pressures: Pikes Peak made him. He worked for the American forces in the war on the resistance of pilots to lack of oxygen at altitude and continued with such problems after the war. Perhaps it was Mabel who raised the possibility of a base in Colorado Springs and of getting Schneider to join the expedition, for she might have met him during one of her earlier visits to Colorado, but then again Yandel Henderson may already have known him at Yale.

Mabel could not agree finally to join the expedition until the house in Oxford had been let by her sisters. They seem often to have let the house during the summer and gone off to visit friends and relatives or travelled abroad where living could be much cheaper for them. Presumably Mabel's share of the rent would provide her with some income which would allow her to take time off from earning money at her job in New York.

Mabel met up with the men in Colorado Springs, then a town of about 20,000 people. Pikes Peak rises to the west of it to a height of 14,000 feet, standing forward prominently from the Rockies far behind and overlooking the prairies which extend eastwards. The pioneers of Californian gold mining crossing the prairies on their way out west could see the peak from a great distance and "Pikes Peak or bust" became a well known American motto.

The timing of the work in Colorado was that the whole group worked hard making preliminary observations for a few days in Schneider's laboratory in Colorado College. Mabel enjoyed being

with the men. Then the men all went quickly to the top of Pikes Peak on the rack railway from Manitou Springs on 12 July and stayed there for five weeks. Mabel remained in Colorado Springs after they had left and started her own work on the survey. She studied men and women acclimatized to a range of heights: large towns - Denver (5100 feet) and Colorado Springs (6000 feet); small towns in the mining areas - Ridgeway (6990 feet), Ouray (7780 feet) and Telluride (8870 feet); and mines where the miners lived and worked - Portland (10,090 feet), Camp Bird (11,300 feet), Tom Boy (11,500 feet), Lewis mine (12,500 feet), and Altman, "a declining mining camp which still boasts its position as the highest incorporated town in America (10,780 ft.)." As Mabel said, "Colorado proved eminently suitable" for her purposes.

When she had finished her work in Colorado Springs, she visited the men on the peak for a few hours on 16 July before moving round behind the peak to work at about 10,000 feet in Altman and at the Portland mine. Then she went to Denver, but on the way she stopped off in Colorado Springs on 30 July to visit the men on the peak for a second time (Figure 11). After Denver, she went about 400 miles west to Ouray (11-17 August) and then to Telluride (23-25 August) nearby for the highest mines. She got back to Colorado Springs by 26-28 August and then set off sightseeing into Utah but was back in New York to see Douglas and Haldane before they left for home on 9 September.

The timing of her movements is not exact: it is derived mostly from the dates and places in her table of observations on her own P_{ACO_2} . She also reports on her experience of mountain sickness - present on her first visit to Pikes Peak but not on her second, which was soon after she had spent 10 days at 10,000 feet.

Mabel did her long-distance travelling by rail and the journey to Ouray from the east of Colorado must have seemed "exquisite" to her, going up the



Figure 11. Mabel FitzGerald on Pikes Peak, with (left to right) Haldane, Henderson, Schneider and Douglas. From the papers of C G Douglas, a keen photographer, who seems to have taken this with a delayed exposure.

canyon of the Arkansas River, crossing the continental divide at 10,856 feet and then down through the Black Canyon of the Gunnison and up the valley of the Uncompahgre to Ridgeway and Ouray.

But when going to the high mines she went on horseback, sometimes helped by a guide and with her gas analysis apparatus and other things strapped to the saddles of the horses.

Her temporary laboratory varied from the office of a mining engineer in a skyscraper to the wooden hut of a miner. In the towns, her subjects were professional people and students; at the mines they were managers or miners. She required that her subjects had lived at altitude for at least a year and at the same altitude for six weeks. Some had been there from birth but it was not realized then that the height of a person's birthplace usually affects lifelong sensitivity to lack of oxygen.

She stayed at a mine for several days, living with the people working there. She became well known for her work and she was reported in the local papers, as were the names of the people who gave her samples of their alveolar air to analyse.

She usually studied a group of about 10 men at each place but the groups of women were much smaller and there were fewer of them except that at Tom Boy mine, for some reason or other, she studied only women. Around Telluride, the groups of men also were much smaller: she had hoped to make enough time to study them thoroughly by crossing a col directly from Ouray to Telluride on horseback, but the trail was blocked by snow even in August and she had to waste several days going round by rail along the valley bottoms and over the Dallas Divide between.

The gas analysis apparatus she used was the small and easily portable one that Haldane devised for measuring CO_2 in the vitiated air of rooms and the technique she used was the one she described in her earlier work: a sample of end expired gas was drawn directly into the apparatus and she analysed it immediately (a three-minute job) (Figure 12).

Her observations stand today. They were often referred to by Haldane and are summarized in Figure 13. They show that changes of P_{O_2} affect breathing even around sea level.

After she had finished the survey she went further west to see Salt Lake City in Utah, but she got back to New York in time to dine with Douglas and Haldane when they were about to leave. Haldane then remarked: "Your work has been much more adventurous than ours."

It had been the sort of travelling she delighted in and the work had gone perfectly as planned, except when the snow on the col blocked the trail. It was Mabel who saw to it that it did go perfectly. Her two earlier trips out west had served as rehearsals. No wonder that Haldane had been prepared to wait for her to be able to come until the last moment.

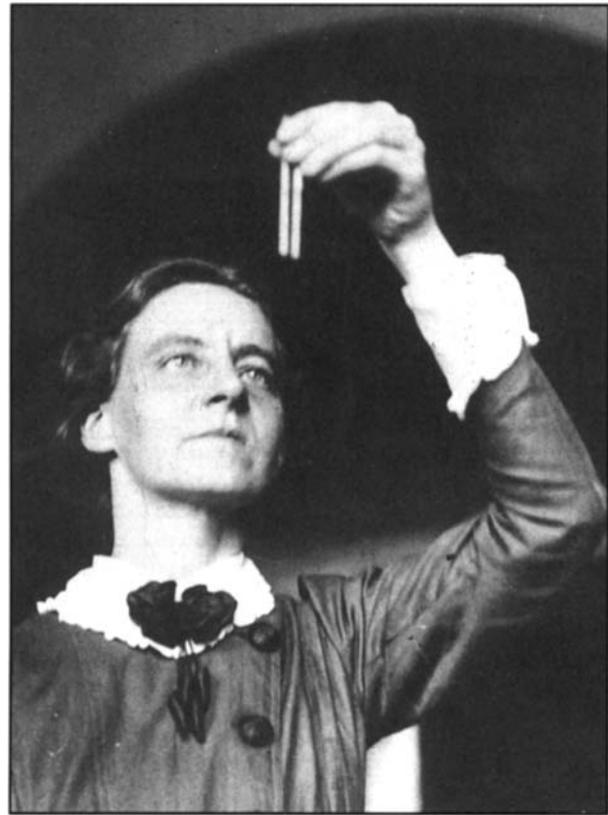


Figure 12. Mabel FitzGerald measures the amount of haemoglobin in a sample of blood in one of two tubes by diluting the sample until it matches the standard in the other tube. (Photograph from Herald Telegraph, Colorado Springs, 8 July 1911.)

Study in New York and publication

At the time of the Pikes Peak expedition and afterwards she seems not have been engaged full time in regular research. It was then that she matriculated at New York University and studied to qualify for entry to a medical school in New York State. Notes survive in economics and in geography and an essay of hers discusses the conditions for a police force to be honest, written in New York. But the subject she really got stuck on was algebra. She had knocked off American history in 24 hours and physics in 28 hours but algebra took her 173 hours. She did eventually pass it in 1915 and the Regents let her by overall. Haldane had written on 15 April 1912:

I heard that you had got ploughed in algebra and sincerely sympathise. I suffered much from examiners myself and was ploughed in physiology for the M.R.C.S. besides other similar experiences.

It may have been the distraction of her academic work at New York University and poor health that made it necessary for Haldane to write a series of letters asking her first for a tabulated set of her results around Pikes Peak and then pressing her for a draft of her paper. He even offered to write the paper for her. It had been decided that she should

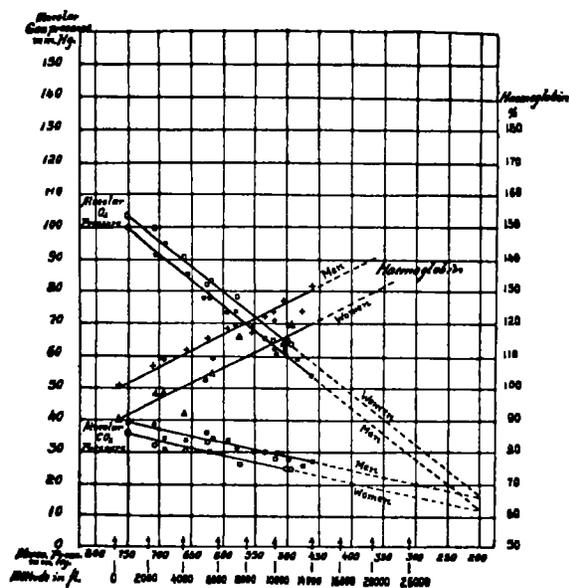


Figure 13. Graph of measurements made on man at altitude. Taken from Haldane's first version of his Silliman Lectures, entitled "Organism and environment", given to Yale in 1916 and published there in 1917.

have a quite distinct paper under her own name but that it should appear in the same issue of *Philosophical Transactions* as the one on the summit, but her progress was slow. All the men got their parts of the summit work written up and that paper came out first.

At this time, Henderson came to suspect that Mabel was being done out of getting full credit for her work by having her paper appear later, but a letter to him from Douglas, copied in Mabel's hand, firmly and at length rejects the suggestion and recounts Haldane's difficulties in getting any copy out of Mabel. Eventually Mabel returned to Oxford for two months up to October 1912 and so she and Haldane got the paper properly written. Among the many drafts of the paper in her own handwriting, there is an early draft in Haldane's writing of the summary, with places left for exact figures to be inserted. (It was from the summary that Charles Michel and I had taken our quotation for comment in the 1973 examination paper.) Haldane's son Jack contributed to the paper by calculating the graph relating barometric pressures to altitude.

At last Mabel's paper came out early in 1913 and very little later than the summit one and it was at least planned that offprints of the two papers would be sent out from Oxford together to give the impression of a single body of work.

North Carolina: lower altitudes

Haldane was interested in altitudes lower than those around Pikes Peak and he got Mabel to make observations at 2000–4000 feet in the Appalachians in 1913, working from a base at Highlands Sanatorium in North Carolina. Again she measured

P_{ACO_2} in long-term residents at altitude. She had done this in Colorado using apparatus that Douglas and Haldane had brought out with them. This time US customs made them take it back straight away, so in the Appalachians she used her own small Haldane apparatus. The data points from both studies are plotted together in the second paper and they fit quite well to their straight lines (Figure 13), though Haldane does remark:

They make beautiful graphic representations except for the ladies of Ouray who for some reason have too much haemoglobin and ought never to have been born . . . The women of Highlands are, like the ladies of Ouray, a disgrace to physiology as regards their haemoglobin. It was lucky that the men's haemoglobin played up.

While at Highlands Sanatorium, Mabel returned to making pathophysiological observations, this time of P_{ACO_2} in patients with pneumothorax, and her findings provoked Haldane into comments on vasoconstriction in the pulmonary blood vessels of collapsed lungs.

Women in physiology

In 1913 Haldane wrote that it seemed silly to him that women were not full members of the Physiological Society for they often were present at the meetings, so he had proposed that the Society should elect women. That incident led to their becoming members in 1915. Mabel had given up working in physiology by that time and so she was not regarded as eligible for election.

Some friends

The letters from Haldane, taken alone, do somewhat suggest that Mabel then was a rather lonely, dull woman, given to poor health, niggling argument and cranky complaint, but the personal letters show that that most certainly was not true. She was the most effective and vivacious of the five sisters and they depended on her capability for big decisions on managing the house in Crick Road and in their other affairs, and they did not have too much money to spend.

She did not marry but most of the brides at that time among the Purefoys and the Jervoises were heiresses, while Mabel was a fifth daughter with two brothers. Many of her men friends were a lot older than she was, just as Thos FitzGerald, her grandfather, had been 32 years older than his heiress wife, Sarah Purefoy Jervoise, whose father had died in the Peninsular War when she was only two.

Mabel had many friends and so, in those days before the telephone, she wrote many letters, and long, lively and sometimes quite affectionate correspondences from several very intelligent men have survived.

Osler managed to get her to collect books for his library, but she managed to get him to support, and to get elected, her candidate, Dreyer, to succeed Ritchie as Professor of Pathology in 1907 and Osler teased her about this in 1913 when he asked her which of the candidates, Starling, Hill, Haldane and Sherrington, was her candidate to succeed Gotch as Professor of Physiology. Osler wanted her to return from the USA to work in a clinical laboratory that he hoped to set up in the Radcliffe Infirmary. She also charmed Lady Osler with violets in her cabin when the Oslers set off from Liverpool at the end of 1906; Osler replied with flowers in Mabel's cabin on New Year's day 1908 when she was in mid-Atlantic on her way to New York.

In the USA she met many old friends again. For 20 years she wrote to one of these, Richard Winning, a member of the family she visited at Pojac and a Harvard man. He was a counsellor at law in Wall Street and a prime mover in the National Self Government Committee, an organization of which Eleanor Roosevelt approved. He sometimes replied in French and he told her once of his sorrows with his horse when he was aide-de-camp to the grand marshal of a presidential inauguration parade.

She also made new friends. For example, she writes to "Dearest Girls", her sisters (15 January 1913):

I lunched with Mrs. Franklin Roosevelt last Saturday, the Senator's wife... she asked me to stay at Hyde Park, their country place up the Hudson, so you see I am being taken up by the 400! and today Mrs. Forbes asked me to dine.

Perhaps the writing up of poor old Pikes Peak got pushed aside by more exciting things.

One of her later correspondents, Dr J J Graham Brown (1853–1925), wrote only when he or she was away from Edinburgh – "As you know, I miss you horribly. The Royal Society Club is still my address". At first it was "Dear Miss FitzGerald" and his full signature, as it always was with Haldane over 20 years, and with the other scientists except Dreyer, but later it became "Dear Mabel" and "Graham". When once he was away in Oxford, he wrote of his delight in walking past the house where she lived and also of feeling inadequate when he dined in Magdalen and the poet laureate was present in the common room and so also was Sherrington. Graham Brown was an Edinburgh physician who taught in the medical school and wrote books on clinical methods and nervous diseases. He was President of the Edinburgh Royal College of Physicians 1912–14. In 1885 he had gone to Spain with Sherrington to study cholera for the Royal Society, and at the time of his letter to Mabel from Oxford, he was staying there with Sherrington in Chadlington Road. His son, Thomas Graham Brown FRS (1882–1965), a neurophysiologist, also worked with Sherrington.

Mabel had the confidence of her background in dealing with people. Many junior women would have been too timid to get themselves to be sole author of their papers, but Mabel's professors were allowed no *droit de seigneur* to add their names to her papers. Mabel could manage men. She had the great good fortune that Haldane had recently devised so elegantly simple a procedure for measuring P_{ACO_2} that she could use it on her own in accumulating observations in respiratory physiology and pathophysiology. In contrast, Douglas usually appears as joint author with Haldane between 1909 and 1922 but their work required two pairs of hands and had a more complex argument for its interpretation. But both for Mabel and for Douglas, Haldane was the great initiator.

Return from the USA

Mabel had finally qualified to enter medical school in mid-1915 when she decided to return home, but she needed a job and her sisters were on the lookout for her. She heard from Ritchie that Edinburgh Royal Infirmary wanted a clinical pathologist to help in working up the bacteriological side of cases. The academic pathology department had Lorrain Smith, a pupil of Haldane, as its head and that was used to tempt her with the chance of research. She accepted and returned in June 1915. Clinical pathologist in bacteriology seems to have been her basic professional status for the rest of her working life. She lived at 54a George Square, then an elegant old square near to the medical school, but she still retained her base in Crick Road. When Haldane crossed the Atlantic to give his Silliman Lectures at Yale in 1916 he had her make up a new slide of her observations (Figure 13) and she asked him to bring back apparatus for use in her clinical pathology such as gonococcal antigen and Wassermann pipettes, but he had to apologize because one of the pipettes he did manage to get was damaged in the Liverpool docks. It was only on a short trip in 1922 that she ever went back to the USA.

In addition to her laboratory work in Edinburgh, she used to lecture in the medical school of the royal colleges, but to do this formally she had first to be examined, for still she had no degree. The ritual was gone through, the president of the Edinburgh Royal College of Physicians signed the noble document and she was allowed to hold courses in the colleges' medical school, but she did have to pay rent for her lecture theatre; the students paid her individually. Her position in the colleges' medical school was lecturer. She was also recognized as an extra-academical teacher of the University of Edinburgh and she was appointed an examiner. These advances in her status must have somewhat compensated her for

her lack of a degree: they allowed her to teach in the Edinburgh School of Medicine for Women.

Old books

There is no evidence of Mabel doing research after she came back from the USA. She had been interested by Osler in old medical books very shortly after he arrived in Oxford in 1905 and she was of course in a fine strategic position to collect them for him in Edinburgh, where there was then a long tradition of medical scholarship. She produced her own book lists and circulated them and so she must have held books herself. She continued selling to the Osler library when Osler himself had died (in 1919) but Lady Osler and her nephew Willie Francis were still expanding the library and were getting it ready, all eight tons of it, to move to McGill in Montreal in 1928. Willie Francis asked her to look out for particular books. For example, he wrote of a "scandaliferous" one, *Flagellation and the Flagellants*, by the Reverend Wm M Cooper BA, a pseudonym.

After Osler's death, Mabel circulated her lists and sold books to Harvey Cushing, Osler's biographer, and then later she read the proofs of the *Readings in the History of Physiology* of John F Fulton, Cushing's biographer. Selling books must have been a commercial operation but for Harvey Cushing, at least, Mabel did not put prices to the books on her list, leaving it to Cushing to decide what he thought right.

Return to Oxford

And then Mabel gave up Edinburgh, and returned to live in Oxford sometime in the late 1930s, when she was about 65. Haldane died in 1936, but Douglas was not yet 60 and he worked in the laboratory for another 15 years. She was known to friends around the country and around the world and to her neighbours in North Oxford, particularly to the Elliots from 1957. All the other sisters had died by 1956, all of them unmarried.

Mabel continued in 12 Crick Road. The lease expired in 1971 and so the house could then have been made to fall to St John's but the Bursar did not do so: Roger Elliott saw to that.

By that time physiology, in the person of Dan Cunningham, had already rediscovered Mabel and in 1961 she had come to the celebration of Haldane's centenary. And when she reached her own centenary in 1972, her world took off again.

Mabel FitzGerald today

Why should we bother about Mabel FitzGerald's work on high altitude today?

She worked on people who had acclimatized to high altitude. But having to acclimatize to height is no longer just a problem for a few heroic climbers

struggling to the top of a remote Himalayan peak, as it usually was in Mabel's day: now thousands of miners work in the Andes at up to 4000 m and more but they commute to work from their homes on the coast. Also, thousands of skiers fly into Colorado for a week or two at over 3000 m. It is the newly arrived who suffer: a healthy long-term resident can withstand the altitude. To help the people with altitude sickness, you should at least know what a healthy person is like who has acclimatized completely to a high altitude, for that is what you would like the new arrival to become instantly. And that must be acclimatization to a particular altitude: acclimatization to one altitude does not imply acclimatization to all other altitudes.

Mabel FitzGerald was the first person to measure any aspect of full acclimatization over a wide range of altitudes, from sea level to over 4000 m. You need to lower the blood bicarbonate so that a fall in P_{ACO_2} does not alter the alkalinity of the blood. Haldane⁸ remarked that bicarbonate could be reduced with NH_4Cl , and you can calculate that, in order to do this, a man would need to take about 1 g of NH_4Cl for each 1000 feet ascended⁹. But NH_4Cl still needs to be tried out properly, and the commuting miners of the Andes would make splendid subjects for a trial.

Normalcy

This example shows how Mabel's work can be valuable even today. Nevertheless, it does not describe completely the steady state of a man who is fully acclimatized to altitude. For example, we know that his body fluid volumes change soon after arrival at altitude, but have they returned to their sea level values when acclimatization is complete? And is the HOC_3^- he got rid of at altitude simply replaced by Cl^- ? So there are many things yet to be done to complete Mabel's work on what is normal at altitude.

In this context, the word normality seems to be used for man at sea level only. A man of Denver is then that epitome of sea level man, a New Yorker, who is in respiratory alkalosis compensated by metabolic acidosis. How much better it would be to accept that what is normal is the relation of a whole array of variables to altitude, of PCO_2 , Cl^- , plasma volume and so on. But the word normality has been pre-empted for a single altitude, sea level – we learn that 40 torr, the value of PCO_2 at sea level, is the normal value. So instead, Dempsey *et al.*¹⁰ have, for this wider meaning, used normality's synonym, normalcy, the word made famous by Warren Harding. Normalcy is used for the whole set of relations of bodily variables to altitude: and normalcy_{Denver} (or normalcy_{1550 m}) describes a man who is fully acclimatized to Denver. On returning to Denver after a period in New York, our man is immediately a man of Denver again, but to begin

with he is in respiratory acidosis and metabolic alkalosis by the standards of Denver, and is moving towards normalcy_{Denver}. And also there is normalcy_{Leadville}, normalcy_{La Paz}, normalcy_{Dead Sea} and normalcy_{everywhere else}, as well.

Oxygen secretion

Mabel was very eager for her work around Pikes Peak to be associated with the work of Haldane and the other men on the summit, but it could well be that this association with Haldane's work contributed to her being forgotten.

Haldane thought that O₂ may be pumped into the blood in the lungs¹¹ and that would obviously be a good thing at high altitude. To show that this happened, he used a complex and indirect method which involved measuring the amounts of O₂ and CO combined with haemoglobin. But about 10 years later, Barcroft used a quite direct method to show that O₂ is not pumped, for the alveolar PO₂ is about equal to blood PO₂, even at altitude. And since then, people have been wondering why Haldane came to his wrong conclusion. There are two groups of possibilities: either his measurements of gases combined with haemoglobin were wrong, or his arguments from his measurements were wrong, and this could have been because he thought that CO does nothing in the body except combine with haemoglobin. But it is now realized that CO is actually formed in the body. If, then, the gas measurements are accepted, they mean that CO, a dangerous natural product of the body, is actively excreted by the lungs, a very different teleology from the O₂ secretion one, but still a very satisfying one. Haldane never really gave up on O₂ secretion, and his tenacity over it must have contributed to the general view of him.

Mabel's normalcy

The oxygen secretion incident may have contributed to Mabel being forgotten, and so may her choice, soon after Pikes Peak, to settle into work on a subject quite apart from physiology. But physiology seems to be the subject that is noticing her again. Perhaps physiologists are realizing that they need to know a lot more about the state of full acclimatization to altitude and about the relation of more variables to altitude in that state. They need to know more about normalcy. About Mabel's normalcy.

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