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THE HIGH-ALTITUDE RESEARCH OF MABEL PUREFOY FITZGERALD, 1911–13

by

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Home schooled without a science education, Mabel Purefoy FitzGerald (1872–1973) attended physiology lectures at Oxford in 1897, even though the school was closed to women. She found work as a researcher, published early noted papers and earned the active respect and support of senior scientists of her day. Her laboratory work with the physiologist J. S. Haldane saw her invited to the join the Pikes Peak Expedition in 1911. While the male team members measured the physiological effects of long-term residency at 14 101 feet, as the sole woman FitzGerald took measurements of haemoglobin and alveolar air from herself and from mining staff and families at altitudes from 6000 to 12 500 feet, travelling to remote mining communities in the Colorado Rockies. A subsequent expedition collected data at lower altitudes. Recorded in two papers, the results presented pioneering evidence of the role of oxygen in breathing.

Keywords: Mabel Purefoy FitzGerald; high altitude; collaboration

Born in 1872, Mabel Purefoy FitzGerald spent her first 22 years in the Hampshire village of Preston Candover. It was a life of modest wealth, based on two 50-acre plots of land. One element was thus in place from which the occasional exceptional woman of science in the Victorian era might emerge: as Ruth Watts noted in her survey of women scientists, 'high achievers were from the upper or middle ranks of society.'[1] A tougher element that binds several such women was that of watching a brother take up the study of science at a university from which they themselves were barred as a result of their gender. Marie Curie (*née* Sklodowska) and her sister Bronia had watched their brother leave home to study medicine at the University of Warsaw and were unable to follow, 'despite first ranking in their respective classes; ... higher educational opportunities for Polish women were to be found only in foreign universities.'[2] In Mabel FitzGerald's case, she was the youngest of five daughters and two sons. The two FitzGerald brothers both received public schooling, after which the elder brother joined the navy, later to become an Admiral, while the younger went on to read science at Oxford before teaching the subject. FitzGerald and her sisters were instead 'privately educated by a good governess with various Masters and Mistresses in addition for special subjects: English (Literature, composition and grammar) French and German languages.' When in her teens she posed for a photograph in a full-length white

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Figure 1. Ms FitzGerald with violin. (Photograph in the possession of Sir Roger Elliott FRS.)

dress, its collar bound tight beneath her throat, a violin tucked somewhat unconvincingly under her arm (figure 1). FitzGerald went on to give a complete summary of her education, in what became a bid for entry into a United States medical college:

> Advanced arithmetic. Ancient history. Modern History. History of great Britain and Northern Ireland. Geography. Physical Geography. Old and New Testament. Drawing (Freehand). Models and casts in pencil and charcoal, water colour, (outdoor work and still life.) Music (Pianoforte, violin and ensemble playing. Harmony.) Domestic Art (General course.)[3]

Physiological studies at Oxford

In 1895 both FitzGerald parents died; separately, suddenly and unexpectedly. The death of her father meant the removal of the dominant male figure in FitzGerald's life, a factor that

liberated several other women scientists from what might otherwise have been life in the domestic round. Nancy Slack notes how widowhood provided the release for some such scientists: the botanists Agnes Chase, widowed at the age of 19 years after a year of marriage; Kate Curran Brandegee, widowed before she was 30 years old; and Ynes Mexia, widowed twice but with no children who first headed to university in her fifties.[4] In FitzGerald's case the elder brother inherited the FitzGerald family home but seems to have been prepared to grant his sisters an independence and freedom that their father would not have allowed. After time spent with their grandmother, the young women set up their own household at 12 Crick Road, Oxford.

None of the sisters went on to marry, and since only Mabel would create a career in science it would be idle to maintain that her career choice kept her single. However, that unmarried state was certainly another factor that allowed her career to emerge. Nancy Slack did find those widowed exceptions, but of the botanists' lives that she studied she maintains: 'It was nearly logistically impossible for a married woman with children to carry out original research,' especially because such botanists had need of such fieldwork as FitzGerald would make her own. Looking at 1921, Slack notes how 'nearly half of the married women scientists with sufficient training and accomplishments to be listed in *American Men of Science* were unemployed. Only 19.5 per cent of those listed under botany were married.'[5]

Any form of career was still a far distant prospect. At the beginning, autodidactism had to replace formal education. Marie Curie had been forced along a similar route: while working as a governess to support her sister Bronia's studies at the Sorbonne, she added lists of the textbooks she was studying to her letters. For her part, FitzGerald's diary noted her engagement with the physiological writings of Thomas H. Huxley. She also attended lectures on health and was guided into study in the medical field by conversations with the local physician and health officer, Dr D'Eath.

Among those factors that Ruth Watts recognizes as significant factors in allowing the advancement of women in science, she notes 'the importance of location'.[6] Surely FitzGerald would have made little progress had her parents' death not freed her from the Hampshire village of her birth. She took immediate action to make the most of her transfer to Oxford. 'In 1897 the School of Physiology was not open to women,' FitzGerald later recalled,

> but in response to a request of the Wayneflete Professor, then Francis Gotch, he gave me and another woman student permission to attend his lectures and take all the courses connected with them in his laboratory during that academic year. . . . At the end of that year, 1897, I assisted Dr Gustav Mann, who was in charge of the Histological methods, in the special research he was doing at the time on the changes accompanying vaccination. Later, at his suggestion, I undertook the difficult task of investigating the inter-relationship of the grey and white matter of the spinal cord of the monkey. This took five years, and was certainly a test of endurance![7]

That final exclamation mark is one of many that punctuate FitzGerald's informal writings. They suggest a woman with the capacity for wry amusement when looking at the predicaments of life. Stubborn persistence can be added to the tally of what helped a woman born in the Victorian era to beat the odds and succeed in science. Gustav Mann was able to highlight further elements that marked FitzGerald out as exceptional:

> She has devoted these seven years to constant and unremitting study. She has worked for the pure love of science and in the most disinterested spirit. Much as this means, there is

> yet another aspect to which I would like to draw attention, namely that in all her work she has aimed at determining the primary cause of the phenomena which she observed and that she does not content herself with mere observation.[8]

That 'pure love of science' perhaps helped her stay single. It is hard to find a mate who would tolerate such devotion, and for a woman marriage would most probably tie her to domesticity. Before meeting his wife Marie, Pierre Curie had 'written that "women of genius are rare", and speculated that marriage to an ordinary woman would place limits on his anti-natural path of almost complete devotion to science.'[9] Marie Curie was one such woman of genius who also needed this 'anti-natural' devotion to science and the extended family. That mission to determine 'the primary cause of phenomena' certainly fitted FitzGerald to work well alongside the man who would be her mentor as she shifted her research to focus on the science of respiration.

Even within an institution that might otherwise block her advancement, a woman was sometimes able to find a mentor with a relatively ungendered view of science. Nancy Slack notes how the widowed botanist Agnes Chase found 'an unusual mentor, the Reverend E. J. Hill', and 'through her botanical mentor Dr Hans Behr [Kate Curran Brandegee] joined the California Academy of Sciences.'[10] In 1904 the great physiologist J. S. Haldane became such a figure for FitzGerald. He taught her how to use his Haldane apparatus to test carbon dioxide pressure inside the human lung. Although Haldane then worked within the university, he was enough of a maverick that he would ultimately separate himself from his institution to run an independent laboratory from his home. His scientific investigations were in pursuit of his philosophy that nothing could be seen as separate from its environment, an approach that suited FitzGerald's focus on 'the primary cause of phenomena'. Much of his research was in the field and at physical extremes such as mountain tops, the bottom of tin mines and on the sea bed. He was inclined toward self-experimentation, believing himself to be a much more eloquent respondent than any animal. With her new skills in place, FitzGerald proceeded to take daily measurements of her own respiratory functions for more than two years, and worked with Haldane to develop normal values for alveolar CO_2 in men, women and children, using her sisters and Haldane's children as some of their subjects. FitzGerald and he published a joint paper on this research in *Journal of Physiology* in 1905.[11]

In a letter to Haldane, his colleague Mr S. Pembrey remarked: 'To be forced to teach ladies, who moreover are not members of the University, would deprive me of the chief interest I take in the efficiency of teaching.'[12] It shows the entrenched viewpoint that Haldane set himself against. As a student Haldane had remarked that women were probably better suited than men for obstetrics.[13] This view that a suitably qualified woman might work well with women patients afforded FitzGerald her next opening. The expertise she gathered with Haldane allowed her to take up work at the Radcliffe Hospital in Oxford, with a particular focus on women patients. Sir William Osler, Regius Professor at Oxford, then headed the hospital and so came to know her. His medical textbook had set the teaching model for the Rockefeller Institute of Medical Research in New York, and his recommendation helped FitzGerald win a Rockefeller Scholarship to study medicine there. She sailed there at the end of 1907 to arrive in January 1908. 'In 1908–1909 I held a Rockefeller Fellowship,' she would explain, 'and spent seven months of the time at the Institute in New York doing Bacteriological work, and the remainder of the time, and three extra months following at the University of Toronto, working in the Biochemical department under Dr A. B. Macallum.'[14]

Figure 2. Group on Pikes Peak summit. From left to right: J. S. Haldane, Mabel Purefoy FitzGerald, E. C. Schneider, Y. Henderson and C. G. Douglas. (Reproduced courtesy of the University of Oxford.)

Figures for 1900 show the good rationale behind FitzGerald's shifting her ambition for a medical degree to the USA. In that year there were 258 women physicians practising in England and 95 in France, whereas in the USA there were already 7000 women practising medicine, and a further 1200 women enrolled in medical school.[15] Abram Kerr of Cornell University Medical College responded to one of FitzGerald's requests to commence a medical degree with the following:

> At your age it seems to me doubtful if it would not be better for you to devote yourself to research along physiological lines where you have proved yourself so competent and in which a knowledge of medicine would not be necessary rather than to take out five years of time to get the medical degree in order to devote yourself to research along lines connected with clinical medicine. There are plenty of doctors of medicine. There are not many research workers.[16]

Pikes peak expedition, 1911

FitzGerald's research skills were, indeed, first-rate. When Haldane was assembling his team to investigate the physiological effects of high-altitude living by residing at the top of Pikes Peak in Colorado for the summer of 1911, Mabel Purefoy FitzGerald was invited along (figure 2).

This expedition shows the extremes to which FitzGerald had broken the mould that expected science by women to be conducted on the domestic front. Rob Iliffe and Frances Willmoth note how, in seventeenth-century England, 'For all classes of women, there was a strong presumption that wives should remain in a domestic setting even though they might be encouraged to learn mathematics or natural philosophy.' Those exceptions, 'learned females who ventured outside their traditional domestic roles were variously classified as wonderful, monstrous, freakish or unnatural.'[17] The same standards could still manifest themselves in the early twentieth century. Ellen Swallow Richards is credited with establishing home economics as a discipline in the USA in the later

Table 1. Ms FitzGerald's calendar of Colorado mine visits.

place	altitude (feet)	date (1911)
Colorado Springs	6000	8–18 July
Victor	9800	21 July
Portland Mill	10300	21–24 July
Portland Mine	10090	21–24 July
Altman	10720	27 July
Denver	5100	2–3 August
Ouray	7780	8–11 August
Camp Bird Mill	9500	12–13 August
Camp Bird Mine	11500	14–17 August
Ridgway	6990	20 August
Telluride	8870	21–24 August
Tomboy Mine	11500	22 August
Lewis Mine	12500	23 August

nineteenth century, asserting the values of chemistry to the homemaker. Although some women physiologists were attracted to 'hygiene', home economics became

> the only field where a woman scientist could hope to be a full professor, department chair, or even a dean in the 1920s and 1930s. ... Other sciences were considered suitable for ladies because they could be done at home. Botany and astronomy were two areas that could both utilize the expertise of amateurs and allow them to remain at home to conduct their investigations.[18]

FitzGerald could not have freed herself and her research more completely from such domestic tethers. Sooner than join the men in residence at the summit, in the 'Summit House' that was turned into something of a combination of a laboratory and a gentlemen's club, her lot was to travel solo to a variety of wild and rough mining locations around Colorado. Here she took samples of breath and blood from those resident at 6000–12500 feet, as well as from herself. The research involved in discovering the mines, in planning the routes (a journey of 440 miles), transport and support networks that would get her and her equipment *in situ*, and in arranging through correspondence that her investigations would be welcomed and patients supplied, is worth reflection when considering the schedule of events drawn together from her notes (table 1).

FitzGerald had her own cased model of Haldane's air analysis apparatus for the work, complemented by an aneroid barometer and a Gowers–Haldane haemoglobinometer for the blood sampling. The team's research base at the Biological Laboratory at Colorado College came from her suggestion, after her independent visit to the facility in one of her earlier journeys around the USA. Haldane used some of a Royal Society grant of £140 to pay for FitzGerald's rail fares. Her commitment was only in fact made possible by the rental of her Oxford house two weeks before departure. The other sisters moved out to stay with relatives and friends for the summer while the house was rented at 5 guineas per week, with the renter also paying the wages of the cook, the house parlour maid, the morning girl and the gardener.[19]

FitzGerald's work began in New York, measuring her own alveolar CO_2 pressure and haemoglobin close to sea level before the 54-hour train journey to Colorado Springs at 6000 feet. Rising to 14101 feet, Pikes Peak provides the backdrop to the city. Three trips of the train up the cog railway brought the male team members and their equipment up to

the summit, where they would settle for the five weeks of their joint expedition. All points lower than this were the province of FitzGerald.

'I have been having a lot of work this week getting to the laboratory at 8.30 and leaving at about 8pm!' she wrote to her sister Laurie on 18 July, 10 days after arriving in Colorado Springs. 'With secondary racing down town for some food thrown in. The people have been giving good results, the CO_2 being steadily lower than at sea level. The men have been awfully nice to me and seem to like having me. We took a walk every evening before dinner.'[20] FitzGerald took the cog railway up to the summit for a Sunday visit three days after the men's journey to the top. The men had fallen sick on arrival, but had largely acclimatized and were back to 'their cheerful selves . . . though JSHaldane looked a little blue.'[21]

FitzGerald had changed colour herself. 'Was quite blue on arrival,' she reports to her sister:

> & got a slight headache up there but my CO_2 did not react. I did some experiments and went for a walk with JS Haldane down the steep part of the track & up to see the effect on me. I could do it comparatively easily with heart going at 130 while his heart was only going at 96. And he was blowing & puffing! They use the steep track for part of their experiments.[22]

It is worth accruing some of her more light-hearted observations from the Peak, where a full laboratory was set up for the men in the stone-built Summit House, their sleeping and dining accommodation established in adjoining rooms. The sustained residence at high altitude and a strict schedule of experimentation brought its own rigours, but these can be set against the austerities of FitzGerald's parallel expedition:

> They are having all the delicacies of the season to eat. Canteloupes in the morning etc. They have many amusing experiences with the trippers. They have a barbed wire door which they call the portcullis which they put across as soon as the train comes. . . . Some lady came in, asked a question, & finally asked if she might leave her hat in the laboratory a huge one with trailing ostrich feathers. She thanked them for the 'accommodation' when she fetched it. We could just contain our laughter till she had gone. The waiter calls them 'the boys' and asks 'What will you boys have?' JSHaldane seems very interested in everything and very amused at all the incidents. He also seems to like the ice cream soda fountains!'[23]

This letter to her sister maintains a jocular vein, while the report in FitzGerald's eventual paper turns more clinical. The CO_2 readings were taken two hours after her arrival and her summit walk with Haldane, by which time her 'cyanosis had slightly increased and was accompanied by some unsteadiness of gait and slight aphasia.' Apart from a slight headache, the five-hour stay 'was unattended by discomfort.' However,

> during the descent the headache increased continuously in severity, and was accompanied by a feeling of fullness in the head and nausea. By the time Colorado Springs was reached it became an effort to carry a light knapsack and overcoat, and owing to the increasing nausea it was necessary to lie down for short time before going to the laboratory at Colorado College to make determinations about alveolar air.[24]

Solo expedition to the high mountains of Colorado

And now she was on her own. FitzGerald's target was a sequence of towns and mining camps, chosen to be at progressive altitudes at 1000-foot intervals. At Colorado Springs

she had been collecting data from university students and professionals. Now she would be working with mining staff, managers and miners both, and their female relations, ones who had been living at their altitude for at least a year and in apparent good health.

The 'Cripple Creek District, an open mountain country, formerly a cattle range,' was around 60 miles by train from Colorado Springs, on the far side of Pike's Peak. The town of Victor, at 9850 feet, was FitzGerald's base, from where she travelled out to other mines. The highest of those was the Altman mine at 10 870 feet, 'reached by the Cripple Creek electric line to Midway and then up a mountain trail on foot. Great interest shown,' she reported, 'and the whole camp desired to be experimented upon.' She had just four hours here, based in the Town Hall, which was a wooden building with one room, and took measurements from nine subjects who had been in continuous residence for 2–19 years (and at high altitudes for 12–30 years). 'Nervous', she remarks, a common adjective for almost all she worked with on her travels,

> and very difficult subjects, living much to themselves in a queer tumble down mining camp, which nevertheless boasted of being 'the highest incorporated town' in the United states. Two women taken, both were very difficult and too unreliable to place faith in the results. One subject had gone to Altman 15 years before with weak lungs. He looked strong and had the appearance of good health now, and he felt better at Altman than anywhere. The 'benefits' derived from living at Altman were generally expressed![25]

In nearby Portland Mills, FitzGerald noted how 'the older men looked older than their years.' They mentioned breathlessness, and the superintendent remarked on FitzGerald's pace when they went walking together. She would not be able to keep it up if she were there for a few months, he advised.

The cluster of mines around the town of Ouray formed the third of what FitzGerald saw as four parts to her expedition. Her official report takes effort to give the setting:

> The Ouray district, situated in the south-western part of the State, in the midst of very wild and mountainous country, was reached by the Denver and Rio Grande Railway, through the Grand Canyon of the Arkansas River, over the Marshall Pass, crossing the Continental Divide of the Rocky Mountains at a height of 10 856 feet, thence through the Black Canyon of the Gunnison and into the valley of the Uncompahgre River.[26]

She reached Camp Bird goldmine by taking a stagecoach and two horses along a wagon road up to 9500 feet, continuing on horseback for the final 2000 feet. The analyser and her other equipment travelled up in the aerial tramway that would normally ferry the ore, a method of transport she considered to be most hazardous. Her work base for the three days at Camp Bird was the 'hospital' room in the miners' boarding house. 'Subjects most nervous,' she noted once more, 'but appeared generally speaking to be strong. Some of the boys/waiters and kitchen helpers and the cook looked the least healthy.'[27]

In Camp Bird Mill, 'the barometric pressure was reduced to 533 mm, the average of the alveolar CO_2 pressure was 29.9 and the haemoglobin 122.6.' Although the arterial blood must have contained at least 16% excess of oxygen, the lowering of the CO_2 pressure and the increase in the percentage of haemoglobin showed 'that it is the partial pressure and not the actual amount of oxygen in the blood that is the essential factor.'[28]

In this same cluster of mines, and at the same altitude as Camp Bird, was Portland Mill, reached again by stagecoach and two horses. FitzGerald was in real concern for the safety of

the glass equipment that travelled with her this time. The noise of the mill, its water, and very probably the drilling, had rendered all of her subjects deaf. 'The Mill situated at the head of a gulch,' she observed in her notes,

> shut in by mountains, the air cold and raw, but wet season when I was there. The mill a small colony with schoolroom but I was unable to get the women enthused with the desire to experiment until it was too late. The psychology very interesting—the craving for excitements very pronounced in the women—card parties, dinner parties and social gatherings of all kinds and dress! Dominant ideas. The Camp Bird Company keep entire control of 'village' and no saloons allowed.[29]

The Ouray Plaindealer made her visit their headline news: 'Making Important Experiments Here: Miss FitzGerald, Member of Famous Scientific Expedition, Comes to Ouray on a Mission of Vital importance.' The news item concluded: 'The most important direct discovery is that the number of blood corpuscles in the body increases in a higher altitude, a discovery which explodes the medical theory that the known increase of the red blood corpuscles in a given amount of blood was due to the decrease in its volume.'[30]

Tom Boy mine was in the final cluster of workplaces, three miles up from Telluride. FitzGerald reached it, she noted,

> by a good wagon road cut out of the side of the mountain. Went up in a two horse bug with driver periodically falling asleep!! Remonstrance in view of the ravines it called forth the reply 'That he was really sheltering his eyes to think of his mother!'! One of the most difficult days of the trip. Delay caused on arrival by heavy storm, and then much time lost by the women being so nervous and unwilling to make a start. One instance of refusal to have H6 taken because of fear. Most difficult subjects to handle. Time did not permit of taking any men.[31]

Lewis Mine at 12 500 feet was kept until last. The 2000-foot ascent from Telluride was a three-hour horse-ride up a steep track, with the apparatus now strapped to the saddle. FitzGerald worked in the miners' boarding house for five hours, with six subjects aged 25 to 48. 'One subject (44)', she noted, 'looked ill and felt prolonged stay in high altitudes had begun to affect him and intended to go to a low level as soon as possible. He remarked that prolonged stay was ultimately detrimental to health. He had lived 18 or more years at a high altitude 11 000 feet or higher.' FitzGerald had by now worked on '131 residents in twelve localities of different altitudes'. She had taken 513 alveolar CO_2 determinations and 128 haemoglobin percentage determinations.[32]

Writing up: the route to publication

'I'm very sorry we have missed here, & have so short a time in New York', Haldane wrote to FitzGerald from New York. 'If you can get the data tabulated by that time we can have a talk about the results & how to publish them. I am very glad you have enjoyed the trip. Your work has been much more adventurous than ours!'[33]

FitzGerald's data showed that CO_2 pressure is lowered 'by about 4.2mm. or 10.5 per cent of the sea level value for each 100mm. diminution of barometric pressure',[34] with a consequent increase in lung ventilation. The same decrease in barometric pressure boosts the percentage of haemoglobin in the blood by 10%, while altitude significantly increases the amounts of oxygen in arterial blood. She took care to note lower amounts of change

for women in these instances. Those results for women were augmented by her resilient documentation of her own CO_2 pressure and haemoglobin, her persona objectified in her published paper as M.P.F-G.

Haldane began writing his team's report on the Atlantic crossing back to England, and wrote to FitzGerald in the following April:

> Now I am coming to the point; which is that 'copy' from you is wanted as soon as possible.... You have already sent me all the data. They make beautiful graphic representations & the various averages fall in well, except for the ladies of Ouray, who for some reason have too much haemoglobin, & ought never to have been born! If you are too busy at present, I will gladly send a draft to you, as I think I have absorbed the results pretty thoroughly.[35]

Haldane's offer was rejected; FitzGerald was 'anxious to finish the thing herself', Pikes Peak team member C. Gordon Douglas wrote to fellow member Yale Henderson:

> When she came here in August the paper was in no way ready neither was it complete when she left three months later for America. We had been working pretty strenuously since we left America to prepare our part for the press as you know that meant doing a lot of additional controls, and as a matter of fact it took us till the end of June to get the stuff into its final form.[36]

Haldane had no sense that FitzGerald was not also working strenuously. She was simply busy on too many fronts, including her persistent ambition to conclude her studies and graduate from the Washington Square Division of New York University. 'She is working too hard,' Haldane told his resolutely unscientific wife in October 1912. 'I wish she had as much contempt for science as you have.'[37]

Haldane's correspondence with FitzGerald on the issue of her article's tardiness kept to measured tones. 'I have done a certain amount of clipping', he wrote to her from January 1913, 'and a little adding, as you asked me to do: also made corrections re which you wrote about, and anything else I noticed.'[38] His additions to her published paper included its final paragraph of acknowledgments. His letters were clearly measured for diplomacy, however. Douglas's letter to Henderson tells how Haldane was in fact 'in despair about Miss FitzGerald'. The 'clipping' was around Haldane's sense that 'in one or two places the author got very involved.'

That letter of Douglas's was in response to one from Henderson, whom FitzGerald had clearly consulted in America, which apparently expressed their joint concern over possible perceived slights to FitzGerald's reputation. Why was her work not included as part of the Pikes Peak Expedition's paper? Why were their two papers to be separated upon publication, with other papers coming between? Would reprints be sent out together? 'Of course Miss FitzGerald's paper is going into the Philosophical Transactions', Douglas responded to a further challenge; 'where else did she or you suppose it was going?'

The Douglas letter provides insights into the ethics of publication, detailing the measures that Haldane adopted in an effort to ensure that FitzGerald's paper received the best possible placement in the Royal Society's journal, and ultimately to be in the journal at all. 'I had originally thought that her paper was going in with ours,' Douglas's letter recalled, 'but it was Haldane who suggested to me when on the Peak that this was not fair to her, as she was doing a great work in which we had no real part: we had no right to take any of the credit due to her.'

Haldane received FitzGerald's paper in December 1913. By then he was aware who had refereed the Pikes Peak paper, and so approached the referee to urge speed should FitzGerald's paper also come his way. The referee completed his work in a week and the paper was rushed into print. 'I think the paper reads very well,' Haldane wrote to FitzGerald, '& there can be no doubt as to its scientific value. It is sure to be often quoted.'[39]

'I saw Miss FitzGerald's paper just before it was sent to the Royal Society and I thought it amazingly good', Douglas wrote to Henderson. 'I was all the more glad that her name alone stood at the top of the paper, and she deserves all the credit for overcoming the great difficulties which she encountered and which we were so singularly free from.'

From 4 March 1913 Haldane wrote to FitzGerald that the paper was taken as read the previous Thursday, although he himself was absent. He told her instead of the happenings at the previous meeting:

> By the way there was a very lively debate at the January meeting over the question of admission of women to membership of the Society! I had moved a resolution in favour of this, & in the end it was only carried by a small majority. It all seems very absurd, considering that women are nearly always present at the meetings & often read papers.[40]

The Highlands expedition of 1913

'I am delighted with your paper for the Royal Society', Sir William Osler wrote to FitzGerald on 1 March 1913. 'It is a very nice piece of work, and if I were Chancellor of the New York University I would give you your degree on that alone.'[41]

Osler's next letter to her was sent to FitzGerald at Highlands Camp Sanatorium in North Carolina. In working out what helped bring successful early women scientists to the fore, Ruth Watts noted that 'women also established their own networks'.[42] In her 1913 paper FitzGerald credits recent research by Dr Adele Bornstein (curiously cited as 'Mme. Bornstein'), looking at the effects on haemoglobin when animals are subjected to increased atmospheric pressure, findings drawn from the work that Bornstein had done in developing the tunnel under the Elbe in Hamburg. That suggests an alertness to women's scholarship, while this trip out to work alongside Mary Lapham shows an active pursuit of female peers.

Lapham had wanted to become a doctor. Her father dissuaded her, and she became a cashier in his bank instead. As with FitzGerald, it was the death of Lapham's father that freed her into her scientific vocation.[43] Lapham graduated from the Women's Medical College of Philadelphia in 1900 and travelled to Germany, Austria and Switzerland for advanced study. In Davos she learned the technique of artificial pneumothorax and brought that back to the Blue Ridge Mountains, where she turned her home into the Highlands Camp Sanatorium in 1908. It was a facility for the treatment of tuberculosis. FitzGerald helped with the routine work, and studied changes in blood and alveolar CO_2 pressure using facilities provided by Lapham.[44]

The September of that year saw FitzGerald roaming out from the Highland Sanatorium to three locations in the Southern Appalachian chain. She experimented on 43 residents who lived at the range of altitudes that she had been forced to omit on her earlier adventures: 2210–3850 feet. She noted how the degree of 'nervousness' in her subjects was much less than in those who lived above 5000 feet. Observing herself, she noted 'signs of being at a physiological disadvantage, due to the low alveolar oxygen pressure, [which] were manifested by the constant feeling of great fatigue and, except during the stay at 4250

feet, when work was in part lessened, by poor and unrefreshing sleep.'[45] Essentially, the conclusions of this separate expedition held to the patterns observed at higher altitudes, and so the findings were confirmed—except for one comical challenge. 'The women of Highlands are, like those of Ouray, a disgrace to physiology as regards their haemoglobin,' Haldane wrote to her. 'It was lucky that the men's haemoglobin played up.'[46]

FitzGerald's trip seems to have been self-financed. Haldane later sent her the residue of the Royal Society Grant as a cheque for £7, which she returned. 'You really ought not to have returned that cheque', he lamented. 'I fear I didn't write when you sent it back, but I felt it was less than your proper share of the Royal Society grant.'[47] Haldane once again supported her editorially in preparing this new paper for publication. 'I'm sorry you were doubtful about using the first personal pronoun, but I think it was really needed to make things clear', he wrote to her. 'It wasn't clear who had done some of the experiments you referred to.'[48]

Robert Torrance, who championed Mabel Purefoy FitzGerald in the late twentieth century, summed up her achievements as part of the Pikes Peak expedition in this way:

> When one goes to stay at high altitude, the body increases breathing to defend its oxygen supply, and over several days carbon dioxide is set to a new and lower level, where it remains. Haldane and his colleagues on Pikes Peak showed for one altitude, 14 101 feet, that the time required for the full resetting to occur was about one or two weeks. But it was FitzGerald who showed the sensitive, lasting, and overwhelming role for oxygen in breathing. She revolutionized our ideas of how breathing is controlled lifelong.[49]

Subsequent career and belated recognition

Dr Yandell Henderson recommended FitzGerald for membership of the American Physiological Society and she was elected as its second woman member in 1913. She worked as an assistant to Henderson on respiratory experiments, and left New York for Edinburgh in 1915 to take up war work in the pathology laboratory in Edinburgh. That essentially meant abandoning her plans to take a medical degree. She retired back to Oxford, taking care of a sick sister, where she was rediscovered in her late seventies in 1961 during preparations for a Haldane centenary celebration.

FitzGerald's new Oxford neighbour, Sir Roger Elliott, then the Wykeham Professor of Physics, lived in the house once occupied by Haldane. A sepia-wash portrait of Haldane still hung on FitzGerald's walls and she reminisced with Sir Roger about the mule journeys she had taken in Colorado some 60 years before. She read the papers every day to keep abreast of world affairs, and such was her interest in the moon landings that a friend borrowed a television so FitzGerald could watch live relays of the lunar drama. As she approached her own centenary, Sir Roger brought in the support of the Regius Professor of Medicine, Sir Richard Doll, as co-sponsor of a degree award for FitzGerald; the degree from which her gender had earlier precluded her.

Would she prefer a quiet ceremony at home, perhaps? 'I prefer to go to a full ceremony', she responded at once.[50] The ceremony in her singular honour was arranged for Convocation House on 14 December 1972. The venue was big enough for her to invite family and friends, and 180 invitations were duly sent out to include professors, doctors, the Lord Mayor, the Chief of Police and her bank manager. Around 200 turned up to fill the hall. She waved to both sides as she passed between them, dressed in her cap and gown and paraded in her wheelchair. As the Vice Chancellor, Sir Alan Bullock, presented her with the degree

Figure 3. Presentation of Ms FitzGerald with her MA degree. (Photograph in the possession of the author.)

of Master of Arts, he admitted that the award came some 75 years late (figure 3). FitzGerald had the car give her a tour of Oxford before taking her home, so she could apprise herself of any changes to the city.

Robert E. Davis, the Benjamin Franklin Professor of Molecular Biology at the University of Pennsylvania, read about the award of FitzGerald's MA in *The New York Times*. 'I have known of your work on gastric secretion and have referred to your paper "FitzGerald, M. P. (1910). Proc. Roy. Soc. B, 83, 56" on many occasions', he wrote to her. 'Women like you are a great inspiration to others and although justice has been so long delayed in your case, your efforts have helped to make some improvement in what has been and continues to be an appalling situation of discrimination against women.'[51]

FitzGerald had apparently overcome any resentment she might have felt at the way in which her gender had excluded her from a full academic career. She had encountered injustice and met with it as best she could. The day after the convocation she was asked what she felt her most important work had been. Quite deaf now and finding speech difficult, she brought up a letter from the pile of congratulations stacked beside her chair. This was her answer. The letter came from Sir Richard Doll and informed her that two out of three scholarships awarded recently had gone to women. It was her example, he wrote, that first convinced Oxford 'that women can do as well as men.'[52]

Notes

1 R. Watts, *Women in science* (Routledge, Abingdon, 2007), p. 194.
2 H. M. Pycior, 'Marie Curie's "Anti-Natural Path"', in *Uneasy careers and intimate lives: women in science 1789–1979* (ed. P. G. Abir-Am and D. Outram), pp. 191–215 (Rutgers University Press, New Brunswick, NJ, 1997), p. 194.
3 Mabel Purefoy FitzGerald Papers, Bodleian (hereafter MPF-G), box 4.
4 N. G. Slack, 'American women botanists', in *Uneasy careers*, *op. cit.* (note 2), pp. 77–103, at p. 84.
5 Slack, *op. cit.* (note 4), p. 101.
6 Watts, *op. cit.* (note 1), p. 195.
7 MPF-G, typed notes, box 28.

8 MPF-G, box 4, reference from Gustav Mann of 15 June 1904, one of several recommending FitzGerald for the Philip Walker Studentship in Pathology.
9 Pycior, *op. cit.* (note 2), p. 198.
10 Slack, *op. cit.* (note 4), p. 85.
11 Haldane was known to the younger scientists who came through his laboratory as 'The Senior Partner', and his collegial view extended to placing the name of his juniors alongside his own in published papers.
12 M. Goodman, *Suffer & survive: the extreme life of Dr J. S. Haldane* (Simon & Schuster, London, 2008), p. 226.
13 *Ibid.*
14 MPF-G, box 28.
15 Watts, *op. cit.* (note 1), p. 72.
16 MPF-G, box 28, MPF-G archives.
17 R. Iliffe and F. Willmoth, 'Astronomy and the domestic sphere', in *Women, science and medicine, 1500–1700* (ed. L. Hunter and S. Hutton), pp. 235–265 (Stroud, Sutton, 1997), at pp. 237 and 239.
18 R. K. Smeltzer, R. J. Ruben and P. Rose, *Extraordinary women in science and medicine* (Grolier Club, New York, 2013).
19 MPF-G, box 6, previous year's letter from a Florence Musgrave to rent the house on such conditions.
20 MPF-G, box 3, letter of 18 July 1911 to her sister Laurie.
21 *Ibid.*
22 *Ibid.*
23 *Ibid.*
24 M. Purefoy FitzGerald, 'The changes in breathing and the blood at various high altitudes', *Phil. Trans. R. Soc. Lond. B* **203**, 351–371 (1913), at p. 368.
25 MPF-G, box 35, as with other notes taken from written notes to the expedition.
26 FitzGerald, *op. cit.* (note 24).
27 MPF-G, *op. cit.* (note 25).
28 M. Purefoy FitzGerald, 'Further observations on the changes in the breathing at various high altitudes', *Proc. R. Soc. Lond. B* **88**, 248–258 (1914).
29 MPF-G, box 35, notes from Camp Bird Mine.
30 *Ouray Plaindealer*, Friday 11 August 1911, p. 2; article by Mrs E. C. Weatherly.
31 MPF-G, *op. cit.* (note 25).
32 MPF-G, *op. cit.* (note 25).
33 MPF-G, box 28, 22 August 1911.
34 FitzGerald, *op. cit.* (note 24).
35 MPF-G, box 28, letter dated 15 April 1912 from Mortehoe Hotel, Mortehoe, North Devon.
36 MPF-G, box 4, letter from C. Gordon Douglas, St John's College, 16 February 1913.
37 MPF-G, box 4, letter from sister Mary, 12 October 1912.
38 MPF-G, box 28, letter of 12 January 1913.
39 *Ibid.*
40 MPF-G, box 28, letter of 4 March 1913.
41 Osler Library Archives, P100, Sir William Osler Collection, 1 March 1913. FitzGerald was working for a degree at the Washington Square Division of the New York University, 'an end unaccomplished owing to absence on War Service for four year,' she notes as an annotation to Osler's letter, 'and being unable then to return to New York to complete the required Course of Study.' This study was presumably one reason for her delay in completing her paper. A chronic staphylococcal infection also afflicted her through the winter of 1912–13.
42 Watts, *op. cit.* (note 1), p. 195.
43 B. Louie, *Northville Michigan* (Arcadia Publishing, Mount Pleasant, SC, 2001), p. 41.

44 K. Lott, *Fevered lives: tuberculosis in American culture since 1870* (Harvard University Press, Cambridge, MA, 1996), p. 96; and Osler Library Archives, *op. cit.* (note 41), 18 July 1913.
45 FitzGerald, *op. cit.* (note 28).
46 MPF-G, box 28, letter from J. S. Haldane, 30 May 1914.
47 MPF-G, box 28, letter from J. S. Haldane, 17 May 1914.
48 MPF-G, box 28, letter from J. S. Haldane, 17 August 1914.
49 R. W. Torrance, 'Major breathing in miners', In *Attitudes on altitude* (ed. John T. Reeves and Robert F. Grover), pp. 59–85 (Boulder University Press, 2001), p. 71.
50 D. B. Dill, 'Mabel Purefoy FitzGerald—our second centenarian', *Physiologist* **16**, 247–248 (1973), at p. 248.
51 MPF-G, box 4, letter of 18 December 1972.
52 *The Ledger*, 25 December 1972, p. 12.