Organic Named Reactions and Social Challenges

The Role of British and European Women Organic Chemists Before, During and After WWI

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1. Introduction

Named reactions are a very useful tool in organic chemistry and their importance became evident as their number increased through time. However, they are becoming increasingly controversial, in spite of their evident benefits, being a product of the time of discovery and popularisation in synthetic routes.[1] One of the major issue arising is that at least half of the population was blatantly forgotten in the naming process: women. One could believe that this matter was intrinsically related only to the organic chemistry community, which failed to recognize the importance of women's discoveries. The problem, however, is much deeper and wider: the limited number of named reactions related to women is a representation of the culture at the beginning of the 20th century, which actively discouraged women from practising science and confined them to the role of homemakers. It was not the scientific world alone that maintained these perspectives, the exclusion of women from research reflects the high degree of sexism inherent in society.

The focus of this project is highlighting the origins behind the limited number of reactions named after women in the first thirty years of the 20th century and celebrating the achievement of women pioneers in organic chemistry in Europe with a particular emphasis on Britain, giving a true reflection of their status and under recognition in this field. The connections between historical events and the increased participation of women in research are discussed, as well as the challenges and obstacles they overcame to achieve recognition and prominent positions both inside and outside academia.

2. Background Knowledge of Named Reactions

Named reactions in organic chemistry appeared for the first time through the 19th century due to improvements in the field and were greatly developed in the 20th century. Other aspects of naming in chemistry were systematically regulated through time, with the International Union of Pure and Applied Chemistry (IUPAC) itself an example of this effort in standardising the chemical nomenclature for organic and inorganic compounds. On the contrary, named reaction have remained easily influenced by scientific communities and thus unregulated.[3] As a matter of fact, there has never been an authority imposing formal names to avoid confusion in their usage. The utility of named reactions is mostly a practical one: using the name of one individual person simplifies scientific communication, avoiding long and complicated denominations which describe the mechanism of the reaction itself.[2] Using proper names has also a very evident mnemonic value[2]: remembering the name "Wittig reaction" is much simpler than

"Reaction of a triphenyl phosphonium ylide with an aldehyde or ketone" and quicker too, as previously mentioned.

Named reactions became part of the jargon, pushing each generation of chemists to know the names of the scientists that supposedly discovered the process. "Supposedly" because some reactions are developed by chemist at the same time or based on previous discoveries and elaborated by a different scientist.[4] It becomes than clear that reaction names can change substantially over time.[4] In any case, a background knowledge of named reactions is needed to consult the literature and understand how professionals talk about their new discoveries.

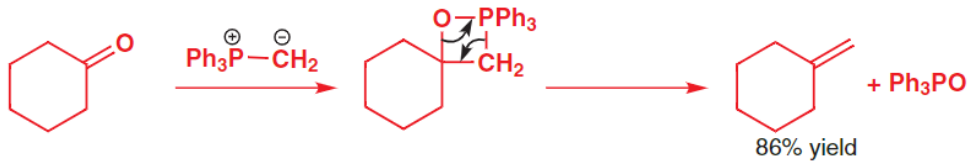


Figure 1: The Wittig reaction, one of the most popular named reactions

3. Women's Education in the late 19th and early 20th Century

To understand the relationship between the discrimination against women in science and the historical setting in which it took place, it is helpful to look at the ways in which women entered education and the societal opinion on female fellows in different European universities. This analysis will focus on middle and upper middle-class women, as they had the greatest opportunities of pursuing a formal education.

In England schooling was considered increasingly important for boys in the Victorian and Edwardian periods, as it was seen as an essential pathway to success. However, the situation was very different for girls. Daughters of wealthy parents were mainly educated at home in a sheltered environment, where sciences and classics were considered less important than painting or singing.[5] These forms of schooling in the home discouraged academic interests and pushed young women towards social commitments, far from the laboratory or mathematical lectures. A similar approach was carried out in the rest of Europe too. There were obviously cases in which the family took great interest in a girl's education and many of the successful female university students at the beginning of the 20th century were home-schooled by a governess or their own parents.[5]

The situation was also complicated in universities. While German universities often excluded women from undergraduate degrees through their admission process (most of them did not sit

the Abitur, an essential exam)[6], French ones allowed female students in public institutes and some private ones, such as the Pasteur Institute.[7] Italian women were legally first admitted to university in 1874 but many applications were rejected after that date solely on the base of gender.[8] The UK gives a clear description of the resistance to women in higher education. Universities founded in the 19th century allowed female students or lecturers, but older and 'elite' universities continued to discriminate against women well into the twentieth century.[5] Oxford awarded its first degree to women in 1920 and Cambridge in 1947, although the first female only Oxbridge college, Girton College in Cambridge, was founded in 1869.[9] As women were not allowed to graduate, they were sent a certificate by post.[10] Male students and professors were alarmed by the presence of women, especially when the newcomers started getting better result than the men, as was the case in mathematics and classics.[10] As a result, many students and professors often stated that women ruined their noble institutions, discouraging male applicants.[11] Higher education was described as dangerous for the mental and reproductive health by certain physicians.[5]

Figure 2: The first five students of Girton College, Cambridge

4. Women as Researchers and Academics in a Man's World

Due to the persistent discrimination from families, fellow students and society as a whole, the women who decided to actively pursue a career in science were deeply motivated and intelligent, as well as wealthy. In fact, it was quite common for women to work for free, either as assistants or even at the same position as remunerated men.[12] The consequence was obvious: the only women who could feasibly work in research were from the richest groups in society,

making the early 20th century science impossibly inaccessible for working class girls. The idea of a wealthy woman receiving payment for her labour was often perceived as scandalous.[12]

On the academic side, female lecturers could achieve senior positions in women's colleges, but they were categorically discriminated against in co-educational settings, as male academics were preferred on the sole ground of gender.[12] Female academics were also excluded from most societies, notably the Chemical Society in Britain. Although a consistent group of women had been publishing in the society's journals and participated to meetings as visitors, the fellowship was denied to them until 1920.[12] While in other countries this achievement came earlier (the German Chemical Society had its first female fellow in 1910[13]), it appears clear that women had to struggle to become distinct academics and enter the scientific network. The issue did not only concern the Chemical society and chemistry in general: the Linnean Society of London, another important learned society, admitted their first female fellow in 1904, after extenuating campaigns in the much more "women friendly" field of botany.[14] In conclusion, women were allowed to be scientists as long as they did not have a career and they did not explicitly compete with men for academic positions.

5. The English Struggle for Recognition: Martha Annie Whiteley

This case study on one of the first female organic chemists in Britain demonstrates how the sexism faced by women scientists in obtaining a fellowship from learned societies at the dawn of the 20th century originated from the public opinion of the time.[12]

Martha Annie Whiteley was a very successful academic of her time. Born in 1866, she obtained a University of London BSc in Chemistry in 1890 and a doctoral degree in 1902 from Royal Holloway College.[15] Although she lived on a teacher salary for a long time, she obtained a position as lecturer at the Royal College of Science (which merged into Imperial College London in 1907) and then she became assistant professor but never a full professor herself.[15] Her academic production is quite limited, possibly because she opposed putting her name on all the works she contributed to.[15] Whether this was to avoid negative preconceptions about her work as a female chemist is unknown but the discrimination against women might have played a part.

Whiteley was openly a feminist and actively improved the lives of chemistry female students and colleagues. She improved the cloakroom facilities for women and founded the Imperial

College Women's Association, encouraging girls' interest in science.[15] A few years after WWI she created the Women's Dining Club of the Chemical Society.[15]

Although no reaction bears her name, Whiteley worked extensively on oximes and their tautomerism, as well as barbiturate compounds. During the First World War she worked on developing ethyl iodoacetate as a tear gas and an incendiary mixture that was macabrely named DW (Dr Whiteley).[15] In the 1920s she largely contributed to the *Thorpe's Dictionary of Applied Chemistry.*[15] Sir Jocelyn Field Thorpe was an eminent organic chemist at the time, who in fact has a reaction named after him, and became Whiteley supervisor and then mentor in the organic chemistry world.

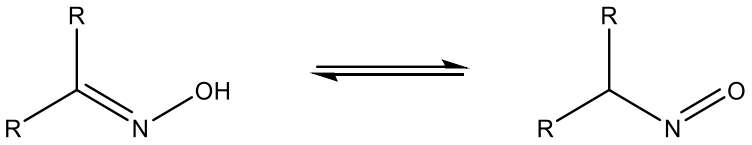


Figure 3: Oxime-Nitroso Tautomerism, one of Whiteley's first research topics

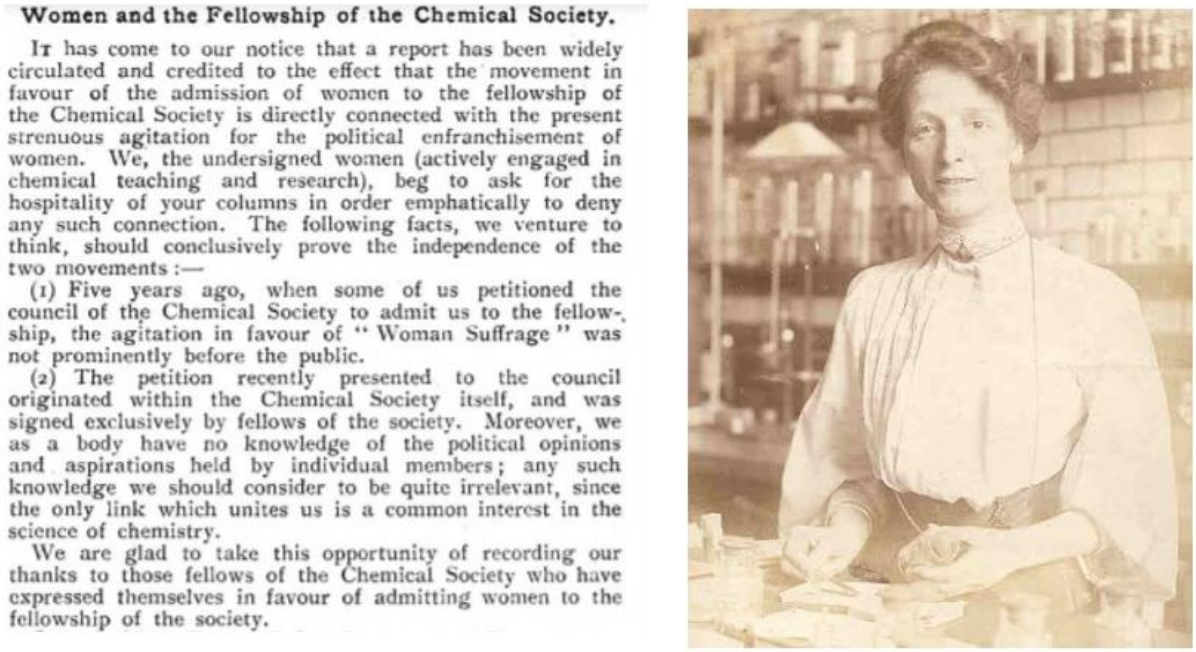
Despite her prominent academic position, the greatest challenge Whiteley had to face was in relation to the admission of women to the Chemical Society. Founded in 1841, the issue of female fellows was first discussed in 1880s and different motions aimed to women association with the society were defeated in the following years.[16] In 1904 Marie Skłodowska Curie was proposed as a Foreign Fellow and a consistent group of chemists took the opportunity to push to obtain equal ordinary fellowships.[10] In the October of the same year Whiteley and other eighteen women signed a petition stating:

> *"We, the undersigned, representing women engaged in chemical work in the country desire to lay before you an appeal for the admission of women to Fellowship in the Chemical Society".*[16]

The petition highlighted the fact that women were sole or joined author of at least 300 papers published in the journals of the society. Of over two thousand members of the governing body, only 45 showed up and 23 voted against the change, effectively banning women yet again.[10] One of the main opposers of the petition was Henry Armstrong, president of the society in the years 1893-1895 and recipient of the Davy Medal, who held some very sexist but quite common views and once stated:

"The very women who have shown their ability as chemists should be withdrawn from the temptation to become absorbed in the work, for fear of sacrificing their womanhood; they are those who should be regarded as chosen people, as destined to be the mothers of future chemists of ability."[16]

In 1909 Whiteley was part of a group of thirty one women asking again for admission through a letter. They formally distanced themselves from the contemporary suffrage movement[17] due to previous accusations of their affiliation, likely by Armstrong himself, but their request was meant to advance women in the field.



Women and the Fellowship of the Chemical Society.

IT has come to our notice that a report has been widely circulated and credited to the effect that the movement in favour of the admission of women to the fellowship of the Chemical Society is directly connected with the present strenuous agitation for the political enfranchisement of women. We, the undersigned women (actively engaged in chemical teaching and research), beg to ask for the hospitality of your columns in order emphatically to deny any such connection. The following facts, we venture to think, should conclusively prove the independence of the two movements :—

(1) Five years ago, when some of us petitioned the council of the Chemical Society to admit us to the fellowship, the agitation in favour of "Woman Suffrage" was not prominently before the public.

(2) The petition recently presented to the council originated within the Chemical Society itself, and was signed exclusively by fellows of the society. Moreover, we as a body have no knowledge of the political opinions and aspirations held by individual members; any such knowledge we should consider to be quite irrelevant, since the only link which unites us is a common interest in the science of chemistry.

We are glad to take this opportunity of recording our thanks to those fellows of the Chemical Society who have expressed themselves in favour of admitting women to the fellowship of the society.

Figure 4: The 1909 Letter and M.A. Whiteley at the Royal College of Science (now Imperial College London)

Many fellows of the Chemical Society were favourable to women at this point in time and 312 of them were sequentially thanked, although the most misogynist and socially traditionalist associates managed to preclude them from becoming full fellows until 1919[16], when the Sex Disqualification (Removal) Act became law, stating:

"A person shall not be disqualified by sex or marriage from the exercise of any public function, or from being appointed to or holding any civil or judicial office or post, or from entering or assuming or carrying on any civil profession or vocation, or for admission to any incorporated society (whether incorporated by Royal Charter or otherwise), and a person shall not be exempted by sex or marriage from the liability to serve as a juror."[18]

Whiteley was officially admitted in December 1920, after sixteen years of failed attempts.[16]

6. Women in Central Europe: Irma Goldberg, from Success to Oblivion

While Whiteley was fighting for her admission to the Chemical Society, Irma Goldberg was one of the most established women chemists in central Europe. This case study highlights how women could have a reaction named after them and how women's academic careers could quickly decline compared to their male colleagues. Irma Goldberg was born in Moscow in 1871 and as many Russian girls of her time she decided to pursue a university course in Switzerland.[19] The main reason for this peculiar choice was the fact that Swiss colleagues were less prestigious than other European universities, thus being more open towards women admission. Although, female students had to face discrimination, because some professors were still openly hostile. Foreign students like Goldberg herself were often considered morally corrupt by their German and Swiss peers[20], making their university experience even more difficult.

It is in this context that Goldberg started publishing her first papers on the derivatives of benzophenone and became assistant in the Organic Chemistry Laboratory of the University of Geneva then *Privatdozentin* in 1897, a title which enabled her to teach. Working closely with Fritz Ullmann, she managed to become quite well known in the chemical community, then moving with him to Berlin in 1905 where she held an assistantship position.[19] Two reactions bear her name: the Goldberg reaction and Jourdan-Ullman-Goldberg reaction. Both reactions describe a copper catalysed process with a halogenated aromatic compound in which a carbon-nitrogen bond is formed.[18] Goldberg's intuition was adding potassium carbonate to the reaction mixture, improving the yield, as well as extending the original copper catalysed ether synthesis discovered by Ullmann to nitrogen containing molecules. She presented her results in a series of single and co-authored papers from 1906 to 1908[20] and she patented her method using K_2CO_3 and cuprous CuI as catalyst.[18]

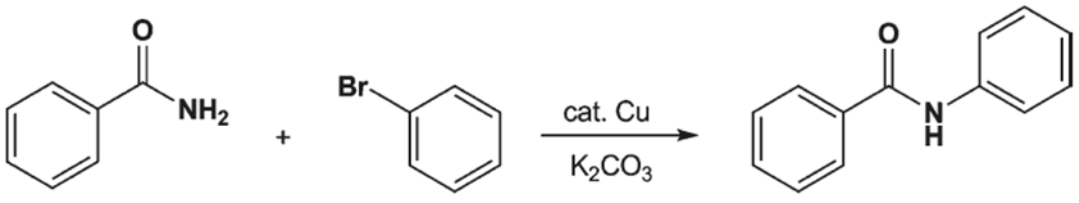


Figure 5: The Goldberg Reaction

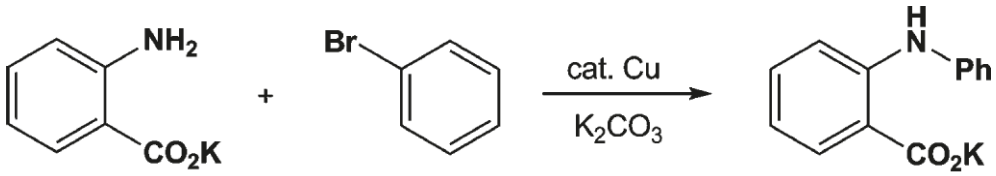
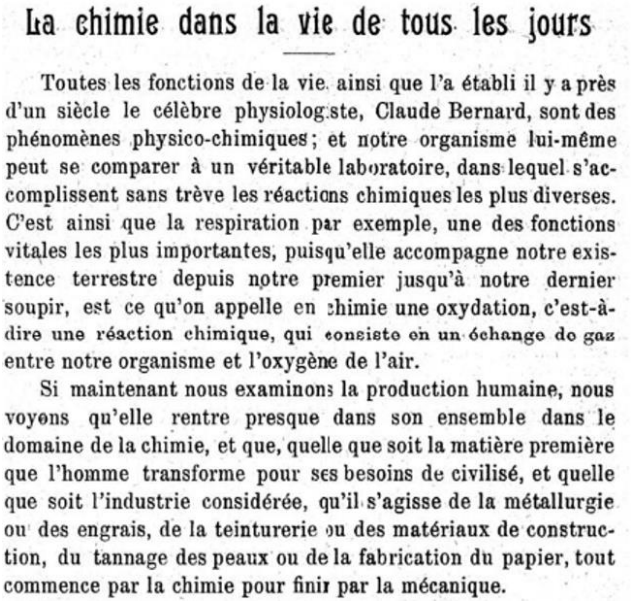


Figure 6: The Jourdan-Ullman-Goldberg Reaction

After enjoying a mostly successful career, Irma Goldberg married Ullmann in 1910[19]. It is interesting to see that the number of her publications rapidly declined after the marriage, especially as they increased their ties with the increasingly important dye industry. In fact, the last paper of Goldberg's academic career was on the derivatives of anthraquinone[19], a colourless substance that becomes a powerful dye depending on the groups introduced. In those years, the couple moved back to Geneva, where Ullmann became professor at the University.[19] It is not known much of Goldberg life after her marriage: as her academic and industrial career shrank, her name was slowly forgotten. In 1927 she published an article on "*Le mouvement féministe : organe officiel des publications de l'Alliance nationale des sociétés féminines suisses"*, a Swiss feminist paper, named *"La chimie dans la vie de tous les jours"*, representing how chemistry affects everyday life.[21] While this is no proof that Goldberg was actively part of the feminist movement at the time, it does highlight some sort of social participation in the chemist's life, who also published an article about dry ice in the Swiss Red Cross.[22]



La chimie dans la vie de tous les jours

Toutes les fonctions de la vie ainsi que l'a établi il y a près d'un siècle le célèbre physiologiste, Claude Bernard, sont des phénomènes physico-chimiques; et notre organisme lui-même peut se comparer à un véritable laboratoire, dans lequel s'accomplissent sans trève les réactions chimiques les plus diverses. C'est ainsi que la respiration par exemple, une des fonctions vitales les plus importantes, puisqu'elle accompagne notre existence terrestre depuis notre premier jusqu'à notre dernier soupir, est ce qu'on appelle en chimie une oxydation, c'est-à-dire une réaction chimique, qui consiste en un échange de gaz entre notre organisme et l'oxygène de l'air.

Si maintenant nous examinons la production humaine, nous voyons qu'elle rentre presque dans son ensemble dans le domaine de la chimie, et que, quelle que soit la matière première que l'homme transforme pour ses besoins de civilisé, et quelle que soit l'industrie considérée, qu'il s'agisse de la métallurgie ou des engrais, de la teinturerie ou des matériaux de construction, du tannage des peaux ou de la fabrication du papier, tout commence par la chimie pour finir par la mécanique.

Figure 7: The beginning of Goldberg's article. Chemistry affects everyone's life, from breathing to industrial processes

Figure 8: Chemistry students at the University of Geneva in 1905

The date and circumstances in which she died are unknown. The last piece of information available comes from her husband's memorial notice in 1939, which Goldberg signed.[19] She was a great, forgotten chemist, who improved organic chemistry through her discoveries but was unfairly obliterated possibly due to her marital status. The relationship between marriage and women's scientific career will be further explored later in this paper.

7. The Great War and Social Changes

World War I was often regarded as an important turning point for women's social emancipation, albeit this view is maybe too optimistic. Female workers life was not easy during the conflict and what women gained during the war was often lost as men came back from the front. However, one should not completely disregard the fact that feminist requests were slowly but progressively granted in the following decades. Examples of this social change can be seen in voting equality which was achieved in several countries in the years 1918-1920, for example Germany, Poland, The Netherlands[23] and partially Britain.[24]

Women proved their worth as an active and crucial part of society, taking up many of the jobs that were previously held by man, now fighting at the front.[24] Men initially opposed women taking up their jobs, considering it an insult to their masculinity.[24] When female workers tried to suggest an improvement, they frequently received a sarcastic reply from older men who detained their position of power during the conflict.[24]

In Britain, the majority of new jobs taken up by women were in the munition domain, which had previously been considered unsuitable for them. The toxic conditions in the factories brought to skin and hair colour change, while medical inspectors hired by the Government ignored the symptoms to maximise production.[24] Similar accounts come from Italy and France. 90% of the industrial chemists were women, who however were mostly given repetitive tasks.[24] Other women holding university degrees sometimes became museum directors, cryptographers, highly recognised doctors in their homeland and abroad, head of laboratories.[24] Interesting in this sense is the figure of M. A. Whiteley, previously discussed in section 5, who took up the important role of researching chemical weapons and explosives in Imperial College at the head of a group of other women, going as far as testing mustard gas on herself provoking blisters over her arm.[15] Others took the increase their responsibilities in museums, as directors or in other roles of influence, to fill in for the men at the front. The war

effort of women was probably one of the prompts in the approval of laws like the Sex Disqualification (Removal) Act, which was itself a compromise over the more radical Women's Emancipation Bill previously proposed by the Labour party. The latter would have allowed women to enter as equal in the British parliament and gain hereditary access to the House of Lords, in addition to what was eventually approved: the removal of any disqualification in juries or public offices.[18]

Another issue that women entering in the workforce or accepting more senior roles had to face was the consistent pay difference compared to men in the same position. The most common argument against equal pay was that jobs taken up by women were easier than the one done by men and thus they deserved a lower wage.[24] Arguments from the time that women were not strong enough for many roles are easily dismissed by the fact that most factories improved productivity during the war due to female employment.[24] They were also criticised for their clothing and *the League of Decency and Honour* in England approved restrictive reforms, basically banning scented soap and underwear made of silk. [24] Accusations that women, who had proven their capability to earn money doing dangerous jobs, were earning too much or were too concerned with frivolous good should be considered sexist and appalling by modern historians. Though these beliefs reflected the social attitudes of time, the negative consequences were real and damaging to women.

8. The End of WWI: Did anything really change?

As men came back from the front in 1918, they took their previous positions back. Women, especially married ones, returned to domestic life and the demographic decrease in the war years forced governments to create a new rhetoric: they were now to be mothers. Although, some social changes did persist and more women than ever were skilled and educated, many of them also having a degree or certificates demonstrating their knowledge.[24] The popular misogynist idea that women were naturally incompetent died out when facing their undeniable contribution in the years 1914-1918. In science, they were relegated to lower-level tasks, especially in analytical chemistry as they were generally more delicate in handling samples.[24] It was perceived as obvious that a woman had to be especially talented to achieve the same position as a male colleague and their career was more often than not abruptly interrupted by marriage.

This concept of marriage meaning the death of one's career is interesting in organic chemistry. It was previously assumed in this same paper that Irma Goldberg had her academic life cut short

when she married Ullmann[19], but two British women in the aftermath of the Great War continued their own research following their wedding, albeit with crucial differences between them. They were Gertrude Maud Robinson, who even has a reaction named after her, and Edith Hilda Ingold. The two following sections describe two case studies, in which women had a successful scientific career but were under recognized for their efforts, especially when coming to salaried or influential positions.

9. Gertrude Maud Robinson, Chemist and Wife

Gertrude Maud Robinson (née Walsh) was born in 1886 in Cheshire and managed to achieve a B.Sc. and a M.Sc. degree at the Victoria University of Manchester.[10] She was a teacher at the Manchester High School for Girls, which was a common salaried job for women, while also beginning her research career. It was in this city that she met Robert Robinson, who was to become one of the most influential chemists of the 20th century. The two married in 1912 and had two children during their life. They couple moved to Sidney, Australia, the same year of their marriage.[10] There Gertrude worked as an unpaid demonstrator in organic chemistry at the university and her husband had a salaried job. In fact, married women were banned from paid positions in the university.[10] She also became and established fire fighter and helped putting out the numerous fires that occurred in the chemistry faculty and laboratories.[10]

In 1930, well after the end of the Great War, she moved to Oxford with her husband, who was appointed professor and became fellow of Magdalen College.[25] Although the couple co-authored most papers and alkaloids were studied in depth by both of them, only Robert was awarded the Noble Prize in 1947.[26] In his Nobel lecture he recognised his wife's impact:

> "*Though it might be invidious to mention individuals, yet I may be allowed to say how much I owe to the constant help of my wife, not quite my first, but my most consistent collaborator, and over the longest period of years."*[27]

Then in Robinson's autobiography "*Memoirs of a Minor Prophet: 70 Years of Organic Chemistry*" published after his death:

> *"Nevertheless, I cannot postpone an acknowledgement of the very great help which she gave me at all stages of my career. Looking back, I can see how she subordinated her interests to mine, was always such a ready collaborator in scientific work, and cheerfully followed my chief vacation activity, namely mountaineering."*[28]

A fascinating part of Gertrude research is her contribution to the Piloty-Robinson Pyrrole synthesis, a named reaction first explored by the couple in 1918. After having considered and deeply studied the Fischer Indole synthesis and its mechanisms, they applied a similar thought process to the synthesis of pyrroles.[29] In the former, phenylhydrazine is heated under acidic conditions with an aldehyde or ketone; in the latter two equivalents of deoxybenzoin and one equivalent of hydrazine could form a ketazine that could then be converted in tetraphenylpyrrole using HCl.[29] Although Gertrude's name is the first one appearing on the 1918 paper, having taken her husband's surname, he is assumed to be the one who should be solely credited.

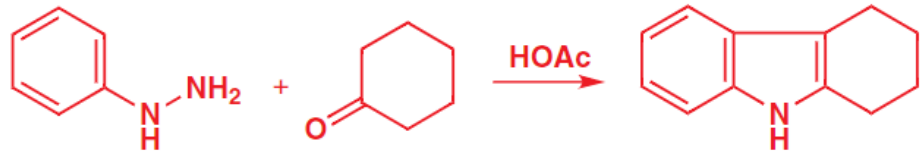


Figure 7: An example of Fischer Indole Synthesis

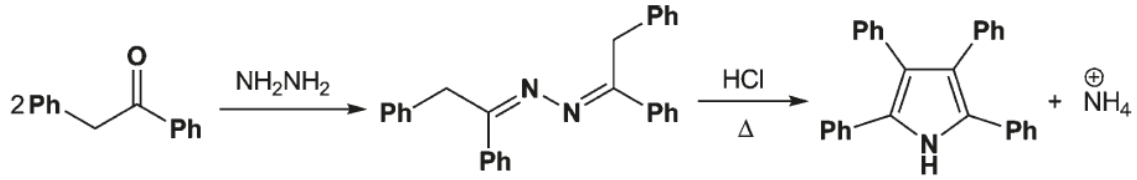


Figure 8: Piloty-Robinson Pyrrole Synthesis

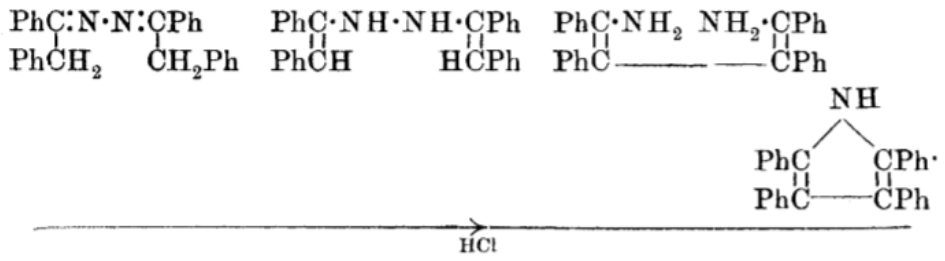


Figure 9: The mechanism for the second step described in Robinson's 1918 paper

The couple collaborated on many publications and Mrs (then Lady) Robinson was a pioneered in the study of fatty acids.[10] She was the first chemist to synthesise oleic acid and worked thoroughly to extract and determine the structure of plant pigments, especially leucoanthocyanins.[30] The Robinsons' method of extraction through partially miscible solvents anticipated some modern separation method such as partition chromatography.[31] She also worked on artificial analogues of penicillin which had antibiotic properties, being the first one

to ever synthesise one, and investigated the chemistry of pyrroloquinoline derivatives as part of a broader project on antimalarials in 1929.[32] During her active years she published a total of 38 papers, nine of which were single authored.

Lady Robinson was excluded from the Alembic Club, the all-male chemistry society at the University of Oxford, and took the issue of the discrimination against women chemist in the university to heart. In 1933 female academics were still banned from attending the Sectional Dinner of the British Association for the Advancement of Science. She organised her own event in the same hotel, fighting social norms, and women were finally accepted at the official dinner from the following year.[10]

Although she did not receive international recognition for her scientific merits in the same way as her husband, Lady Robinson was awarded an Honorary Degree of Master of Arts from the University of Oxford in 1953, acknowledging her contributions and qualities as a chemist.[27] It is regretful to think that she only died the following year after this achievement due to a sudden heart attack.[10] Her life is remembered in a long and telling obituary, which highlights her importance as a chemist and her crucial role in the scientific community of the time.[33]

10. Edith Hilda Ingold, Wife and Chemist

Edith Hilda Usherwood was born in 1898.[34] Daughter of an engineer, whose talent had been ironically spotted by the same Armstrong impeding women entrance to the Chemical Society, she had a brilliant academic career as a student.[34] She won a scholarship in the modern North London Collegiate School and a total of ten prizes when undertaking a chemistry degree at Royal Holloway College in London between 1916 and 1920.[34] While WWI was raging in Europe, Professor Moore started a research project on the oxidation of ethylene to acetylene with his female students at the university, which gained her the College's Driver Prize.[34]

Edith achieved First Honours at the end of her degree and pursued her interests in a Ph.D. at Imperial College under Dr Whiteley's supervision. Considering her supervisor's research topic at the time, Hilda also published her thesis on tautomerism with the title "*Experiments on the Detection of Equilibria in Gaseous Tautomeric Substances. The Formation of Heterocyclic Rings Involving Reactions with the Nitroso and Nitro Groups in Various Tautomeric Modifications."* and then a joined paper with Whiteley on oximes.[34] These single-authored publications on tautomerism, along with many others, granted her a D.Sc. in 1925.[10]

She proved the fact that hydrogen cyanide exists as a tautomeric mixture of nitrile and isonitrile, determining the specific heat capacities at constant volume (C_v) over a temperature range.[34] Edith Hilda found that HCN in its gaseous form exist as 99% formonitrile.

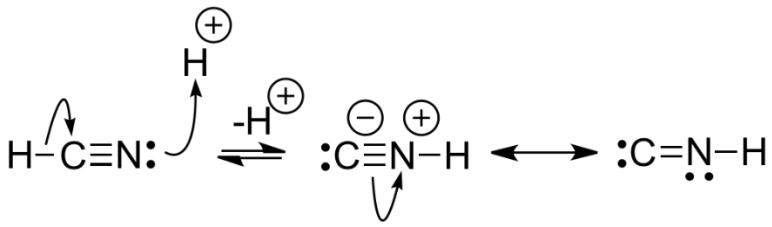


Figure 10: Nitrile (Formonitrile) and Isonitrile tautomerism (and resonance hybrids of the latter)

In the paper about hydrogen cyanide from 1922, she thanked Christopher Ingold for his advice on how to work with the substance safely.[34] While Hilda continued her research on tautomerism in the following years, they then collaborated on a publication named *"The specific heats of gases with special reference to hydrogen"* regarding the relationship between degrees of freedom and specific heat capacities.[35] Using the equipartition theorem, they incorporated the idea of translational, rotational and vibrational degrees of freedom to the change in temperature and C_V of diatomic molecules (H_2, N_2 and Cl_2), also exploring the effect of mass and force constant in the vibrational case. Finally it faced the idea of dissociation of gases at higher temperatures.

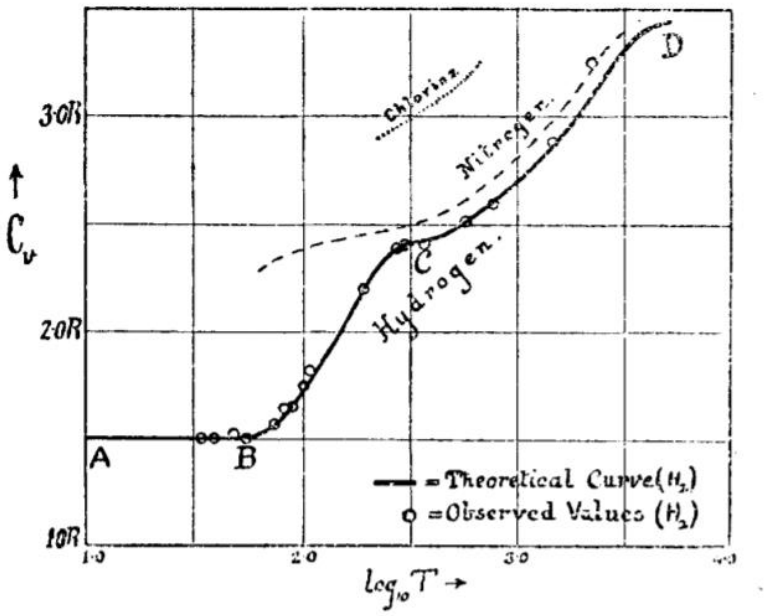


Figure 11: The diagram from the 1922 paper, showing theoretical and experimental data

The discoveries of Miss Usherwood were challenged by one of the greatest physical chemists at the time: J.R. Partington. He mentioned that Hilda did not consider the possibility of polymerisation in her studies, and thus her thermal values were inaccurate.[34] She managed to prove him wrong, by describing how such polymerisation only occurs in a very limited range of the temperatures they had considered.[34]

Miss Usherwood married Ingold in 1923 and cooperated with him for a few more years, moving with him to Leeds and working as an unpaid demonstrator.[10] The controversy with Robert Robinson on the electronic theory is notable from the 1920'. Ingold was accused of plagiarising Robinson's research on the topic, although the former did not have the same opinion on the electronic structure of molecules and organic mechanisms as the latter: Ingold believed in Flürscheim theory of affinity for organic molecules, where substituted groups could either make high or low demand, which alternated through the carbon chain.[36] This also established whether the electrophilic aromatic substitution on a benzene ring would be ortho, para or meta directing.[36]

This theory, which did not include the idea of octet and covalent bonds formed through electron sharing, brought the Christopher Ingold and his wife, as co-author of some papers and often assistant, to the wrong conclusions about the nitration of benzylamines and other substituted molecules. They wrongly stated, also due to some incorrect experiments, that free amines would produce meta substitution, while ammonium salts would end up in ortho/para substitution.[36] They finally accepted Robinson theory of electronic structure in 1926 and they experiments were proven to be wrong. In this context, the Ingolds repeated the experiment, in particular in the case of S-methylthioguiacol and after 72 hours of unstopped work they realised their mistake.[10]

When her children were born, Hilda Ingold slowed down on her publications, albeit she participated in the evacuating efforts during World War II of UCL to Aberystwyth.[34] There she finally got a paid job through her husband's intercession, who had always recognised her merits.[10] Unbelievably for her academic status and all the responsibility she took upon herself, she was only paid as a secretary.[10]

As her husband continued with his brilliant career, she left the scene as a chemist and started taking on the role of "professor's wife", which she did not appreciate in the past being quite shy.[34] The move was probably dictated by society itself, as her role of mother meant she had to be more dedicated to the family and possibly imposed the traditional gender roles. This

clearly distinguishes her from Gertrude Robinson, who was active until her death. The now Lady Ingold, as her husband was knighted in 1958, died in 1988.[34]

11. Conclusion

All the cases presented here are meant to give a picture of how society discouraged women to pursue scientific careers in organic and physical organic chemistry, although not always officially excluding them. Moreover, it is hoped that the examples given can highlight the ground-breaking effort of these female scientist, who had successful lives in their field even if they went mostly unrecognised.

The historical descriptions are supposed to clarify the position of society and universities on women and show that the issues of this period were not inherent in the organic chemistry community, even if some leading scientist did openly discriminate women. It is not only about the simplistic but common approach of attribution of original work to male scientists: the thread of named reaction is important to see that discrimination had multiple facets and was often finely hidden behind the façade offered by a male dominated reality.

While much has changed since then and there are many highly recognised female organic chemists nowadays, it is crucial to look back at the past to make sure that the future years provide further improvements and the chemistry community does not retrocede on these matters, giving credit to some “hidden” role models and spreading the word to young science students who might feel underrepresented in organic chemistry.

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Pictures

Figure 1: Clayden, Jonathan., Nick. Greeves, and Stuart G. Warren.”” Organic Chemistry. Second ed. Oxford ; New York, 2012: 689

Figure 2: “The Great Scheme.” Girton College, n.d. https://www.girton.cam.ac.uk/pioneering-history/the-great-scheme

Figure 4: Whiteley , Martha A., Smedley, Ilda and others “Women and the Fellowship of the Chemical Society.” *Nature*, 1909,399. and Cahen, Edward. Photograph. n.d. College Archives Imperial college London.

Figure 5, 6 and 10: Olson, Julie A, and Shea, Kevin M. "Critical Perspective: Named Reactions Discovered and Developed by Women." Accounts of Chemical Research 44, no. 5, 2011: 311-21.

Figure 7: Irma, Ullmann-Goldberg. “La Chimie Dans La Vie De Tous Les Jours.” Le mouvement féministe : organe officiel des publications de l'Alliance nationale des sociétés féminines suisses 251, 1927: 10–11.

Figure 8: Hauert, Jonas. “170 Years of Chemistry at the University of Geneva, 1800–1970.” CHIMIA 63, no. 12, 2009: 803.

Figure 9: Clayden, Jonathan., Nick. Greeves, and Stuart G. Warren.”” Organic Chemistry. Second ed. Oxford ; New York, 2012: 775

Figure 11: Robinson, Gertrude Maud, and Robinson, Robert. "LIV.—A New Synthesis of Tetraphenylpyrrole." J. Chem. Soc., Trans 113, 1918: 642

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