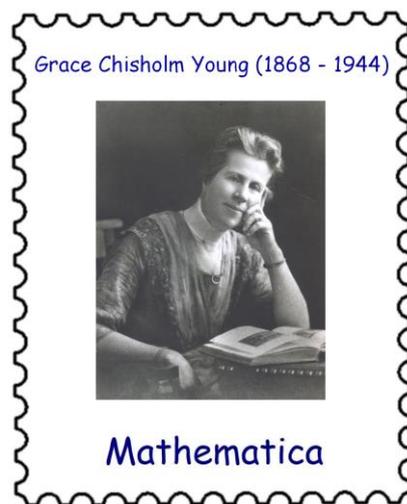


GRACE CHISHOLM YOUNG (March 15, 1868 – March 29, 1944)

by HEINZ KLAUS STRICK, Germany

When GRACE CHISHOLM was born, her mother ANNA LOUISA BELL was already 44 years old and her father, the high-ranking government official HENRY WILLIAMS CHISHOLM, was about to retire.

GRACE often suffered from headaches as a child, so the family's doctor recommended that she should be home-schooled, and if possible only in subjects that did not bother her: GRACE was particularly interested in mathematics and music. At the age of 17, she successfully passed an examination (*Cambridge Senior Examination*) and thus actually had the formal prerequisite for studying at Cambridge.



Picture of Grace Chisholm Young with courtesy of SYLVIA WIEGAND, University of Nebraska-Lincoln (granddaughter of GCY)

Her parents rejected her wish to study medicine. So she decided to study mathematics. Since women were not admitted to regular studies at *Cambridge University*, she applied to *Girton College*.

In the 1860s, the first activities of women's rights activists in England were aimed at creating opportunities for women to study. The fact that women who wanted to study were soon allowed to take the entrance examination at *Cambridge University* was only an apparent step forward, because passing the examination did not entitle them to a place at the university. Therefore, the only option was to establish separate higher education institutions for women.

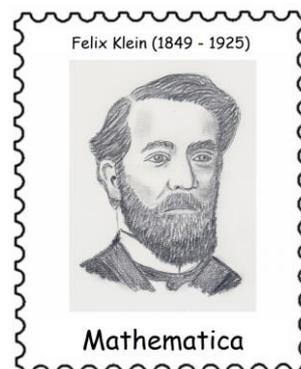
In 1869, the first *College for Women* at *Benslow House* opened in Hertfordshire, north of London and thanks to numerous donations, a site was then acquired in the village of Girton, only a few miles from *Cambridge University*. By 1873, 13 female students were living in what was now known as *Girton College*.

At the end of their studies, the young women took an examination in which they had to fulfil the same requirements as the (male) students at the university – but the value of a degree at *Girton College* remained low. Despite all efforts, there was little progress towards recognition of the institution in the first half of the 20th century. It was not until 1948 that *Girton College* was officially integrated into the *University of Cambridge* as a college.

GRACE CHISHOLM's strict and feared teacher at *Girton College* was WILLIAM HENRY YOUNG, who challenged and encouraged his talented student. In 1892 she passed her exams (comparable to the Bachelor's examination) with top marks. She also met the requirements of the final examination at Oxford (which was considered even more demanding) and here she surpassed all the male graduates of her year.

After her exams, GRACE CHISHOLM wanted to continue her studies. At first she stayed at Cambridge for another year and then she moved to Göttingen, where FELIX KLEIN had set up a course especially for female students.

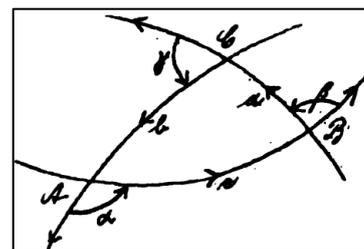
In 1895 she received her doctorate with a thesis on algebraic-group-theoretical investigations of spherical trigonometry.



(drawings © Andreas Strick)

In the first volume of his *Elementary Mathematics from the Advanced Standpoint*, KLEIN presented the results of CHISHOLM's investigations:

Let us consider an ordinary spherical triangle ... and fix the directions of the three sides in such a way that $a, b, c < \rho$, and the angles, $\alpha, \beta, \gamma, \dots$ the exterior angles of the triangle ...



It is now clear, that of the 6 measurements of the spherical triangle thus defined, only 3 can be varied continuously independently of each other ...

The formulae of spherical trigonometry represent a number of algebraic relations ... between their 12 cosines and sines, by which only 3 of these 12 quantities can be arbitrarily variable, while the other 9 depend algebraically on them. ...

We interpret the quantities

$$x_1 = \cos(a), x_2 = \cos(b), x_3 = \cos(c), x_4 = \cos(\alpha), x_5 = \cos(\beta), x_6 = \cos(\gamma),$$

$$y_1 = \sin(a), y_2 = \sin(b), y_3 = \sin(c), y_4 = \sin(\alpha), y_5 = \sin(\beta), y_6 = \sin(\gamma),$$

as coordinates of a 12-dimensional space \mathbb{R}^{12} , the totality of all those of its points which really correspond to possible spherical triangles represents a 3-dimensional algebraic manifold M_3 of this \mathbb{R}^{12} .

GRACE CHISHOLM chose a somewhat different approach in her dissertation (using the representation by the cotangents of half angles) and among other things, she succeeded in proving that all spherical triangles can be represented as the intersection of three 2nd-degree surfaces (with underlying quadratic equations) in a 6-dimensional subspace.

GRACE CHISHOLM was the second woman in the history of mathematics in Germany to obtain a doctorate.

Unlike SOFIA KOVALEVSKAJA, who was awarded her doctorate *in absentia* in 1874, she had to face an examination colloquium with several professors from different disciplines.



GRACE CHISHOLM would have liked to continue her research work in Göttingen. But since her father was now 86 years old and in need of help, she returned home to take care of him.

At home she also met her former mathematics teacher WILLIAM YOUNG again, to whom she had previously sent a copy of the dissertation – full of pride at what she had achieved.

She initially rejected his marriage proposal, but when he did not give up, she finally agreed to the marriage.

WILLIAM YOUNG was an outstanding mathematician who, however, never succeeded in finding permanent employment and he kept changing his field of activity.

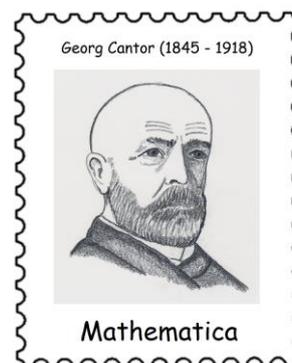
During a stay in Italy, their first son Frank was born in 1897 (nicknamed BIMBO as a short form of *Bambino*). From 1899 onwards, the couple lived in Göttingen for nine years, where they worked together with FELIX KLEIN and concentrated on set theory.

During this time another five children were born, whose upbringing and home schooling – not only because of the father's frequent absence – was mainly taken over by GRACE.

Together GRACE and WILLIAM YOUNG wrote a mathematics book for children (*A First Book of Geometry*), which dealt in particular with geometric insights through paper folding.

GRACE wrote two books to encourage children to explore science (*Bimbo* and *Bimbo and the frogs*).

From 1908 the family lived in Geneva, and from 1915 in Lausanne, where they wrote a total of 220 articles on mathematical subjects and two reference books. A book on set theory (*The Theory of Sets of Points*, 1906) was particularly appreciated by GEORG CANTOR.



Even though most of the published articles were written in collaboration, and many would not have been written without her assistance, her husband had a problem with claiming joint authorship. Since if both their names were mentioned, he argued, neither of them would have anything. He needed the credit now and she did not, he said, but later they could change that: "*Right now you can't have a career – you have your children*".

WILLIAM YOUNG commuted between his family's chosen home and various universities where he held temporary teaching posts: Wales, London, Calcutta, Liverpool. He lectured at universities all over the world.

He was admitted as a member of the *Royal Society*, was president of the *London Mathematical Society* for two years, and of the *International Mathematical Union* (IMU) for seven years. He was honoured for his publications by the *SYLVESTER Medal* and the *DE MORGAN Medal*.

Meanwhile, GRACE took care of the education of her six children – for example, each of them learnt a musical instrument of their own. And it was not enough that she now spoke six foreign languages, but first in Göttingen, then further in Geneva, she completed her medical studies, though in the end she did not take a formal degree.

At the same time, she continued her mathematical research work. In 1916 she published – under her name only – a paper on the foundations of differential and integral calculus, for which she was honoured with a prize from *Girton College*.

The death of her son FRANK, who was killed as an airman in the British service during the First World War, threw GRACE off course. Her health deteriorated visibly. In the mid-1920s, her mathematical activities came to an end.

When World War II broke out, two of her grandchildren were visiting her in Switzerland. GRACE took them back to their parents in England, but then could not return to Switzerland herself, because the German troops had begun the *French campaign*.

So GRACE and WILLIAM spent the last years of their lives apart without seeing each other again and he died lonely two years later, while she lived with one of her daughters until 1944.

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<https://www.spektrum.de/mathematik/monatskalender/index/>

Translated 2021 by John O'Connor, University of St Andrews

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