SNAPSHOTS FROM THE HISTORY OF MATHEMATICS

WILLIAM OUGHTRED

by **Jenny Ramsden**

William Oughtred is a mathematician of whom few people have heard, yet to whom we owe a great deal in the mathematical world. He invented the slide rule, gave us the multiplication symbol and was responsible for the mathematical education of several of our famous scientists. All of this from a very quiet, reserved clergyman whose brain was forever active.

Oughtred was born on 5th March 1574 in Eton, Buckinghamshire. He atten-ded Eton College and from there he went to King's College, Cambridge in 1592 and became a Fellow in 1595, gained a BA in 1596 and an MA in 1600. Although Oughtred was passionate about mathematics, despite very little of it being taught at that time in either Eton or Cambridge, his main calling was for the Church and he was ordained in 1603. His first ministry was in Shalford in Surrey in 1604; in 1610 he moved to the parish of Aldbury in Surrey, where he remained for the rest of his life, passing away in his vicarage there on 30th June 1660.

Oughtred indulged his passion for mathematics by studying well into every evening and by tutoring privately. His most famous pupils were the mathematician John Wallis, astronomer Seth Ward and the architect Christopher Wren. He gave these lessons free of charge, with many of his pupils living in the vicarage while undergoing their studies. Oughtred was particularly fond of using symbols in his mathematical writings and in 1631 published a good systematic textbook on arithmetic, called *Clavis Mathematicae*, which contained almost everything known about the subject at that time. In it he used over 150 symbols, some of which were in common use at that time, others were of his own invention. Three of his symbols introduced in this book are still in use today; these are: the multiplication symbol ×, the symbol for absolute difference ~ (where a~ b is the positive difference between a and b), and the 'in proportion' symbol ::. Prior to this, the equation we understand today meaning a:b = c:d was usually written as a–b–c–d. Oughtred expressed it as a.b::c.d, using a dot to denote division or a ratio. This book was very popular in its time and is believed to have been instrumental (along with Descartes' *Géométrie*) in convincing Newton to study mathematics instead of chemistry as his main subject of study at Cambridge in 1661.

The invention for which Oughtred is most famous is that of the slide rule. Napier's discovery of logarithms in 1614 had revolutionized the speed at which calculations in arithmetic could be carried out. In 1620 Edmund Gunter plotted a logarithmic scale along a single straight ruler and by using a pair of dividers, could add and subtract lengths in order to carry out multiplication and division calculations. Oughtred extended this idea and used a pair of these logarithmic rulers together, dispensing with the dividers, to perform similar calculations. He first described his method for a circular slide rule in *Circles of Proportion and the Horizontal Instrument*, published in 1632, and his rectilinear slide rule was described in an *Addition* to this work in 1633. As is often the case, the ownership of the invention of the circular slide rule was disputed very strongly. One of his pupils, Richard Delamain, accused Oughtred of stealing his invention from him, since Delamain had published a booklet *Grammelogia, or the Mathematicall ring* in 1630, describing a circular slide rule. Oughtred retaliated, saying that Delamain had stolen the idea from him. The row was never settled and dogged Oughtred for the rest of his life. However, he did have sole claim to the invention of the rectilinear version, which he designed as early as 1621. Immediately adopted by mathematicians, it was used extensively (undergoing several adaptations and augmentations) right up until the 1970s, when the hand-held, electronic calculator saw the slide rule's demise.

Oughtred published several other important books including *Trigonometrie*, in 1657, in which he introduced abbreviations for cosine and cotangent, to complement those already in use since 1626 for sine, tangent and secant due to Girard. This was a very important advance in symbolism, but was mainly forgotten until Euler reintroduced them in 1748. On the last two pages of his work, Oughtred also used the colon : to denote a ratio.

Others of his published works were on watch-making, solving spherical triangles by the planisphere and methods to determine the position of the Sun.

The cause of Oughtred's death is apocryphally attributed to the excitement and delight he felt on hearing that the House of Commons had voted for the King's return to power (the Restoration) – this is somewhat discredited by the date of his death. More plausible is the idea that he died of old age, since he was 86 years old at his demise. He is perhaps one of the lesser known of English mathematicians, yet it is to Oughtred that the present mathematical world owes so much. His slide rule made arithmetical calculations very swift to perform and his two main texts, *Clavis Mathematicae* and *Trigonometrie*, are responsible for the methods and treatment of arithmetic, algebra and trigonometry with which today's mathematicians are so familiar.

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The Mathematics of Secrets
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I really enjoy those whodunit stories set in Tudor times. In the one I have just finished the hero is living in Paris and wishes to convey a message to Sir Francis Walsingham to inform him of a Catholic threat against Elizabeth I. The cipher he uses replaces each letter of the message by ones in different books. This is a system which Holden refers to early in his account of cryptography (the writing of ciphers and codes) and cryptanalysis (the breaking of those codes).

The early chapters give a gentle introduction. The simple process of replacing letters by shifting them along the alphabet is familiar to us all and dates to Julius Caesar. Holden explains how the strength of the cipher depends on the factors of the number of letters in the alphabet and so concepts of modular arithmetic and composite numbers are introduced. Very quickly he makes use of Euclid's algorithm to find greatest common divisors and how these relate to the strength of the cipher. The reader learns about polyalphabetic ciphers in which more than one letter may have the same cipher. Frequency analysis of letters in a language is explained and how this, combined with the use of lowest common denominators, leads to more efficient cryptanalysis. The historical context from Alberti in the 15th century through Babbage in the 19th century to Friedman in the 20th century gives a richness to the text.

Holden gives detailed explanations of mechanical and electrical devices engaged in cryptanalysis, especially the famous Enigma machine. Transposition ciphers from those used in ancient Sparta to contemporary methods are dealt with embracing the mathematics of factorials, permutations, probability and variance. By Chapter 4, Holden considers the use of computers in cryptology. This requires explanations of number bases and binary codes. Interesting is why, for example, 56 bit codes were used instead of 128 bit ones. The reader then engages with recurrence relations to understand stream ciphers, and then modular arithmetic and Fermat's little theorem to understand codes. This leads on to public encryption and the RSA (Rivest, Shamir, and Adleman) process. Holden finishes by discussing the concepts of quantum computers and lattice based cryptology which gives rise to concerns about internet security of the future and the importance of finding new mathematical techniques.

This book is a very comprehensive, if not exhaustive, review of the history and development of cryptology. It is written with a real sense of passion and enthusiasm. Though the style is relaxed and readable some of the detail requires some in-depth thought by the reader. For anybody interested in codes and ciphers this is an excellent book. To mathematicians, it provides some real world applications of number theory and probability.

John Sykes

Developing Fractions Knowledge
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This is the fifth and newest book in the *Mathematics Recovery* Series and is a detailed guide to a progressive approach to assessment and constructivist teaching. The opening chapter sets the scene for the whole book giving scenarios and principles for teachers to use in class. This includes organizing progression into topics and enhancing the mathematical knowledge of pupils.

The next couple of chapters look at alternative approaches for pupils rather than memorizing a whole series of rules that, to most, don't make much sense. There is an assessment tool for teachers to identify pupils' stages of unit measure coordination and is similar to the bars method from the previous chapter (often we hear about the Singapore bar method). These are set out in tasks which can be used directly in a classroom.

The remaining chapters are the developmental progress from the notion of early number concepts through to multiplying and dividing fractions finishing with algebraic fractions. The chapters follow a similar pattern being split into three sections – an overview of the topic, assessment tasks to find out exactly where a pupil is in their learning and finally five instructional activities to improve the learning of that topic. In all, there are 39 assessment tasks and instructional activities so plenty for all teachers!

The book concludes with further references and an index. There is also a three-page glossary which I have to admit to referring to a couple of times as some terms were different from terms I would use. The full colour throughout enhances the diagrams to make the question, task or concept clear. Everything is broken down in clear and concise explanations and no matter the mathematical background of a teacher, this book is accessible to all, primary and secondary.

Chapters can be read individually, but I would advise having a pencil and paper close by to take notes as many other ideas came to mind while reading it. Even as simple as variations to suit the class I would use these methods with. All in all, it was an enjoyable book and I think would be a worthwhile investment for a department, even to use parts of it during departmental meetings for discussion.

N. G. Macleod