

# Falconer's Cryptology

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**Abstract** *Cryptomenysis Patefacta* by John Falconer is only the second text written in English on the subject of cryptology. We will examine what types of ciphers Falconer addressed, and pay particular attention to some of the math he used. We will also look at what can or can't be said about John Falconer himself.

## 1 Introduction

In *The Codebreakers* (Kahn 1996, pp. 155–156) David Kahn states that *Cryptomenysis Patefacta; Or, the Art of Secret Information Disclosed Without a Key. Containing, Plain and Demonstrative Rules, for Decyphering*, written by John Falconer and first published in 1685, was only the second text printed in English on the subject of cryptology. Kahn goes on to say that Falconer had made a

... praiseworthy assault on that old bugbear polyalphabetic substitution.

and had given the

... earliest illustration of a keyed columnar transposition cipher ...

In the next paragraph Khan states that the texts on cryptology from this time period “have a certain air of unreality about them” and that the “authors did not know the real cryptology being practiced.” But, he seems willing to exclude John Falconer from this comment. It should be noted, however, that in his text Falconer never actually takes credit for deciphering any particular cipher of any importance.

Falconer's work was significant enough to still be read or at least referenced over the next century and a half, though occasionally with criticism not praise. For example, William Smith referenced Falconer's work in *A Natural History of Nevis, and the Rest of the English Leeward Charibee Islands in America* (Smith 1745 p. 253) published in 1745, stating that he had considered republishing the text as it had become rare and difficult to find. Later in 1772, Philip Thicknesse in *A Treatise on the Art of Decyphering, and of Writing in Cypher: With an Harmonic Alphabet*

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(Thicknesse 1772) referenced Falconer in a number of places, later still Falconer and *Cryptomenysis* are listed with other authors and works in the entry on ciphers in the 1819 printing of the reference *Pantologia: a new cabinet cyclopaedia...* (Good et al. 1819). He was even referenced, along with other works, by H.P. Lovecraft in 1928 in “The Dunwich Horror.” (Lovecraft 2011, p. 258). Thus, while not perhaps as significant and well known as other works and authors, Falconer and *Cryptomenysis* seem to have been widely enough read and referenced that both Falconer and his work are worthy of closer examination.

## 2 Dating Falconer’s Work

The publication date in Falconer’s text is 1685, with a second printing in 1692. Therefore, we know when the text was published, but not necessarily when it was written. In *The Codebreakers* (Kahn 1996, pp. 155–156) Khan states that *Cryptomenysis* came out posthumously in 1685, after Falconer had followed King James II into exile in France where he died. The implication seems to be that Falconer wrote the text before, perhaps long before, it was published.

James Stuart (1633–1701), Duke of York and later King James II of England, went into exile for the first time from about 1648 to 1660. During this time he did serve with the French Army. His second period of exile occurred between 1679 and 1681 after he was accused, due to his Catholicism, of being part of a popish plot to assassinate his brother Charles; a plot that never in fact existed. However, this exile was largely in Brussels and Edinburgh, not France. Finally, in 1688 James II, who had now been king for 3 years, was overthrown in the Glorious Revolution and went into exile in France for good in 1689.

So if Falconer’s work was published posthumously and he died in exile in France with James, he must have written his work prior to or during James’s earlier exile, 1648–1660. However, there are some issues in accepting this date range for when Falconer could have written *Cryptomenysis* (many of which are pointed out in by Tomokiyo on his website (Tomokiyo 2014) and which we discuss below). In particular the first edition of the text is addressed to Charles Earl of Middleton and secretary of state for King James II; this is an office Charles assumed in 1684. This would seem to imply almost immediately that the work must not have been written long before its publication. However, it could be the case that this preface was not written by Falconer but added by the publisher to appeal to the current ruler, so let us proceed.

### 2.1 References Within *Cryptomenysis*

Within his text, John Falconer references a wide variety of other works on cryptology. Two repeatedly referenced works are by John Wilkins and Gaspar Schott. When Falconer refers to Wilkins’ writing it is generally to disparage it and

to point out ways in which the proposed ciphers could be easily broken. Wilkins' work (Wilkins 1694) was originally published anonymously in 1641, thus references to Wilkin's work do not contradict the possibility that Falconer wrote his work in the 1640's or 1650's. However, when Falconer refers to Wilkins himself it is as Bishop Wilkins, and John Wilkins (1614–1672) did not become Bishop of Chester until 1668. Falconer also refers in many places, and with more respect, to Gaspar Schott's *Magia universalis* (Schott 1657) and his *Schola steganographica* (Schott 1665) published in 1665. Thus these references push the date of writing to 1668 or 1669 at the earliest.

## 2.2 *Motivation for Cryptomenysis*

In discussing his motivation for writing his work Falconer expresses his regrets that it is necessary for men to keep secrets, but that it is the case that princes and kings may have need of secrecy. To highlight this point he refers to the recent rebellion by the late Earl of Argyll as described in "An Account of Discoveries Made in Scotland" which was written by George Mackenzie and published in 1685.

Archibald Campbell, the ninth Earl of Argyll, lived from 1629 to 1685. He rebelled against the government/crown of England twice, once in 1681 and again in 1685. The first time he was able to escape to exile, but the second time, when he returned with the intent of overthrowing King James II in favor of the Duke of Monmouth, he was captured and executed. One of the reasons that Falconer refers specifically to this rebellion is because among the Earl's letters were some which were enciphered and had proved difficult to crack.<sup>1</sup> Thus we see the motivation for Falconer's emphasis on analysis as well as encipherment. In fact, there are no less than eight references to the Earl of Argyll and his rebellion against the crown.

Given the frequency with which the late Earl of Argyll is mentioned, it seems unlikely that the text was written prior to 1685. In fact, since Argyll was executed in June of 1685 and Falconer frequently refers to him as the *late* Earl of Argyll it is tempting to place the writing of, or at least completion of, *Cryptomenysis* in the second half of that year. However, in an issue of the London Gazette from May 1685 (Gazette 1685, p. 2) Archibald Campbell is also referred to as the late Earl of Argyll so it is possible that Falconer was referring to the fact that he was no longer Earl, not that he was dead.

While it might have been possible, or even likely, that a later editor or compiler would have changed one or two references, or could have written a new introduction it seems unlikely that they would have rewritten large portions of the text. Based both on the references and the stated motivation in the text it seems likely that it was written not long before it was published. Thus, we can narrow down the writing of

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<sup>1</sup>The Earl's letters were decrypted by a Mr. Gray of Crichtie, later Lord Gray.

the text to between 1681 (if a new introduction was written) and the end of 1685. But what can we say about Falconer's life and the claim that the work was published posthumously?

### 2.3 *Falconer's Biography*

In *The Codebreakers* we find very little information about Falconer and when he seems to have lived (Kahn 1996, pp. 155–156). The source for what little information there is comes from a text in the New York public library labelled *Falconer's Writings* published in 1866 and written by Thomas Falconer. In the appendix to *The Codebreakers* it states that Falconer is not listed in any of standard histories concerning King James including *The Memoirs of James II: His Campaigns as Duke of York*. Neither is Falconer mentioned in either volume of the *Parochial Register of Saint Germain-en-Laye: Jacobite Extracts of Births, Marriages, and Deaths* (Lart 1910) which would seem to indicate that if he did go into exile with James in 1689 then he was not a central member of James's court. Also, in a search of names indexed in Charles Middleton's papers in the British Library and National Archives, Falconer is not listed. So it would seem that John Falconer will be a hard man to get a hold of; let us begin to try by looking at the writings of Thomas Falconer.

Thomas Falconer is apparently a descendent of John Falconer, a great great grandson to be precise. In the mid-nineteenth-century Thomas wrote a number of texts concerning his ancestry, these include (Falconer 1860, 1870) which are largely genealogical, containing general notes, baptismal records, some wills, and records of what is written on monuments. Thomas also compiled a bibliography of his family's writings (Falconer 1866) which is one of the sources listed for many of the Falconer entries in some volumes of the Dictionary of National Biography (Stephen and Lee 1889). In (Falconer 1860, p. 59 in the e-copy), we find the quote:

This John Falconer was entrusted with the private cypher of James II whom he followed to France where he died

which is the information we had looked at previously. However, Thomas goes on to tell us that John was married to Mary Dalmahoy (1663–1754) on February 14th 1681. Thomas also tells us of Mary and John's children, in particular their son William, Thomas's great grandfather, who became the recorder of Chester and died in 1764 at the age of 65. Curiously, only dates of death and ages are listed for three of Mary and John's four sons. Their first son, born shortly after they married, died young. The other sons, based on the information given, seem to have been all born after 1690 with William, the youngest, born around 1699. Thus, based on the information given to us by Thomas, assuming his facts are accurate, it is impossible for John Falconer to have died prior to the publication of either edition of his text. However, given the lack of birth records for his sons it is possible that they were not born in Scotland or England but in exile with their father in France (though clearly this is not the only possibility).

What is missing from Thomas Falconer's works is any specific reference to John Falconer's parentage. In (Falconer 1860) he lists the baptismal records for several John Falconers, two or three of whom may be the one we are interested in. Based on what we know so far, his marriage date and the dates for his son's lives, the most likely John Falconer that Thomas lists was born to John Falconer and Elizabeth Cant on February 15, 1650. However, if we try to verify that this is the correct John (or Johne as he is sometimes listed) through a database such as Ancestry.com, we are stymied. There are records available for John and Mary's wedding and for the deaths of some of their sons and for Mary (but not John). There are records of a John being born to John Falconer and Elizabeth Cant in 1650, but there is nothing to connect the two. In fact a search for birth and baptismal records for John Falconer in Scotland in the mid to late seventeenth century returns several hundred hits. So, the question becomes what can we know and verify beyond what Thomas wrote down nearly two hundred years later?

For starters the monument inscriptions that Thomas quotes, at least for John and Mary's sons Thomas and William, can still be viewed today. Also, Thomas's comments about John's writings are identical to what was said about him in an obituary for another Thomas Falconer from April 1839 (Pickering 1839, p. 436) and one for a William Falconer in 1825 (Longman et al. 1825, p. 413). It is possible that these were written by Thomas himself, or that he has the same source (likely someone in the family) as the obituaries, but it is still worth noting that they predate his work by over 30 years. Finally, searching for official government records we find Edinburgh poll tax records from 1694–1699, in these is a record of a John Falconer and Mary Dalmahoy living in the same location at that time (Poll Taxes 2014). This last piece of evidence is one of the most interesting since it was not mentioned by Thomas Falconer in (Falconer 1860, 1866, 1870) and places John in Scotland at least 2 years after the second printing of *Cryptomenysis* and 5 years after James II went into exile.

Given the evidence at hand, if it is accurate, we may conclude that *Cryptomenysis* was likely written between 1681 and 1685, more likely in 1685. John Falconer definitely seems to have been alive at the time the work was published. And, it is not immediately clear that he went into exile in France and died there (though there is a general lack of evidence on his life).

### 3 Contents of *Cryptomenysis*

#### 3.1 Overview

Falconer's text is broken into the five chapters:

- Chapter I: Of Secret Writing and the Resolution Thereof
- Chapter II: Of Secret Information by Signs and Gestures and its Resolution
- Chapter III: Of Cryptology or the Secrecy Consisting in Speech

- Chapter IV: Of Secret Means for Conveying Written Messages
- Chapter V: Of Several Proposals for Secret Informations Mentioned by Trithemius in His Epistle to Arnoldue Bostius, & c.

The first four chapters cover various aspects of cryptology while the fifth is a discussion/defense of the work of Johannes Trithemius, a sixteenth century clergymen and cryptologist who had been accused of dabbling in the occult. Our focus will be on chapter one. We will look at what he covers and how he covers it, with special attention to some of the mathematics he touches on.

Chapter one is divided into six sections and in these Falconer covers all of the following methods of conveying secret messages:

- Basic Monoalphabetic Ciphers
- Polyalphabetic Ciphers
- Keyed Columner Transpositions (by word and by character)
- Hiding the intended message inside an innocuous message
- Transcribing text into a binary or trinary alphabet
- Transcribing text into multiple fonts
- Omnia Per Omnia (where any cipher text may represent any text)
- Shorthand
- Scytale and similar
- Secret inks and such

For each he is careful to, where appropriate, give a reference for where he gathered his information. Also, unlike some earlier authors, he is very careful to give examples of how one might attempt to break the ciphers he is presenting. Further, he takes the time to explain even some of the basic mathematics that he employs with respect to either enciphering or deciphering.

### 3.2 *Specific Examples*

Falconer discusses the use of permutations, prime factorizations, and the multiplication principle. Permutations (which he calls combinations) first appear when he calculates the number of possible keys which could be used for a monoalphabetic substitution cipher. He correctly gives this number as 620448401733239439360000 (which is  $24!$ , since he was using to the 24 character Latin alphabet of the time) and references *Schola Steganographia* and *Magia Universalis* by Gaspar Schott ( $\approx 1665$ ) as his source for this. However, Falconer then proceeds to give the reader a way to try and understand exactly how large this number is:

For if one writer in one day write forty pages, every one containing forty combinations, 40 multiplied by 40, gives 1600, the number he completes in one day, which multiplied by 366, the number of days (and more) in a year; a writer in one year shall compass 585600

distinct rows. Therefore in a thousand million years he could write 58560000000000, which being again multiplied by 100000000, the number of writers supposed, the product will be 5856000000000000000000, which wants the number of combinations no less than 34848401733239439360000. (Falconer 1685, p. 5)

Later in his text Falconer carefully discusses permutations of letters for a given number of letters and he discusses prime factorizations both of which he then proceeds to use in his exploration of keyed-columnar transposition ciphers.

He begins by giving the number of ways we can arrange any number of letters into different permutations:

Letters	—	Several ways
1	May be combined	1
2		2
3		6
4		24
5		120
6		720
7		5040
8		40320
9		362880
10		3628800
11		39916800
12		479001600
&c.		

However, he does not stop at just providing the table. Falconer spends three pages carefully walking us through how to generate each new row from the last. For example once we know that there are two combinations of two letters, *AB* and *BA*, he observes that:

From the Combination of two Letters we find that of 3, for the new Letter added is three times applicable to the former Positions, viz. in the beginning, middle, and end. . . (Falconer 1685, p. 39)

And, thus we get *CAB*, *ACB*, *ABC*, *CBA*, *BCA*, and *BAC*, which are the six possible combinations of these three letters. He proceeds to describe this process for four and five letters as well.

Once we know all the ways to arrange letters he introduces “*A new Method how to Write Secretly by the Art of Combinations.*” First we pick some number of letters, say three, and then some subset of all the possible combinations of those letters. We set these out in a table as follows:

Order of positions		A	B	C
1	CBA			
2	CAB			
3	ACB			
4	BCA			
5	BAC			

so that the combinations of letters at the side indicate the order in which we should fill the columns of each row. To send a message such as “*The quick brown fox jumps over the lazy sleeping dog,*”<sup>2</sup> we fill the table from top to bottom writing the letters one at a time in the order indicated by the combination key for each row. So, in the first row we write down the “*The*” with the “*T*” under the C, the “*h*” under the B, and the “*e*” under the A, because the key for that row is CBA.

Order of positions		A	B	C
1	CBA	E	H	T
2	CAB			
3	ACB			
4	BCA			
5	BAC			

In the next row we put down the “*qui*” with the “*q*” under the C, the “*u*” under the A, and the “*i*” under the B, because CAB is the key for the second row.

Order of positions		A	B	C
1	CBA	E	H	T
2	CAB	U	I	Q
3	ACB			
4	BCA			
5	BAC			

The remaining “*ck*” from “*quick*” and the “*b*” from “*brown*” are placed in the third row in columns A then C then B since the key there is ACB.

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<sup>2</sup>This is not Falconer’s example but a shorter one which was chosen for demonstration purposes.



Order of positions		A	B	C
1	CBA	E	H	T
2	CAB	U	I	Q
3	ACB	C	B	K
4	BCA			
5	BAC			

We proceed row by row in this manner until all the rows are filled.

Order of positions		A	B	C
1	CBA	E	H	T
2	CAB	U	I	Q
3	ACB	C	B	K
4	BCA	W	R	O
5	BAC	F	N	O

Once each row is filled we return to the top and start the process over with the remaining message. So, the remaining "x" from "fox" will go in row one column C and the "ju" from "jumps" goes in columns B and then A.

Order of positions		A	B	C
1	CBA	EU	HJ	TX
2	CAB	U	I	Q
3	ACB	C	B	K
4	BCA	W	R	O
5	BAC	F	N	O

This process of writing down the message letter by letter in the rows according to the order given by the key for each row proceeds until the message is completely copied down.

Order of positions		A	B	C
1	CBA	EUS	HJY	TXZ
2	CAB	UPE	ISE	QML
3	ACB	COP	BEN	KVI
4	BCA	WHO	RRG	OTD
5	BAC	FL	NEG	OA

The enciphered message is then written out from left to right and top to bottom as follows:

Δ ÈUS HJY TËZ UPE ÍSE QML COP BEN ĶVI WHO RĚĜ OTD FL ÑÈĜ OA

where the triangle is to tell your compatriot how many letters were in your combinations and the dots indicate terminal letters in words. He remarks that these markings aid in decipherment, which he demonstrates, but then he also shows us how we may decrypt such a message without the markings.

If we do not know the number of letters in the key (i.e., the number of columns), but we do know the method of encipherment, we may make an educated guess by examining the divisors of the number of groups of letters. To aid in this Falconer gives a complete process for finding all the divisors of a number. Supposing there are 450 groups of letters, he begins much as we might today by finding the prime divisors, though he uses a table instead of a factor tree. Each time we divide by a prime factor we write the prime underneath the number we are currently factoring and write the result of the division at the top of the next column. In this way factoring 450 gives us this table.

450	225	75	25	5	1
2	3	3	5	5	

He then walks us through a very nice way of delineating all of the possible factors of the number we are interested in, not just the prime factors. He begins by making a new table and writing out all the prime factors with repetition as the headers of the columns. Then he tells us to, starting with the second column, multiply the header for each column by all the numbers to its left by which it has not already been multiplied and write this down in that column. Under the 3 at the top of the second column we place a 6 since  $3 \times 2 = 6$ , then under the 3 at the top of the third column we place a 9 for  $3 \cdot 3$  and an 18 for  $3 \times 6$  but not a 6 for  $3 \times 2$  because we already wrote that product down in the previous column. Working from left to right this process will give us all the possible factors:

2	3	3	5	5
	6	9		
		18		
			10	25
			15	50
			30	75
			45	150
			90	225
				450

Since we supposed that there were 450 groups of letters, the number of letters in the key for the cipher must be one of these factors.

In our example there are 15 letter groups so the factors are:

3	5
	15

Assuming it would be pointless to have a 1 letter key and silly to have a 15 letter key, there must have been either 3 or 5 letters in the key.

Curiously, after going through all this trouble to find potential key lengths Falconer uses a completely different method to crack the cipher. He writes each letter group from the enciphered message

Δ ÈUS HJÝ TǪZ UPE ÍSE QML COP BEN ĶVI WHO RRĠ OTD FL ÑÈĠ OA

vertically so that we get the following array:

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	E	H	T	U	I	Q	C	B	K	W	R	O	F	N	O
2	U	J	X	P	S	M	O	E	V	H	R	T	L	E	A
3	S	Y	Z	E	E	L	P	N	I	O	G	D		G	

He does this because he recognizes that the first letter of each group (now all in the top row) were the first letters written down. Likewise those in the second row were written down on the second pass through the array and the third row were written down on the third pass through (which explains the blanks). Now we can treat each row as an anagram. When we find a word we can rearrange the columns that the letters of the word are in and we should start to see words under the ones we found. Eventually all these should hopefully give us the message. In our example in the first row we see the *E*, *H*, and *T* that could be the word *THE*. There is also a *Q* that should be with a *U*. Arranging the columns appropriately we get:

	3	2	1	6	4	5	7	8	9	10	11	12	13	14	15
1	T	H	E	Q	U	I	C	B	K	W	R	O	F	N	O
2	X	J	U	M	P	S	O	E	V	H	R	T	L	E	A
3	Z	Y	S	L	E	E	P	N	I	O	G	D		G	

The presence of the word *JUMPS* in the second row and *SLEEP* in the third assures us that we are on the right track. We can also see that the second word in the first row should probably be *QUICK*. Proceeding in this way we complete the message:

	3	2	1	6	4	5	7	9	8	11	12	10	14	13	15
1	T	H	E	Q	U	I	C	K	B	R	O	W	N	F	O
2	X	J	U	M	P	S	O	V	E	R	T	H	E	L	A
3	Z	Y	S	L	E	E	P	I	N	G	D	O	G		

This example is typical of all of Falconer's explanations. He carefully explains and demonstrates not only how to encipher a message but also how to decipher and, if need be, how to decrypt messages. Along the way he always tries to demonstrate to the reader the whys and hows of the work he is doing.

## 4 Conclusion

John Falconer's *Cryptomenysis* is an interesting study in the history of cryptology for a variety of reasons. Though he was an amateur<sup>3</sup> he still presented a broad view of cryptology including both enciphering and decrypting. His exposition is clear and generally thorough, covering background material, such as the mathematics discussed earlier, when needed. Also, given his stated motivations for undertaking this project and his attitude toward the ninth Earl of Argyll (who he clearly considered a traitor) and Bishop John Wilkins (whose work he did not seem to respect) his text presents some interesting connections to the history of the time.

In this article I focused on only the first chapter of *Cryptomenysis* and on John Falconer's life, therefore there is still plenty of material left to investigate. In particular, there is still little known about John Falconer himself; any further information about him will likely need to come from the papers of those around him; Charles Middleton to whom he addressed his text, his children or grandchildren who seem to have gone on to have successful lives, his very long lived wife, or her family. His numerous reference, both cryptologic and historic, offer various avenues for further study.

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<sup>3</sup>As opposed to individuals like John Wallis, Thomas Phelippes, and the Rossignol family who had been directly employed by royalty in England and France for their skills.

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