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*MA Talk,  
Andrew Wiles Building,  
Oxford.*

Ahnentafel  
Numbers,  
Ancestry &  
Succession to  
the Crown.

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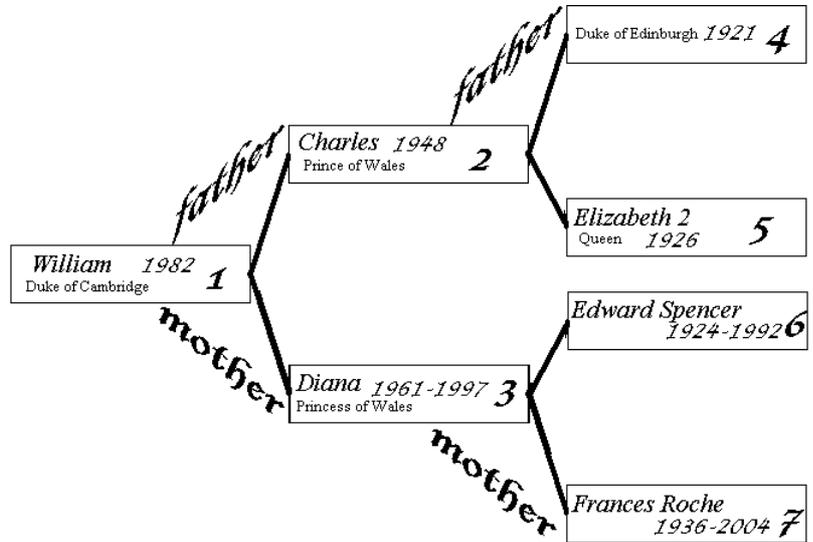
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## Ahnentafel Numbers

Many people are interested in tracing their relatives and their ancestors going back many generations. There are various ways of recording this data, some using some sort of diagram and some using just text. Using text is particularly convenient if one wants to circulate or print out the information.

One way of doing this is to give all our ancestors an Ahnentafel (German for *ancestor table*) number. This system is also called the *Etyzinger* method, or the *Sosa* method, after genealogists who used this method. To see how it works let us consider Prince William and his parents and grandparents. We could display this on a diagram as follows.

All those from the same generation are in a column, with the youngest generation on the left. Reading across we read **up** to see each person's **father**, and read **down** for each person's **mother**. The large numbers in each box give the **Ahnentafel number**, they start at William (or the subject of the table in general) having number one, then we read across and down giving each person the number as shown. Continuing in this way, we see that the father of the Duke of Edinburgh would be 8, his mother 9, so that King George 6<sup>th</sup> (father of the queen and subject of the *King's Speech*) would be 10 etc.



If one looks up Ahnentafel number in Wikipedia, they list Williams ancestors up to number 127, who

was Katharine Forbes (1812-1893). Queen Victoria (1819- 1901) is given as having Ahnentafel numbers of both 79 and 81. We could write this as  $79 \equiv 81$ . It also says that Ahnentafel numbers 78 & 80 represent the same person, that is  $78 \equiv 80$  and also  $82 \equiv 32$  and  $83 \equiv 33$ .

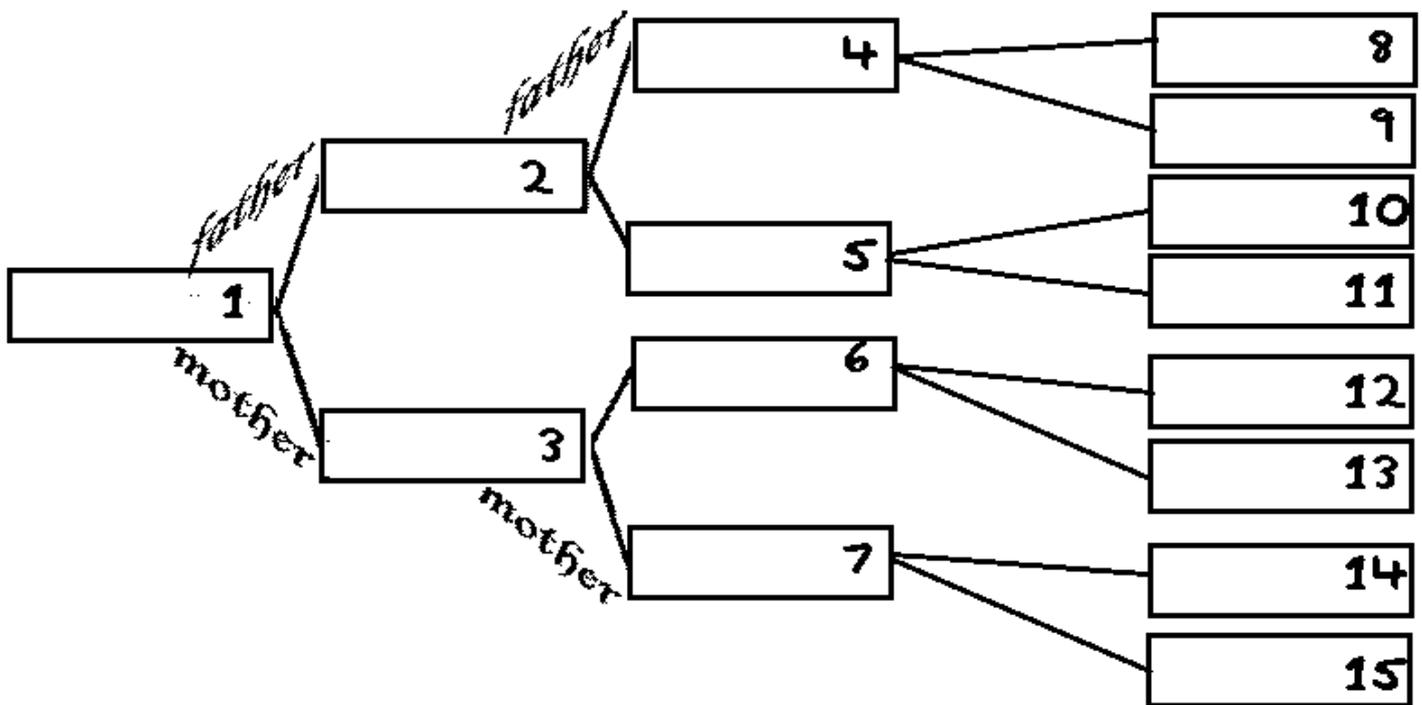
Wikipedia also gives similar short ancestry tables for many of the subjects of its entries.

Binary representation of numbers is useful here. As a reminder, the binary equivalents for the first few numbers are;

Number	1	2	3	4	5	6	7	8	9	10	11	12	13
Binary	1	10	11	100	101	110	111	1000	1001	1010	1011	1100	1101

### The reader might like to answer the following questions;

1. What is the Ahnentafel number of the late Queen mother?
2. What are the Ahnentafel numbers of the Queen Mother's parents?
3. What can be deduced about a person (other than the subject, person 1) whose Ahnentafel number is (i) even , (ii) odd?
4. If a person has a Ahnentafel number of  $x$ , in any such table what is the Ahnentafel number of their (i) father (ii) mother?
5. In the Wikipedia table, going up to person 127, how many generations of ancestors does this represent for William (not including himself)?
6. Men inherit their chromosome Y from their fathers. What is the Ahnentafel numbers of all those who have the same chromosome Y as the male subject of the table? Women do not have a Y chromosome.
7. We all have Mitochondria in our cells, with their own DNA, but we inherit this DNA only from our mothers. What is the Ahnentafel numbers of all those who have the same mitochondrial DNA as the subject of the table?
8. As  $80 \equiv 78$ , what other Ahnentafel numbers **must** be equal for William's table?
9. Which other person(s) will have exactly the same ancestor table as William?
10. If the subject of the table were Queen Elizabeth 2<sup>nd</sup>, what would be the Ahnentafel number(s) of Queen Victoria in her table?
11. We see that  $80 \equiv 78$ , and  $81 \equiv 79$ . Why is it likely that if one pair of numbers represent the same person, there will be another pair. If, in a different ancestor table  $68 \equiv 86$ , what other pair are likely to be equal? Why is it not certain that these two will be equal?
12. In a similar tree would it be possible for (i)  $4 \equiv 6$  (ii)  $2 \equiv 6$ ? If so what would these mean?
13. Which of the following will have Ahnentafel numbers in William's tree, and what are the values of those that exist? (i) George 3<sup>rd</sup>. (ii) James 1<sup>st</sup> England, and 6<sup>th</sup> of Scotland. (iii) Henry 8<sup>th</sup>. (iv) Henry 7<sup>th</sup>.
14. William and Kate have two children, George and Charlotte, what would be the Ahnentafel number of Queen Elizabeth 2<sup>nd</sup>, in George's tree? What about in Charlotte's tree?
15. Using just the information given, what was the relationship between the Duke of Edinburgh and Queen Elizabeth 2<sup>nd</sup> before they married? (I know that neither person had that title then, but the reader will know who we mean. We don't just mean fiancée.)
16. For your own parents and grandparents, write down names, dates, and other information corresponding to Ahnentafel numbers 1, 2, 3, 4,....., and fill in the diagram on the next page as far as you can



In case you haven't already realised, when the Ahnentafel numbers are written in binary, they give a simple link to the ancestry of a person. The first (most left) digit is always one, then reading from left to right, zero means father and one means mother, so 1011, means father's mother's mother, which for William, is Charles mother's mother, that is the late Queen mother.

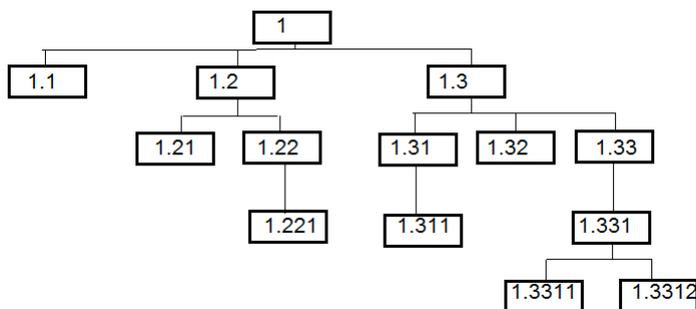
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### Numbering of Relatives.

The Ahnentafel number gives all ancestors a position in a list. When we have found the information on these people, then this could either be stored on cards, or if using a computer, we could use either a standard word-processing or a spreadsheet program, for example *Excel*.

Now, of course, not all our relatives are ancestors, and it is also possible to draw a descendant tree.

As each person always has two parents an ancestor tree always has the same structure for anyone. However a **descendant** tree will have a different structure for different people, and a typical one is shown below.



This also shows a possible numbering system. The starting person is again numbered one, each of their children is assigned the numbers 1.1, 1.2, 1.3 etc in birth order. This is then repeated down the generations as shown in the diagram. We don't know the sex of person 1.3311, but we do know that they are four generations younger than the starting person. That is 1 is the great-great grandparent of 1.3311. The *Henry* system of numbering descendants is similar. We also know birth order from these numbers, but with the Ahnentafel numbers we knew the gender, but not

the birth order of each person. If a person has more than 9 children, then this system needs to be modified, as we would run out of digits. Originally Henry suggested X for the 10<sup>th</sup> child, then A for the 11<sup>th</sup>, B for the 12<sup>th</sup> etc. To fit in with some computer notation systems others have used A for the 10<sup>th</sup>, B for the 11<sup>th</sup> etc. Others have suggested using brackets, so 1.(13) would be the subject's 13<sup>th</sup> child etc, with their 15<sup>th</sup> child being 1.(13)(15). Working with today's families, this is likely to be less of an issue.

The *Dollarhide* system puts these two systems together, so that remembering that person with Ahnentafel number 4 is our paternal grandfather, 4.1 is his oldest child, so is either our father, or an uncle or aunt. Person 4.32 would therefore be either ourselves, or a sibling, or a cousin. So this system is using a decimal number, where the whole number part is going up (older) in the generations, and the part after the decimal point is coming back down the generations. More information is available on the internet about these various systems. But I want to suggest something further, giving someone a number like 1.11.6.1. Normally, of course we only have one decimal point in a number, and the actual separator we use is arbitrary. So it might be clearer to write this number as 1.11;6.1.

So what does this mean? Well person 1.11 is the subject's oldest grandchild (actually the oldest child of the subject's oldest child, not quite the same thing). So 1.11;6 is their maternal grandfather, and so 1.11;6,1 is the latter's oldest child.

I also wish to suggest an alternative way of dealing with large numbers of children in a family. If using Excel, the automatic sort will order, say 14.7, 14.71, 14.8, 14.9, 15 correctly, but 14.A will be treated as text so would not be put in the most appropriate place. I would therefore suggest the following numbering of large families.

We number the **eighth** child of person 14 as **14.8.**, then the **ninth** is **14.91**, the **tenth** **14.92** etc up to the **16<sup>th</sup>** who is numbered as **14.98**. The 17<sup>th</sup> child would be numbered as 14.991, the 18<sup>th</sup> as 14.992, etc up to the 24<sup>th</sup> who would be 14.998.

Person numbered 14.939956 would represent the 6<sup>th</sup> child of 14.93995, who is the 21<sup>st</sup> child of 14.93, who is the 11<sup>th</sup> child of person 14. Whenever a '9' is seen the next digit(s) to the right should be read with it.

The automatic sort will put these people in place consistent with the rest of the chart. My version of Excel will display a number like 47.1234567891234, that is a maximum of 15 digits. This is going to be sufficient for most people's needs, but if one wanted longer numbers, they would have to be stored as strings, and the sort procedure will be different.

To see how all this works out in practice, the table at the end shows some members of the extended Royal family, using Queen Elizabeth 2<sup>nd</sup> as the subject. Note that we do not need to specify spouses explicitly as, say the Duke of Edinburgh automatically appears Charles' (1.1) father, so 1.1;2. If a couple have several children together, then 1.1;2≡1.2;2 etc. If in a table, 1.1;2 and 1.2;2 were different then both 1.1 & 1.2 would be children of person 1, but they would have different fathers, namely they would be half siblings.

To show spouses of childless couples, we can introduce a fictional child with birth order 0. We then write the spouse as the appropriate parent of this fictional child. Because it is possible to have several childless marriages, we introduce an extra counter after the zero. Again this would cause a potential problem if there were more than nine such marriages, but this is unlikely. To see how to apply this, Edward 8<sup>th</sup>, (the Duke of Windsor) is 4.1, his fictional child 4.10, and as Wallis was his first such wife, we give her the numbering 4.101;3, the final three because she would be the mother of this fictional child. Wallis' parents become 4.101;6 & 4.101;7. In a similar way William is 1.11, and so Kate is 1.1101;3. If they have children then her number will change to 1.111;3. The person with the most complicated relationship shown is Lucy Lindsay Hogg, with a code of 2.21;2.3;3. The reader is invited to make sure that they understand how she is related to the others in the table.

It may seem that this coding look very complicated, but trying to explain the same relationships precisely, in ordinary language, will show how efficient they are. This coding uses gender and birth order, but if we were only interested in whether a person is related to us by going up or down the generations we could use a much simpler code. We use / for going up (older) and \ for down (younger) /. Of course any two symbols could be used, U & D if one prefers. This simple code is also shown in our table.

So parents would be /, grandparents //, children \, grandchildren \\. This means that / is a sibling, // a cousin, \ a spouse. A sequence like /////\ with six of each would represent fifth cousins, whilst /////\ would be second cousins three times removed. With this simple notation, it is very easy to reverse the relationship. For example, the subject's great uncle would be ///, and from the great uncle as subject, his great nephew (or niece) would be \\. In the full numbering a great uncle could be 8.2, but we could not reverse this code without knowing more information. The great nephew could be 2.131 or 2.211 for example. With this simpler coding, several people can share the same coding, not possible with the more detailed coding.

*Cousins* mean that we share a set of *ancestors*. First cousins mean that we share some grandparents, second cousins that we share some great grandparents. We could think of Siblings as zero-<sup>th</sup> cousins. We don't have a word for going the other way, so I would like to suggest the word *Nisuooc*, for those who share *descendants*. So Elizabeth 2<sup>nd</sup> and Earl Spencer (Diana's father) would be first nisuoocs. To his father, Elizabeth 2<sup>nd</sup> could be described as first nisuooc, once removed. Spouses are similarly zero-<sup>th</sup> nisuoocs. We could invent another word, *Nissins* to mean that we are related to someone else by a zig-zag up and down path, like say Elizabeth 2<sup>nd</sup> to Lucy Lindsay Hogg. In this case they are of the same generations.

If one just considers ancestors or descendants, we soon run out of people that have been known to us personally. Moving up and down the generations in the way we have considered links together many people who we might actually know. The interested reader might like to draw up a similar table for their own relatives.

This numbering system works well with a spreadsheet like Excel. The people can be entered in any order. The numbering codes are entered in decimal blocks, the whole number part being the Ahnentafel number, and the descendant the decimal. The automatic sort facility in Excel then puts all the people in the required order. This was done with the table shown. Even the simpler code could be used to sort out our relatives into an order. We can also sort into age, birthday, alphabetical order of names, or places. We could use more columns to enter such facts as place of birth, death, current address, qualifications etc, and the sort facility of Excel makes this very versatile. To display all this information on a family tree diagram would be very complicated, and with a little experience one can easily read off family groups from tables similar to that above.

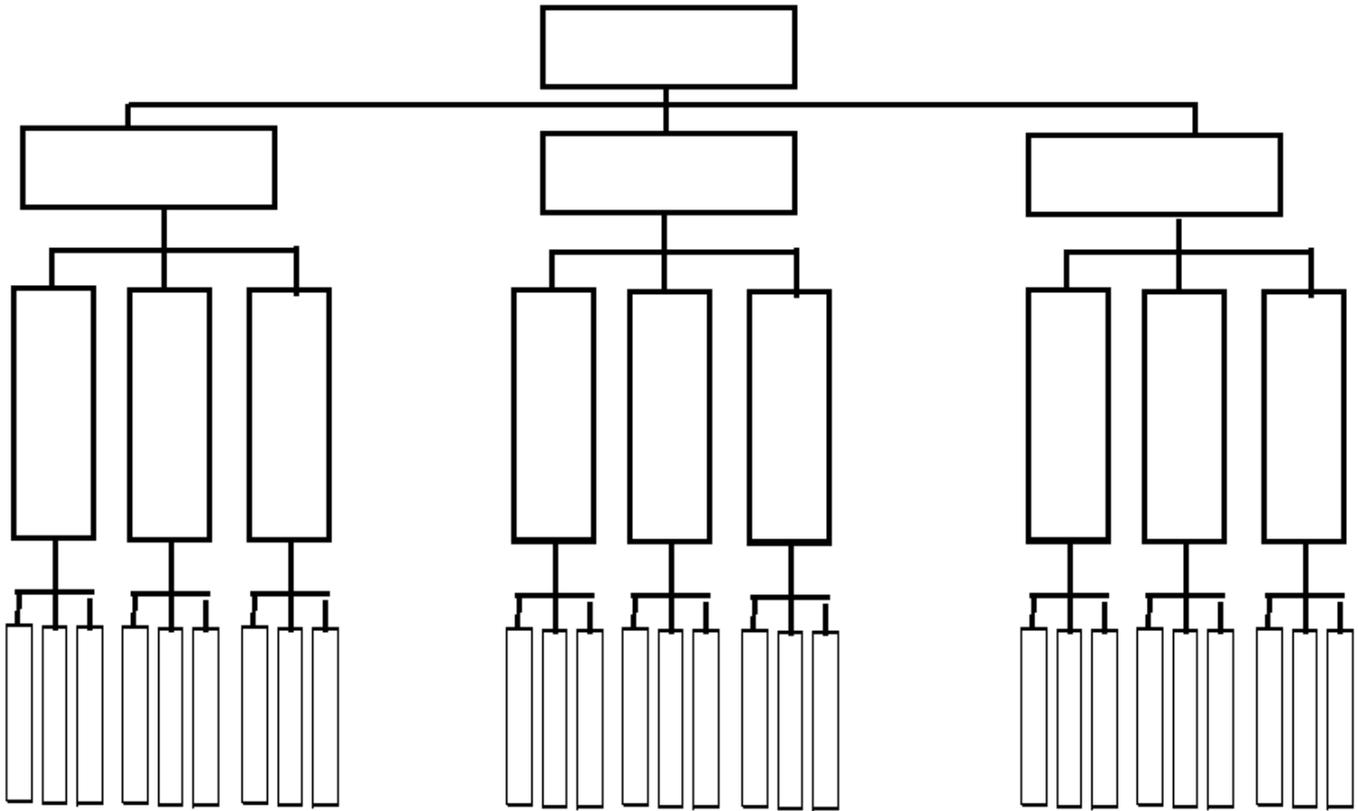
Sometimes children are adopted, so that the people they call mum and dad are not their biological parents. If one wanted to show this, it could be done by say, underlining the appropriate code.

Consider, for example, the case of John & Laura, whose 16 year old daughter, Emily gives birth to a baby, David. John & Laura bring up David as their own, he calls them mum and dad, and he considers Emily his sister. So if David were the subject of a numbering as described above he would have John as 2 or 6, Laura as 3 or 7, and Emily as 2.1≡3.1 or 3. From Laura's numbering, David could either be 1.11 or 1.2.

Table showing the above numbering system applied to some members of the extended Royal family;

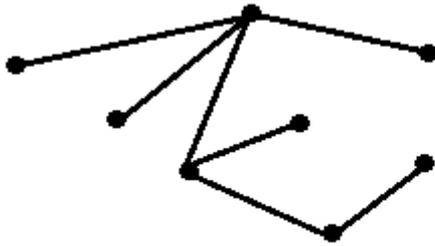
Ahnen1	Ahn2	Ahn 3	Simple code	Person	Born	Died
1				Queen Elizabeth 2nd	1926	
1.1	2		V	Duke of Edinburgh	1921	
1.1			\	Prince Charles	1948	
1.101	3		VV	Camilla	1947	
1.11	3		VV	Diana, Princess of Wales	1961	1997
1.11	6		VVV	Earl Edward Spencer	1924	1992
1.11	6.1		VV^	Lady Sarah McCorquodale	1955	
1.11	6.2		VV^	Jane Fellowes	1957	
1.11	6.3		VV^	Charles Spencer	1964	
1.11	6.4			≡1.11;3		
1.11	7		VVV	Frances Roche	1936	2004
1.11	12		VVVV	Albert Spencer	1892	1975
1.11			VV	Prince William	1982	
1.1101	3		VVV	Kate Middleton	1982	
1.1101	6		VVVV	Michael Middleton	1949	
1.1101	7		VVVV	Carole Middleton nee Goldsmith	1955	
1.12	3			≡1.11;3		
1.12			VV	Prince Harry	1984	
1.2	2		V	≡1.1;2		
1.2			\	Princess Anne	1950	
1.3			\	Andrew	1960	
1.4			\	Edward	1964	
2			/	King George 6th	1895	1952
2.1				≡1		
2.2			^	Princess Margaret	1930	2002
2.21	2		VV	Antony Armstrong Jones	1930	
2.21	2.3	3	VVV	Lucy Lindsay Hogg		
2.21	2.3		VV^	Frances Armstrong Jones	1979	
2.21	2.4		VVV	Jaspar Cable-Alexander	1998	
2.21			VV	David Armstrong-Jones	1961	
2.211			VVV	Charles Patrick Armstrong-Jones	1999	
2.212			VVV	Margarita Elizabeth Armstrong-Jones	2002	
2.22	2		VV	≡2.21;2		
2.22			VV	Lady Sarah Chatto	1964	
3			/	Queen Mother	1900	2002
3.1				≡1 ≡2.1		
3.2			^	≡2.2		
4			//	King George 5th	1865	1936
4.1			V^	Edward 8th	1894	1972
4.101	3		VVV	Wallis Simpson nee Warfield	1896	1986
4.101	6		VVVV	Teacle Wallis Warfield		
4.101	7		VVVV	Alice Montague		

**Exercise.** For one of those ancestors (or someone else you know) you have already listed in question 16 above, write down their descendants names and other information you remember. Fill in the tree on the next page using your own data.

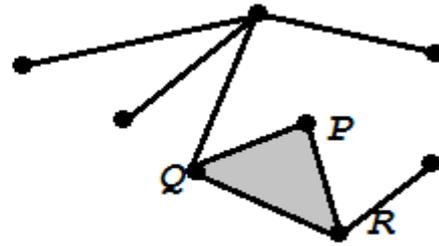


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### Family and other Trees



*A Tree, no circuits nor enclosed regions*

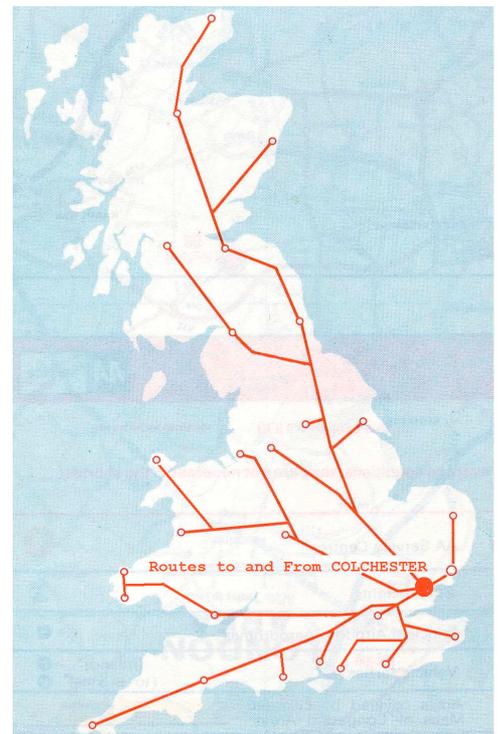


*NOT a TREE*

We have already considered two types of tree sometimes used, one an *ancestor tree* and the other a *descendent tree*. As well as its biological meaning the word tree is also used in Mathematics for a Network of points (called nodes) and lines (arcs) connecting them, provided that there are no circuits. That is there is only **one** route between any two nodes. This is equivalent to saying that the network has **no enclosed regions**. In the diagram, the network on the left is a tree, but that on the right is not a tree. There is the circuit PQR, and this gives an enclosed region (shown shaded).

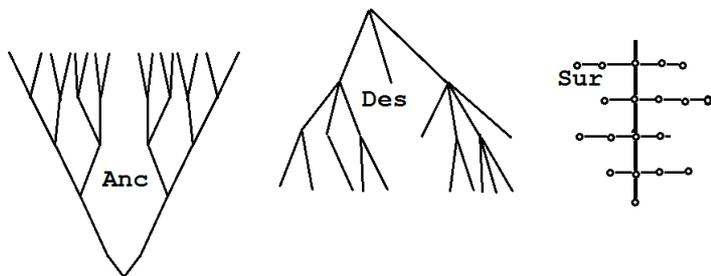
Although the term tree is used for Family tree, if cousins, even distant cousins, marry and have children, then there can be two routes between some people in the diagram, so these are not trees in the mathematical sense. Above we saw that both Queen Elizabeth and the Duke of Edinburgh are descendants of Queen Victoria, this means that there are several routes from Victoria to Prince Charles, in either an ancestor tree or a descendent tree.

The ordinary road or rail networks are not trees, as there are several ways of going from one place to another. If not and a road were blocked then certain places would become impossible to reach! However, if one just considers the best way of going from say our homes, to anywhere else, then a tree is formed. "Best" has to be carefully defined, and it could be shortest route, or quickest



route, amongst other possibilities. Before the days of SatNavs and computer generated routes, motoring organisations used to publish such tree routes, centred on major cities or major ports. The diagram on the right shows such a simplified map, centred on Colchester. Such a map gives the radial routes from the home town, and these are the routes which we are likely to use.

Sometimes an alternative **family tree** is drawn up, I don't know if it has an official name, but I shall call it a **Surname tree**. Below are simplified sketches of Ancestor, Descendent, and Surname trees.



In the Surname tree the subject is at the bottom of a thick trunk. Directly above them is their father, his father, the latter's father and so on. So all those will share the same surname (hence my name for this sort of tree). All these males will also share the same Y chromosome, as this is passed down the male line. The horizontal branches show all the siblings of those on the trunk, so they will also share the same surname (females before marriage, ie their maiden names), and the males will also have the same Y chromosomes. There is nothing sexist here, we can equally well draw up a similar diagram showing all the female lines. In this case it will show all the family members sharing the same Mitochondrial DNA. We all have mitochondrial DNA, but we inherit it only from our mothers.

We can draw one of these trees for the Royal family starting with William, Duke of Cambridge. The trunk directly above him (shown with shaded boxes) shows a line of direct descent. It mainly shows the male line, but not entirely, to show the descent of the Monarchy. Not all those in this line have actually been monarch, and some not in this line have been monarch. The actual monarchs are shown in red (colour version) and bold & italic font. I am sure that readers will see why these people in the trunk and the actual monarchs are not exactly the same.

I have shown Charles and William as monarchs, as at the time of writing, these are most likely to be the next two kings. In some places there was not enough space to show all the siblings, and only full legitimate siblings have been included.

				<b>George 2<sup>nd</sup> 1683-1760</b>	Sophia 1687-1757							
				Frederick 1707-1751	Anne 1709-1759	Amelia 1711-1786	Caroline 1713-1757	George 1717-1718	William 1721-1765	Mary 1723-1772	Louisa 1724-1751	
			Augusta 1737-1813	<b>George 3<sup>rd</sup> 1748-1820</b>	Edward 1739-1767	Elizabeth 1740-1759	William 1743-1805	Henry 1745-1790	Louisa 1749-1768	Frederick 1750-1765	Matilda 1751-1775	
<b>George 4<sup>th</sup> 1762-1830</b>	Fred 1763-1827	<b>William 4<sup>th</sup> 1765-1837</b>	Charlotte 1766-1828	Edward 1767-1820	Augusta Sophia 1768-1840	Elizabeth 1770-1840	Ernest 1771-1851	Augustus Frederick 1773-1843	Adolphus 1774-1850	Mary 1776-1857	Sophia 1777-1848	
				<b>Victoria 1819-1901</b>								
			Victoria 1840-1901	<b>Edward 7<sup>th</sup> 1841-1910</b>	Alice 1843-1878	Alfred 1844-1900	Helena 1846-1923	Louise 1848-1939	Arthur 1850-1942	Leopard 1853-1884	Beatrice 1857-1944	
			Albert Victor 1864-1892	<b>George 5<sup>th</sup> 1865-1936</b>	Louise 1867-1931	Maud 1869-1938	Alex John 1871-1871					
			<b>Edward 8<sup>th</sup> - 1894-1972</b>	<b>George 6<sup>th</sup> 1895-1952</b>	Henry 1900-1972	George 1902-1942						
				<b>Elizabeth 2<sup>nd</sup> 1926-</b>	Margaret 1930-2002							
				<b>Charles 1948-</b>	Ann 1950-	Andrew 1960-	Edward 1964-					
				<b>William 1982-</b>	Harry 1984-							

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## Genealogy, and the Succession of the Crown.

With the recent birth of Princess Charlotte, and her position of 4<sup>th</sup> in line to the throne, it is interesting to see how this line of succession is calculated.

To see how all this works out in practice, the table below shows some members of the extended Royal family, using Queen Elizabeth 2<sup>nd</sup> as the subject. This table is a modification of the earlier one, removing some of the more distant relatives, and also showing the Catholics.

Ahnen #	Person	Born	Died	Catholic?
1	Queen Elizabeth 2nd	1926		
1.1	Prince Charles	1948		
1.11	Prince William	1982		
1.111	Prince George	2013		
1.112	Princess Charlotte	2015		
1.12	Prince Harry	1984		
1.2	Princess Anne	1950		
1.21	Peter Phillips	1977		
1.211	Savannah Phillips	2010		
1.212	Isla Phillips	2012		
1.22	Zara Tindall, Née Phillips	1981		
1.221	Mia Tindall	2014		
1.3	Prince Andrew	1960		
1.31	Princess Beatrice	1988		
1.32	Princess Eugenie	1990		
1.4	Prince Edward	1964		
1.41	Louise Mountbatten-Windsor	2003		
1.42	James Mountbatten-Windsor	2007		
2	King George 6th	1895	1952	
2.1	≡1			
2.2	Princess Margaret	1930	2002	
2.21	David Armstrong-Jones	1961		
2.211	Charles Patrick Armstrong-Jones	1999		
2.212	Margarita Elizabeth Armstrong-Jones	2002		
2.22	Sarah Chatto, Née Armstrong-Jones	1964		
2.221	Samuel Chatto	1996		
2.222	Arthur Chatto	1999		
3	Queen Mother	1900	2002	
3.1	≡1 ≡2.1			
3.2	≡2.2			
4	King George 5th	1865	1936	
4.1	Edward 8th	1894	1972	
4.2	≡2			
4.3	Mary	1897	1965	
4.31	George Lascelles	1923	2011	
4.311	David Lascelles	1950		
4.312	James Lascelles	1953		
4.313	Jeremy Lascelles	1955		
4.32	Gerald Lascelles	1924	1998	
4.321	Henry Lascelles	1953		
4.322	Martin Lascelles	1962		
4.4	Henry, Duke of Gloucester	1900	1974	
4.41	Richard, Duke of Gloucester	1944		
4.411	Alexander Windsor	1974		
4.4111	Xan Windsor	2007		
4.4112	Cosima Windsor	2010		
4.412	Davina Lewis, Née Windsor	1977		
4.4121	Senna Lewis	2010		
4.4122	Tane Lewis	2012		
4.413	Rose Gilman, Née Windsor	1980		
4.4131	Lyla Gilman	2010		
4.4132	Rufus Gilman	2012		
4.5	George, Duke of Kent	1902	1942	
4.51	Edward of Kent	1935		
4.511	George Windsor	1962		Married to
4.5111	Edward Windsor	1988		Yes
4.5112	Marina Charlotte Windsor	1992		Yes
4.5113	Amelia Windsor	1995		
4.512	Helen Taylor, Née Windsor	1964		
4.5121	Columbus Taylor	1994		
4.5122	Cassius Taylor	1996		
4.5123	Eloise Taylor	2003		
4.5124	Estella Taylor	2004		
4.513	Nicolas Windsor	1970		Yes
4.5131	Albert Windsor	2007		

4.5132	Leopold Windsor	2009		
4.5133	Louis Windsor	2014		
4.52	Princess Alexandra	1936		
4.521	James Ogilvy	1964		
4.5211	Alexander Ogilvy	1996		
4.5212	Flora Ogilvy	1994		
4.522	Marina Ogilvy	1966		
4.5221	Christian Mowatt	1993		
4.5222	Zenouska Mowatt	1990		
4.53	Prince Michael of Kent	1942		Married to
4.531	Frederick Windsor	1979		
4.5311	Maud Windsor	2013		
4.532	Gabrielle Windsor	1981		
4.6	John	1905	1905	
5	Mary of Teck	1867	1953	
6	Claude Bowes Lyon	1855	1944	
6.1	Violet Bowes-Lyon			
6.2	Mary Elphinstone			
6.3	Patrick Bowes-Lyon			
6.4	John Bowes-Lyon			
6.5	Alexander Bowes-Lyon			
6.6	Fergus Bowes-Lyon			
6.7	Rose Leveson-Gower,			
6.8	Michael Bowes-Lyon			
6.9	≡3, The Queen Mother			
7	Cecilia Cavendish-Bentinck	1862	1938	

We remember that sometimes different numbers correspond to the same person, for example 2.1≡1.

The interested reader could draw up a similar table for their own relations, say on *Excel*.

The table above gives people in their approximate order of succession to the British throne. There are four reasons why the list does not give the true order, they are;

1. The Dead cannot ascend the throne.
2. Males were given priority over females.
3. Catholics, or those married to Catholics were ineligible to ascend.
4. The list includes those who are not of royal descent. For example 6.1, 6.2 etc, and if, say the Queen Mother had had children from an earlier or later marriage then they would not be in the line, but would have had numbers like 3.3, 3.4 etc.

We now consider how to modify our table to allow for these constraints. The *Succession to the Crown Act* of 2013, gives equal status to male and female children. So a younger brother to Charlotte will not be given precedence over her. However this is **not** retrospective. So whilst the birth order of Elizabeth 2<sup>nd</sup> 's children was Charles, *Ann*, Andrew, and Edward, their order of succession stays as Charles, Andrew, Edward, and *Ann*.

The same act has stopped the prohibition of being married to a Catholic, but the monarch cannot be a Catholic themselves. This is clearly discriminatory, but it is not appropriate to discuss the politics here. It is interesting to note that there is no similar legislation against Atheists, Buddhists, Hindus, Jews and Moslems. Although I suspect it would be very controversial, if any of these were in line for the throne.

We now modify the Ahnentafel numbers to allow for these extra conditions. To exclude the small number of Catholics we give them a very large number, I have used 1000, to put them right at the bottom of the list. To exclude the dead, again they have been given 1000. Repeated people, and those not of royal descent like 6.1, are also given the value 1000.

To give the male priority, the starting person is again numbered one, each of their **Sons** is assigned the numbers 1.1, 1.2, 1.3 etc in birth order, but the **Daughters** are numbered 1.91, 1.92, 1.93 etc in their birth order. So the '9' acts as a code for daughters, and this numbering will ensure that the children are ordered as required.

If dealing with large families as previously suggested, we could use an '9' as a code for females, and '8' as a code for a large family. But we will not do this here.

The table below has been drawn up in this way, then the data has been sorted by *Modified Ahnentafel Number*, and this gives the correct order of succession. Note that Elizabeth 2<sup>nd</sup> has been numbered zero in this list.

Note that Andrew's modified AN is 0.1 less than his original AN, and the same applies to all his descendants. Note also that similarly 4.5"x" becomes 4.4"x" etc.

Ann and her descendants go from 1.2"x" to 1.91"x". This can be done automatically by calculating  $(AN-1.2)/10+1.91$ .

Ahnen #	Modified A#	Person	Born	Died	Catholic ?	Line #
1	1	Queen Elizabeth 2nd	1926			0
1.1	1.1	Prince Charles	1948			1
1.11	1.11	Prince William	1982			2
1.111	1.111	Prince George	2013			3
1.112	1.112	Princess Charlotte	2015			4

1.12	1.12	Prince Harry	1984		5
1.3	1.2	Prince Andrew	1960		6
1.31	1.21	Princess Beatrice	1988		7
1.32	1.22	Princess Eugenie	1990		8
1.4	1.3	Prince Edward	1964		9
1.42	1.31	James Mountbatten-Windsor	2007		10
1.41	1.391	Louise Mountbatten-Windsor	2003		11
1.2	1.91	Princess Anne	1950		12
1.21	1.911	Peter Phillips	1977		13
1.211	1.9111	Savannah Phillips	2010		14
1.212	1.9112	Isla Phillips	2012		15
1.22	1.912	Zara Tindall, Née Phillips	1981		16
1.221	1.9121	Mia Tindall	2014		17
2.21	2.21	David Armstrong-Jones	1961		18
2.211	2.211	Charles Patrick Armstrong-Jones	1999		19
2.212	2.212	Margarita Elizabeth Armstrong-Jones	2002		20
2.22	2.291	Sarah Chatto, Née Armstrong-Jones	1964		21
2.221	2.2911	Samuel Chatto	1996		22
2.222	2.2912	Arthur Chatto	1999		23
4.41	4.31	Richard, Duke of Gloucester	1944		24
4.411	4.311	Alexander Windsor	1974		25
4.4111	4.3111	Xan Windsor	2007		26
4.4112	4.3112	Cosima Windsor	2010		27
4.412	4.312	Davina Lewis, Née Windsor	1977		28
4.4121	4.3121	Senna Lewis	2010		29
4.4122	4.3122	Tane Lewis	2012		30
4.413	4.313	Rose Gilman, Née Windsor	1980		31
4.4131	4.3131	Lyla Gilman	2010		32
4.4132	4.3132	Rufus Gilman	2012		33
4.51	4.41	Edward of Kent	1935		34
4.511	4.411	George Windsor	1962	Married	35
4.5113	4.4113	Amelia Windsor	1995		36
4.5131	4.4121	Albert Windsor	2007		37
4.5132	4.4122	Leopold Windsor	2009		38
4.5133	4.4123	Louis Windsor	2014		39
4.512	4.4191	Helen Taylor, Née Windsor	1964		40
4.5121	4.41911	Columbus Taylor	1994		41
4.5122	4.41912	Cassius Taylor	1996		42
4.5123	4.41913	Eloise Taylor	2003		43
4.5124	4.41914	Estella Taylor	2004		44
4.53	4.43	Prince Michael of Kent	1942	Married	45
4.531	4.431	Frederick Windsor	1979		46
4.5311	4.4311	Maud Windsor	2013		47
4.532	4.432	Gabrielle Windsor	1981		48
4.52	4.591	Princess Alexandra	1936		49
4.521	4.5911	James Ogilvy	1964		50
4.5211	4.59111	Alexander Ogilvy	1996		51
4.5212	4.59112	Flora Ogilvy	1994		52
4.522	4.5912	Marina Ogilvy	1966		53
4.5221	4.59121	Christian Mowatt	1993		54
4.5222	4.59122	Zenouska Mowatt	1990		55
4.311	4.9111	David Lascelles	1950		56
4.312	4.9112	James Lascelles	1953		57
4.313	4.9113	Jeremy Lascelles	1955		58
4.321	4.9121	Henry Lascelles	1953		59
4.322	4.9122	Martin Lascelles	1962		60
2.1	1000	≡1			61

Every effort has been taken to avoid errors, but inevitably some may remain. The factual information was obtained from *Wikipedia*.

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## Ahnentafel Numbers, More on Ancestry and a Binary Binary Operation.

In William's ancestor tree, Queen Victoria (1819- 1901) is given as having Ahnentafel numbers of both 79 and 81. We wrote this as  $79=81$ . Also  $78=80$ ,  $82=32$  and  $83=33$ .

Wikipedia also gives similar short ancestry tables for many of the subjects of its entries.

Some research using *Wikipedia* gives the following information from such ancestry tables;

Subject	Ancestor	Ahnentafel number
Prince William	Queen Victoria	79≡81
Queen Victoria	George 2 <sup>nd</sup>	16
George 2 <sup>nd</sup>	George 1 <sup>st</sup>	2
George 1 <sup>st</sup>	James 1 <sup>st</sup> (6 <sup>th</sup> of Scotland)	14
George 1 <sup>st</sup>	Mary Queen of Scots	29
Mary Queen of Scots	James 5 <sup>th</sup> of Scotland	2
Mary Queen of Scots	James 4 <sup>th</sup> of Scotland	4
Mary Queen of Scots	Henry 7 <sup>th</sup> of England	10
Mary Queen of Scots	Edward 4 <sup>th</sup> of England	22
Edward 4 <sup>th</sup> of England	Edward 3 <sup>rd</sup> of England	16≡28
Edward 3 <sup>rd</sup> of England	Edward 2 <sup>nd</sup> of England	2
Edward 3 <sup>rd</sup> of England	Edward 1 <sup>st</sup> of England	4
Edward 3 <sup>rd</sup> of England	Henry 3 <sup>rd</sup> of England	8
Edward 3 <sup>rd</sup> of England	John of England	16
John of England	Henry 2 <sup>nd</sup> of England	2
John of England	Henry 1 <sup>st</sup> of England	10
John of England	William 1 <sup>st</sup> , the Conqueror	20

So suppose in person A’s ancestor tree, person B has number  $x$ , and in B’s tree person C has number  $y$ . What would be C’s number in A’s tree? This is the problem we look at in this section?

To give this some notation we call this result  $x\odot y$ . Because this takes **two** positive integers as inputs and gives one output, like addition, and multiplication, this is called a **binary** operation. So given two values  $x$  &  $y$ , how do we calculate  $x\odot y$ ?

To consider a relatively simple example, we have seen that in William’s tree the Queen mother is number 11. By considering her tree, her maternal grandfather would have number 6. So we are trying to calculate  $11\odot 6$ .

Readers familiar with the **Binary** representation of numbers might have noticed that the subject’s father is 10, their mother 11, and the father & mother of person  $x$  is “ $x0$ ” & “ $x1$ ” respectively. By “ $x1$ ” we don’t mean  $x\times 1$  or  $x+1$ , but the digits of “ $x$ ” with 1 put at the end.

. As a reminder, the binary equivalents for the first few numbers are;

Number	1	2	3	4	5	6	7	8	9	10	11	12	13
Binary	1	10	11	100	101	110	111	1000	1001	1010	1011	1100	1101

So the Queen Mother’s Ahnentafel number in binary (relative to William) is 1011. Reading from left to right, the first digit is always one, after that we just read father’s mother’s mother. This correctly gives the relationship of the QM to William.

An alternative way to have described this relationship in a short code would have been simply to write FMM.

In a similar way, the Queen Mother’s maternal grandfather could be described as MF, with Ahnentafel number 110 in binary or 6 in decimal notation.

It might be thought that describing one’s ancestors as just a row of M’s and F’s would be better as we are using one less character each time than the corresponding Ahnentafel number in binary. However we have to be careful, as 00101 is the same as 101 in binary, but FFMFM is not the same ancestor as MFM. So the one at the beginning is effectively telling us the length of the binary number, relating to the number of generations going back. A two digit (binary) Ahnentafel number represents two generations (including the subject) and in general an  $n$ - digit (binary) Ahnentafel number represents  $n$  generations. But we must **not** omit initial zeroes.

To find the ancestor required from the FMM & MF above we just write FMMMMF. This putting together of two strings of characters is called **concatenation**. So the  $\odot$  stands for a modification of concatenation. For the Ahnentafel numbers we write;

$$1011\odot 110 = 101110_{\text{bin}} = 46_{\text{dec}}$$

It may help the reader to separate the first ones and rewrite as;

$$1,011\odot 1,10 = 1,011,10_{\text{bin}} = 46_{\text{dec}}$$

The commas are there just to break up the number into the relevant parts for this problem, not the usual convention.

Working with the decimal equivalents we would have;

$$11\odot 6 = 11 \times 2^2 + (6 - 2^2) = 44 + 2 = 46.$$

For larger numbers we have calculations like;

$$1110\textcircled{1}000101 = 1,110\textcircled{1},000101 = 1,110,000101$$

$$14\textcircled{6}9 = 14 \times 2^6 + (69 - 2^6) = 896 + 5 = 901$$

The reader is advised to look at these calculations in detail to see how they work. The second,  $y$ , number has its most significant one removed, that is the highest possible power of two is subtracted from it. Then the first,  $x$ , number is put at the front (in binary) which is the equivalent of adding the same power of 2 multiplied by  $x$ .

So in general we could write;

$$x\textcircled{y} = x \times 2^n + (y - 2^n) = 2^n(x - 1) + y \text{ where } 2^n \leq y < 2^{n+1}, \text{ so } n = \left\lfloor \frac{\log y}{\log 2} \right\rfloor, \text{ where } \lfloor \ ] \text{ means, as usual, the integer value rounded down.}$$

The interested reader can easily put this into a spreadsheet if they wish.

The reader is invited to check that  $6\textcircled{1}1 = 51$ , so that the operation  $\textcircled{\phantom{x}}$  is not commutative.

Thinking about the context of the question, it is clear that  $\textcircled{\phantom{x}}$  must be associative, namely  $(x\textcircled{y})\textcircled{z} = x\textcircled{(y\textcircled{z})}$ .

The reader is also invited to check this with some simple numbers.

It is easy to see that there is an identity for this operation, namely 1, as  $1\textcircled{x} = x\textcircled{1} = x$  for all  $x$ . But no inverses as  $x\textcircled{y} = 1$  will not be possible.

Some equations of the form  $a\textcircled{x} = b$  or  $x\textcircled{a} = b$  will have solutions but in general there will be no solutions. Writing the values in binary it is easy to see why this is so, and if we try to solve  $5\textcircled{x} = 81$ , we get  $x = 17$ , so Queen Victoria is 17 on Elizabeth 2<sup>nd</sup>'s tree. But no solution to  $5\textcircled{x} = 79$ , even though 79 and 81 are the same person. The equation  $x\textcircled{5} = 81$  has a solution of  $x = 20$ , but this has no relevance to Elizabeth 2<sup>nd</sup>'s tree.

We have already seen that in Prince William's tree Queen Victoria has number 81. We use this value rather than 79 as it is the route through Elizabeth 2<sup>nd</sup>, rather than through the Duke of Edinburgh. We now consider all numbers in Prince William's tree.

George 2<sup>nd</sup> is  $81\textcircled{16} = 1,296$ .

Edward 2<sup>nd</sup> of England is  $10,620,256\textcircled{2} = 21,240,512$ .

George 1<sup>st</sup> is  $1296\textcircled{2} = 2,592$ .

Edward 1<sup>st</sup> of England is  $10,620,256\textcircled{4} = 42,481,024$

James 1<sup>st</sup> of England is  $2592\textcircled{14} = 20,742$ .

Henry 3<sup>rd</sup> of England is  $10,620,256\textcircled{8} = 84,962,048$

Mary Queen of Scots is  $2592\textcircled{29} = 41,485$ .

John of England is  $10,620,256\textcircled{16} = 169,924,096$ .

James 4<sup>th</sup> of Scotland is  $41485\textcircled{4} = 165,940$

Henry 2<sup>nd</sup> of England is  $169,924,096\textcircled{2} = 339,848,192$ .

Henry 7<sup>th</sup> of England is  $41485\textcircled{10} = 331,882$ .

Henry 1<sup>st</sup> of England is  $169,924,096\textcircled{10} = 1,359,392,770$ .

Edward 4<sup>th</sup> of England is  $41485\textcircled{22} = 663,766$ .

William 1<sup>st</sup> of England is  $169,924,096\textcircled{20} = 2,718,785,540$ .

Edward 3<sup>rd</sup> of England is  $663,766\textcircled{16} = 10,620,256$ .

This last number is almost 3 billion, much larger than the human population a thousand years ago. This is because many people will have several Ahnentafel numbers, in some cases an individual must have thousands of different Ahnentafel numbers. It is also interesting to look at the value of William the Conqueror's number in binary,

10,100,010,000,011,010,110,000,000,000,100; in octal it is 24,203,260,004, and in hexadecimal, it is 0A2,0D6,004.

Remember it is much easier to convert between binary and octal, than it is between binary and denary. One just reads the triples of the binary and convert them to octal. Hexadecimal is similar, reading in sets of four binary digits. Remember also that extra symbols are needed in hex, usually they are A for ten, B for eleven etc.

From the binary value, we see that there are 32 generations (including first and last) from William 1<sup>st</sup> to Prince William. We can also put this 32 digit binary number in the table below.

Gen.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Binary digits	1	0	1	0	0	0	1	0	0	0	0	0	1	1	0	1
	Prince William	Prince Charles	Elizabeth 2 <sup>nd</sup>	George 6 <sup>th</sup>	George 5 <sup>th</sup>		Victoria.				George 2 <sup>nd</sup> ,	George 1 <sup>st</sup> .			James 1 <sup>st</sup>	Mary Queen of Scots

The table continues as;

17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0
James 5 <sup>th</sup> S			Edward 4 <sup>th</sup> .				Edward 3 <sup>rd</sup> .	Edward 2 <sup>nd</sup> .	Edward 1 <sup>st</sup> .	Henry 3 <sup>rd</sup> .	John	Henry 2 <sup>nd</sup>		Henry 1 <sup>st</sup>	William 1 <sup>st</sup> .

From this table it is easy to see the direct line of descent from William 1<sup>st</sup>. The reader is invited to fill in the names of the blank spaces. The binary form of the Ahnentafel number of any of these people is easily read by just reading the binary digits and stopping at the appropriate person, for example Elizabeth 2<sup>nd</sup> is 101, and Victoria is 1,010,001.

Put another way William 1<sup>st</sup> is 31 generations older than William 5<sup>th</sup>, that is the former is (one of) the latter's great<sup>29</sup> grandfather(s).

Prince William was born in 1982, and William the Conqueror about 1027, so with 31 generations between them, this gives an average of 30.8 years per generation. Relative to Elizabeth 2<sup>nd</sup>, William 1<sup>st</sup> has an Ahnentafel number of 571,301,892 or 100,010,000,011,010,110,000,000,000,100 in binary.

**Footnote.**

The Binary binary operation we have discussed is not programmed into scientific calculators, however there are some such operations which are. They are *and*, *or* and *xor* (exclusive or).

They work as follows;

52 and 30=20, 52 or 30=62 52 and 30=42.

Looking at the binary forms, we can see what they are doing;

```

      52    1 1 0 1 0 0
      30    0 1 1 1 1 0
and  20    0 1 0 1 0 0
or   62    1 1 1 1 1 0
xor  42    1 0 1 0 1 0
    
```

*And* only gives 1 if both inputs are 1. *Or* gives an output of 1, if either, or both, the inputs are 1. *Xor* gives an output of 1, if either, but not both, the inputs are 1.

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**Breakdown of powers of two- Number of Ancestors.**

We all have two parents (biological, we may have more step or adopted ones, and, of course, not necessarily still alive), four grandparents, eight great grandparents etc.

This suggest that if we go back *n* generations then we have 2<sup>*n*</sup> ancestors in that generation. Given that there are about 4 or 5 generations in a century, so about 500 years ago we would have somewhere between 2<sup>20</sup> =1,048,576 or 2<sup>25</sup> =33,554,432 ancestors. Going back 1000 years we get a value of over a trillion ancestors (10<sup>12</sup>) This is clearly not so, and it means that some of these people must be the same. That is we must have cousin marriage, even though the individuals will not have known this, perhaps, say, eighth cousins three removed.

We have already considered the *ahnentafel* of **Prince William, Duke of Cambridge**. Wikipedia gives Williams full ancestry right up to number 127, that is a full six generations of his ancestors. A few are reproduced below.

1. Prince William, Duke of Cambridge (born 21 June 1982)
  2. Charles, Prince of Wales (born 14 November 1948)
  3. Diana, Princess of Wales (1 July 1961 – 31 August 1997)
  4. Prince Philip, Duke of Edinburgh (born 10 June 1921)
  5. Elizabeth II, Queen of the United Kingdom et al. (born 21 April 1926)
  6. Edward Spencer, 8th Earl Spencer (24 January 1924 – 29 March 1992)
  7. Frances Roche (20 January 1936 – 3 June 2004)
  32. Christian, King IX of Denmark (8 April 1818 – 29 January 1906)
  33. Princess Luise of Hesse-Kassel (7 September 1817 – 29 September 1898)
  78. Albert, Prince Consort (26 August 1819 – 14 December 1861)
  79. Queen Victoria (24 May 1819 – 22 January 1901)
- 80≡78, 81 ≡ 79, 82≡32, 83≡ 33.

So for certain members of the Royal family we can easily see how many generations we need to go back before the powers of two sequence breaks down.

In principle we can draw up the following table for anyone, but unless we have done a lot of ancestry research, it is easier to use say, Prince William.

Generation	1	2	3	4	5	6
Number of ancestors of William in this generation	2	4	8	16	32	62

The last entry is 62 not 64 because ancestors 80 & 81 have already been counted as 78 &79. So for William the sequence breaks down in the **sixth** generation.

We note that if we have *a* ancestors in generation *n*, the number in generation *n*+1 is less than or equal to 2*a*.

We also note that as all of 78, 79, 80 & 81 are ancestors through Charles rather than Diana (why?), we can draw up a similar table for Charles as follows;

Generation	1	2	3	4	5
Number of ancestors of Charles in this generation	2	4	8	16	30

So for Charles the sequence breaks down in the **fifth** generation.

Now ancestors 78 & 79 are ancestors of Charles through his father, Philip, whilst 80 & 81 are ancestors of Charles through his mother, Elizabeth, (why?), this means that both Elizabeth and Philip have a full number of ancestors four (the furthest we can deduce) generations back.

Counting the number of generations back before the number of our ancestors is below the appropriate power of two, gives us a measure of how related two separate individuals may be, and it also gives a measure of how inbred a person (or animal) is.

However we can improve on this measure as it does not tell us if ancestors of one generation have married those of another generation, who may well be of similar ages. We therefore now look at the total number of ancestors a person has, including themselves) to *n* or fewer generations. For many people this will look like;

Generation	0	1	2	3	4	5	6
Total Number of ancestors up to and including this generation	1= 2-1	3= 4-1	7= 8-1	15= 16-1	31= 32-1	63= 64-1	127= 128-1

But for William the table would be;

Generation	0	1	2	3	4	5	6
Total Number of ancestors of William up to and including this generation	1	3	7	15	31	63	123

Again the sequence breaks down at generation **six**, but 123 is **four** less than the maximum value of 127. We have also used persons 82 & 83 which were the same as 32 & 33.

For Charles the table would be;

Generation	0	1	2	3	4	5
Total Number of ancestors of Charles up to and including this generation	1	3	7	15	31	59

In the most severe inbreeding, which is illegal in almost all cultures (Ancient Egypt being an exception), but which has been used controversially to produce pedigree dogs, a brother and sister produce a child. The table would then be;

Generation	0	1	2
Total Number of ancestors up to and including this generation	1	3	5

Here the subject has just one pair of grandparents. The '5' in the table would be replaced with a '4' if a father produced a child with his daughter, again illegal in most cultures.

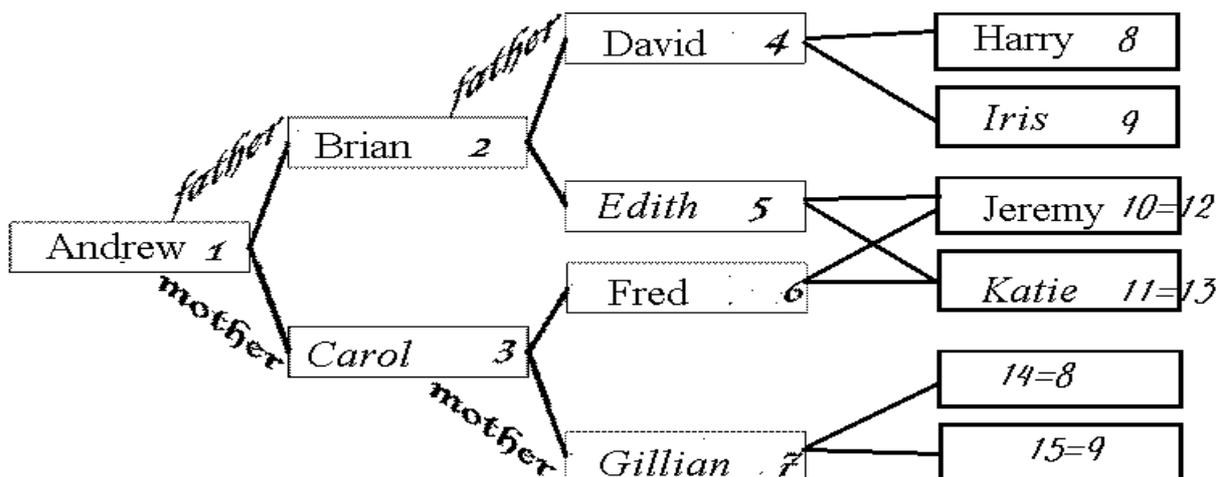
If a pair of first cousins marry and produce a child, then its table could be;

Generation	0	1	2	3
Total Number of ancestors up to and including this generation	1	3	7	13

So two short in the 3<sup>rd</sup> generation back.

It is possible to legally have **four** short in the 3<sup>rd</sup> generation back, with the table;

Generation	0	1	2	3
Total Number of ancestors up to and including this generation	1	3	7	11



The ancestor tree shows the full situation. Here two pairs of siblings have married. D is G's brother, and F is E's brother. D & E are married as are F & G. So here A has just four great-grand parents. It is double cousin marriage, and harmful recessive genes are more likely to manifest themselves in this sort of situation.

So we can either see how close two individuals are by seeing the first generation of combined ancestors which is less than the sum of the powers of two. Or we can see how inbred an individual is, by looking at all their ancestors up to a certain generation and seeing when that is less than the sum of the powers of two.

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## Forbidden Marriages- A symmetrical coding.

In the traditional Church of England Prayer book the following table is given:

### A TABLE OF KINDRED AND AFFINITY, WHEREIN WHOSOEVER ABE RELATED ARE FORBIDDEN IN SCRIPTURE AND OUR LAWS TO MARRY TOGETHER.

*A man may not marry his*

- 1 GRANDMOTHER,
- 2 Grandfather's Wife,
- 3 Wife's Grandmother.
- 4 Father's Sister,
- 5 Mother's Sister,
- 6 Father's Brother's Wife.
- 7 Mother's Brother's Wife,
- 8 Wife's Father's Sister,
- 9 Wife's Mother's Slater.
- 10 Mother,
- 11 Step-Mother,
- 12 Wife's Mother.
- 13 Daughter,
- 14 Wife's Daughter,
- 15 Son's Wife.
- 16 Sister,
- 17 Wife's Sister,
- 18 Brother's Wife.
- 19 Son's Daughter,
- 20 Daughter's Daughter,
- 21 Son's Son's Wife.
- 22 Daughter's Son's Wife,
- 23 Wife's son's Daughter,
- 24 Wife's Daughter's Daughter.
- 25 Brother's Daughter,
- 26 Sister's Daughter,
- 27 Brother's Son's Wife.
- 28 Sister's Son's Wife,
- 29 Wife's Brother's Daughter,
- 30 Wife's Sister's Daughter.

*A Woman may not marry with her*

- 1 GRANDFATHER,
- 2 Grandmother's Husband,
- 3 Husband's Grandmother
- 4 Father's Brother,
- 5 Mother's Brother,
- 6 Father's Sister's Husband.
- 7 Mother's Sister's Husband,
- 8 Husband's Father's Brother,
- 9 Husband's Mother's Brother.
- 10 Father,
- 11 Step-Father,'
- 12 Husband's Father.
- 13 Son,
- 14 Husband's Son,
- 15 Daughter's Husband.
- 16 Brother,
- 17 Husband's Brother,
- 18 Sister's Husband.
- 19 Son's Son,
- 20 Daughter's Son,
- 21 Son's Daughter's Husband.
- 22 Daughter's Daughter's Husband,
- 23 Husband's Son's Son,
- 21 Husband's Daughter's Son.
- 25 Brother's Son,
- 25 Sister's Son,
- 27 Brother's Daughter's Husband.
- 28 Sister's Daughter's Husband,
- 29 Husband's Brother's Son,
- 30 Husband's Sister's Son.

These and other restrictions come from Leviticus 18, and it is interesting to see, say, number 5 in some different versions, verse 13:

**King James:**Thou shalt not uncover the nakedness of thy mother's sister: for she is thy mother's near kinswoman.

**Revised Standard version** You must not have sexual intercourse with your mother's sister, because she is your mother's flesh.

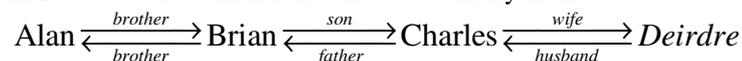
**New International Version** Do not have sexual relations with your mother's sister, because she is your mother's close relative.

Here the restriction is on a blood or genetic relative, and certainly there may be problems with harmful recessive genes from such a union, however some of the restrictions are for what we would call in-laws. For example verse 16: *You shall not uncover the nakedness of your brother's wife; she is your brother's nakedness.* This is restriction 18 above.

The list above does not restrict homosexual marriage, but verses 22& 23 are: *You shall not lie with a male as with a woman; it is an abomination. And you shall not lie with any beast and defile yourself with it, neither shall any woman give herself to a beast to lie with it: it is perversion.*

The purpose of this article is not to discuss the ethics of these restrictions, but to see if they are consistent, and if they can be represented more simply than by the above list of 60 wordy restrictions.

In 27 we see that a man is not allowed to marry his *Brother's Son's Wife*, which can be represented diagrammatically as:



where Brian's son is Charles etc. So Alan is not allowed to marry Deirdre. From Deirdre's point of view Alan is her Husband's Father's Brother, and we see that this is 8 in the women's list. So 27 in the men's list corresponds to 8 in the women's. Before reading on see if you can find the correspondence for all the other rules.

The full mapping is :

1↔19, 20	7↔30	13↔10	19, 20↔1	28↔9
2↔23, 24	8↔27	14↔11	21, 22↔3	29↔6
3↔21, 22	9↔28	15↔12	23, 24↔2	30↔7
4↔25	10↔13	16↔16	25↔4	
5↔26	11↔14	17↔18	26↔5	
6↔29	12↔15	18↔17	27↔8	

It will be noticed that as 8↔27 we also have 27↔8, as each entry is symmetrical on each side of the table.

We also notice that 1 is paired with 19 & 20, this is because the term grandmother includes both maternal and paternal ones. We have also paired 11 with 14, and we notice that they have not been consistent in their wording, why not say *Step-Mother* and *Step-Son*, or *Father's wife* and *Husband's Son*.

We can also simplify this table if we use the following abbreviations:

**p** for parent, **d** for daughter (or son) ie child, **s** for spouse, **N** for sibliNg.

Using this notation we can code each of the relationships above as follows. Both 6 & 7 are *Parent's sibling's spouse* so we can code these as: **pNs**.

Now this coding has not been chosen carelessly, if we write **pNs** on a piece of paper and turn it upside down we get **sNd**. Now this is just spouse's sibling's child which is either 29 or 30. A relationship is called symmetric if it can be turned around. Both spouse and sibling are symmetric relationships, as if Alan is the spouse of Betty, then Betty is the spouse of Alan. We have picked letters for them which have rotational symmetry. Parent is not a symmetric relationship. Parent and child are inverse relationships and the letters we have used for these are related so that one is the image of the other following a half turn.

The following table gives the coding for each of the relations above:

1. pp	7. pNs	13. d	19. dd	25. Nd
2. pps	8. spN	14. sd	20. dd	26. Nd
3. spp	9. spN	15. ds	21. dds	27. Nds
4. pN	10. p	16. N	22. dds	28. Nds
5. pN	11. ps	17. sN	23. sdd	29. sNd
6. pNs	12. sp	18. Ns	24. sdd	30. sNd

Looking at the above we can reduce the number of restrictions to just eleven, which are just (allowing for rotations of these codes). They are: p, N, pp, pN, ps, sp, Ns, pps, spp, pNs, spN.

A first cousin would be coded as pNd, and this is not prohibited. This notation allows us to describe other relationships very easily, for example second and third cousins would be p<sup>2</sup>Nd<sup>2</sup> & p<sup>3</sup>Nd<sup>3</sup> respectively where p<sup>3</sup> stands for ppp etc. However we cannot rotate the code p<sup>3</sup>, whereas we can rotate ppp to give the reciprocal relation ddd..

Similar restrictions apply in Judaism and in Islam. In almost all societies marriage between brothers and sisters is forbidden, with Ancient Egyptian, Hawaiian, and Inca royalty being the rare exception. In many societies marriage between some first cousins is preferred, while at the other extreme, the medieval Catholic church prohibited marriage between distant cousins.

The **Deceased Wife's Sister's Marriage Act** was passed in the UK in 1907, as previously, it was forbidden for a man to marry the sister of his deceased wife. This is restriction sN in our coding, 17 in the list.

In the 1950's version of the Church of England Prayer book it gives:

<i>A man may not marry his</i>	10. Wife's Mother,	20. Son's Son's Wife
1. Mother,	11. Wife's Daughter.	21. Daughter's Son's Wife
2. Daughter	12. Father's Wife,	22. Father's Sister,
3. Father's Mother,	13. Son's Wife	23. Mother's Sister,
4. Mother's Mother,	14. Father's Father's Wife	24. Brother's Daughter,
5. Son's Daughter,	15. Mother's Father's Wife	25. Sister's Daughter,
6. Daughter's Daughter	16. Wife's Father's Mother.	With an equivalent list for a
7. Sister,	17. Wife's Mother's Mother.	woman.
8. Father's Daughter.	18. Wife's Son's Daughter	
9. Mother's Daughter,	19. Wife's Daughter's Daughter	

The coding for each of the above relationships is:

1. p	7 N	12 ps	18 & 19 sdd
2. d	8 & 9 pd	13 ds	20 & 21 dds
3 & 4 pp	10 sp	14 & 15 pps	22 & 23 pN
5 & 6 dd	11 sd	16 & 17 spp	24 & 25 Nd.

So we have the following prohibited (allowing for rotation of the codes):

p, pp, N, pd, sp, ps, spp, pN.

This table includes pd which was not in the earlier list. But parent's child is sibling or at least half sibling so was implied in the earlier list. However the later list does not include Ns, pNs and spN. In a similar way we can think of spouse as child's parent, so s can be written as dp. So the 1950 list of 9 restrictions, becomes 8 as N and pd are effectively the same, so they can be

written; **p, pp, pd, dpp, pdp, pddp, dppp, pppd.**

The extra three restrictions from the traditional prayer book become: **pddp, ppddp, dpppd.**

These are sibling's spouse, (remember Henry 8<sup>th</sup> married his brother's widow); uncle's wife, wife's aunt. With the male & female alternatives in each case. None of these are blood relatives, so the problem of harmful recessive genes does not arise.

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### Answers to exercise;

- 11 (or 1011 binary).
- 22 (or 10110 bin) for father, actually Claude Bowes Lyon, and 23 (10111 bin) for mother, Cecilia Cavendish-Bentinck.
- (i) male, (ii) female.
- (i)  $2x$  (ii)  $2x+1$ . In binary a 0 or 1 placed at the right end of the original number,
- 7.
- 2, 4, 8, 16, 32, 64, etc, in general the powers of two. In binary, a one followed by all zeros, eg 1000000.
- 3, 7, 15, 31, 63, 127 etc, ie one less than the powers of two. In binary, all ones, eg. 111111. Here and in question 6, we have to assume that the nominal parents of each person are also their actual biological and genetic parents. It is not for me to comment on the validity of this assumption!
- As 80 & 78 are the same people, so must their fathers, namely 160 and 156, and their mothers, namely 161 and 157. Repeating this gives us an infinite number of pairs, including  $320 \equiv 312$ ,  $322 \equiv 314$ . In binary 80 is 1010000, and 78 is 1001110, so 1010000 followed by any block of binary digits is the same person as 1001110 followed by the same block of binary digits.
- His brother Harry. In general full siblings will have exactly the same table.
- As Queen Elizabeth 2<sup>nd</sup> is William's father's mother, any of his ancestors through her, will have a binary Ahnentafel number starting 1-01-. As 81 is 1 01 0001, to obtain the Ahnentafel number relative to the queen we cross out the second and third digits, to give 1 04 0001, that is 10001, or just 17. Note that we could not have used the 79 which was 1001111 in binary, as this line goes through the Duke of Edinburgh.
- As  $78 \equiv 80$  in binary we have  $1001110 \equiv 1010000$ . This means that people 100111 and 101000 have the same father. So it is likely, but not certain that they will have the same mother, that is  $1001111 \equiv 1010001$ , that is  $79 \equiv 81$ . So as  $68 \equiv 86$ , we have by the same logic, it is likely that  $69 \equiv 87$ . We have the same person having two different Ahnentafel numbers when there is mating between relatives, most usually cousin marriage, which is considered advantageous by many cultures.
- (i) This would mean that the subject's parents were brother and sister. They would be full siblings if also  $5 \equiv 7$ , or half siblings otherwise. (ii) would represent a father having a child (the subject) with his daughter. Both of these situations represent incest and would be illegal in most countries. Although not biologically impossible, they increase the chance of rare harmful recessive genes manifesting themselves, so such offspring are likely to be less healthy than other individuals. Some pedigree dogs have been, controversially, bred in this way.

13. Person	Ahnentafel number (binary)	Ahnentafel number
Queen Victoria	1001111 or 1010001	79 or 81
George 3 <sup>rd</sup>	1001111 00 or 1010001 00	316 or 324
George 2 <sup>nd</sup>	100111100 00 or 10100010000	1264 or 1296
George 1 <sup>st</sup>	10011110000 0 or 10100010000 0	2528 or 2592
James 1 <sup>st</sup> /6 <sup>th</sup>	100111100000 110 or 101000100000 110	20230 or 20742
Henry 7 <sup>th</sup>	100111100000110 1010 or 101000100000110 1010	323690 or 331882

NB Henry 8<sup>th</sup> does not have an Ahnentafel number because he is not an ancestor of William. In fact he has no legitimate descendants alive.

- Any of William's ancestors have a binary Ahnentafel number in the form of 1- then a block of zeros and ones. For George or Charlotte, their Ahnentafel number will be 1-0- then the same block of zeros and ones. So 101 becomes 1001, or 5 becomes 9 in ordinary numbers.

15. We note that Queen Victoria is  $79 \equiv 81$ , or in binary  $1001111 \equiv 1010001$ . The Duke of Edinburgh is 100, so the 4 ones following this mean that Victoria was his mother's, mother's, mother's, mother. The Queen is 101, so the 3 zeros and a one following this, mean that Victoria is her father's, father's father's, mother. Working to younger generations we see that;

$100111$  &  $101000$  (39 & 40 in decimal) are siblings, they are full siblings as also  $78 \equiv 80$  was Prince Albert.

$10011$  &  $10100$  (19 & 20) are first cousins.

*1001 & 1010* (9 & 10) are second cousins.

***100 & 101* (4 & 5) are third cousins.**

But we were also told that 32 $\equiv$ 82 (Christian, King of Denmark) (& 33 $\equiv$ 83, Princess Luise of Hesse Kassel) & or in binary *100000* $\equiv$ *1010010*.

So *10000* & *101001* (16 & 41) are full siblings.

*1000* & *10100* (8 & 20) are first cousins.

*100* & *1010* (4 & 10) are second cousins.

**So *100 & 101* (4 & 5) are second cousins, once removed. This is the closest.**

*Anthony C Robin,*  
*29 Spring Lane, Eight Ash Green,*  
**COLCHESTER, CO6 3QF.**  
`Anthony_robin@hotmail.com`