

# A Study of Prime Sextuplet Analysis Using Gestalt Approach

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## 1 Introduction

Following an interest in prime sextuplets and whether this prime “edge-case” could provide hints as to whether the number of prime sextuplets is infinite, I found structures that could provide clues and which provide possibilities for analysis.

Even though the focus for my interest was/is sextuplets, the structures make themselves immediately amenable to quintuplet and quadruplet analysis also, almost automatically. The primary focus, unless otherwise noted, will be sexuplets, but quints and quads are also included here. I will occasionally refer to the word “Tuplets” which refers in general to sextuplets, quintuplets, and quadruplets as a group.

All the structures described here were first worked out on paper, and then, as proof of concept, written into computer code. The structures, and associated equations, worked and 100% accurate lists of Tuples can be generated. The computer code is not the most efficient, nor the fastest, but it does prove that the methods and structures in this document are correct. The code and app can be found at: <https://github.com/Juulius/juusprime>.

The work focuses on blocks of numbers which fall naturally out of the primes. The primes are divided into three major groups each handled differently. Rather than primality testing, it uses the “effect” a prime group will have at any particular point in the number line.

## 2 Preface

My education is in Biology, and I am only familiar with the usual mathematics associated with such a study. I have been very careful to check all the work and equations and structures for correctness, and, as mentioned, have put these into play in a proof of concept computer program. There are areas where I see possibilities for potentially insightful analysis that are, at this time, mathematically beyond me. I will point these out and perhaps a more mathematically minded person will find them of interest and be able to solve them.

I may mention things here that are already common knowledge to more mathematically inclined people. If that is the case, I apologize, and do hope you will find something new that can picque your interest.

I will also go into more detail than would be otherwise be normal in a mathematically themed paper because I anticipate that my audience, if any, will be primarily not professional mathematicians, and so I seek to be clear and readable, and avoid confusion. And some details are simply reminders for me.

## 3 Initial Assertions

Before getting to the description of how the three groupings of the primes numbers used to develop this prime sextuplet study are built, there are some observations about primes that will be of use in said development.

### 3.1 The “effective” start of a Prime’s influence

First principles for this “effective” start come from a study of the simple sieve of Erathos-thenes.

This assertion is that any prime number will not be “effective” at clearing a sieve until we reach that prime number’s value squared. This means we don’t need to consider a prime’s effects until its square.

We show this by applying primes piecemeal. For instance consider the sieve in fig. 1. We first apply only the prime 2. When we do, we find the sieve tells us that all odd numbers are “prime”. That is, there are many “false” primes remaining. However also note that at 2’s square, 4, the primes are accurately sieved up to 9.

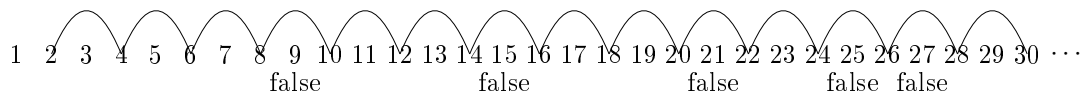


Figure 1: Sieve of Eratosthenes with only 2 applied

Now apply 3, as in fig. 2, and many of these false primes are removed. All, in fact, between 9 ( $3^2$ ) and 25 ( $5^2$ ).

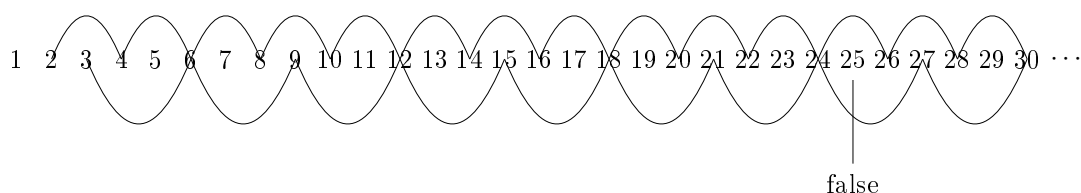


Figure 2: Sieve of Eratosthenes with only 2 and 3 applied

Finally we apply the primes 2, 3, and 5 and see clearly that a prime has no effect on the sieve until its square. Prime 7, which has not been applied yet, has absolutely no effect on anything less than 49, its square. Were we now to apply 7, the false primes of 77, 91, and 119 would disappear, but 121 ( $11^2$ ) remains falsely shown as “prime”. Similarly, Prime 11 has no effect and does not help in identifying primes less than 121.



This is what is meant by primes have no effect/influence until their squares. This will be of importance when we construct the prime structures for 31-59.

### 3.2 Interval-izing regions between squares

It will be of use to us to be able to compare regions between squares of primes based on a chosen interval size. While this is certain to be derived in some mathematical text, I have no reference for it, and so re-derive it here. This will be of use for prime structures 31-59.

This assertion is not limited to primes but applies to any pair of numbers, and in this section it will be generalized for any number  $n$ .

The difference between two numbers is exactly a factor of the distance between their squares. One can choose this difference, or interval, as one likes.

For example, assume we want, for whatever reason, to construct comparable regions for squares for an interval size of 8. Pick any number  $> 0$  and add our interval to it. Let's say we pick 7 as our number, so we add 8 to it for our next number: 15. The region between  $7^2$  and  $15^2$  will be exactly divisible by 8; that is, that region is divided up into some number of intervals of size 8.

Were we to pick 25 as our number, we add 8 to get 33. We also find that the region between those numbers squared will also be evenly divisible by 8.

In general, with  $p$  being the initial number we choose, and  $C$  being the interval we want, our second number will be  $p + C$ . Taking the difference of their squares and dividing by  $C$  will give us  $x$  (the number of intervals of  $C$  length in the region between their values squared). We start with  $p$  and  $p + C$ :

$$\begin{aligned} x &= \frac{(p + C)^2 - p^2}{C} \\ x &= \frac{p^2 + 2pC + C^2 - p^2}{C} \\ x &= \frac{2pC + C^2}{C} \\ x &= 2p + C \end{aligned} \tag{1}$$

$C \neq 0; p \geq 0$

**Checking:**  $7^2 = 49$  and  $15^2 = 225$ . Taking the difference:  $225 - 49 = 176$  and dividing by 8:  $176/8 = 22$ .

Using the formula with  $p = 7$  and  $C = 8$ :  $2(7) + 8 = 22$

So the region between these squares has 22 sections each of which has a size of 8.

We also want to extend this relationship as a series from our initial number  $p$  ( $= 7$ ) each determined by our interval ( $= 8$ ). We can generalize the equation for any member of our series by calculating the range from  $p + Cn$  to  $p + C(n + 1)$ , which expands to  $p + Cn + C$ :

$$\begin{aligned} x &= \frac{(p + Cn + C)^2 - (p + Cn)^2}{C} \\ x &= \frac{p^2 + 2pCn + 2pC + 2C^2n + C^2 + C^2n^2 - p^2 - 2pCn - C^2n^2}{C} \\ x &= \frac{2pC + C^2 + 2C^2n}{C} \\ x &= 2p + C + 2Cn \end{aligned} \tag{2}$$

$C \neq 0; p \geq 0; n \geq 0$ ; we see that equation (1) is the special case of equation (2) where  $n = 0$ . Note that after an initial selection of starting number,  $p$ , then  $2p + C$  becomes constant.

As regards our example series that begins with 7 and uses intervals of 8:  $n$  corresponds to the 0 based cardinal value of the member of the series. The first of of this (zero based) series is 7-15 ( $n = 0$ ), the 2nd is 15-23 ( $n = 1$ ), the 3rd 23-31 ( $n = 2$ ), and so on. Using the 3rd of our example series setting  $p = 7; C = 8; n=2$ :

**Checking:**  $2(7) + 8 + (2 \times 8 \times 2) = \frac{(31^2 - 23^2)}{8} = 54$

## 4 Prime structures

When the prime sextuplets were analyzed as regards their formation and “survival”, it became clear that the primes could be arranged into groups that would facilitate sextuplet study.

There are three groupings of primes that are here considered “natural”:

- Primes 2,3,5
- Primes 7-29
- Primes 31-59

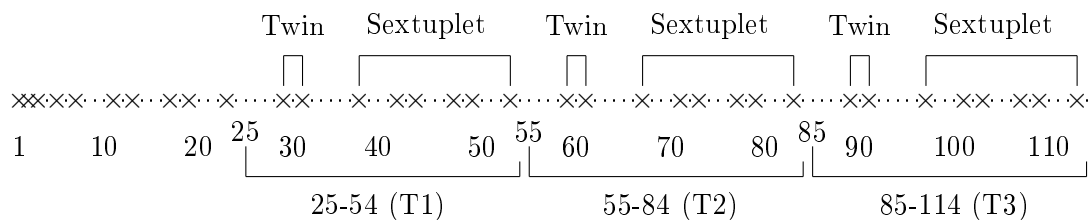
There are also indications that the 3rd group has other natural regions that may be worthy of study.

The idea is to set up the number line structure into groups that can be checked for Tuplets by block addition, in effect a Gestalt, or pattern, check. This means that no numbers are analyzed to see if they are prime at all. In essence, all 6 members of the sexuplet (and tuplet) structures are checked at once. After developing this idea one finds order in the primes that was not before apparent, order that can be quantified, to a good extent, in equations.

### 4.1 Primes 2, 3, & 5: Template Block

The formation seed of sextuplets is easily seen when we return to the partial sieve of Erathosthenes of 2/3/5. As shown in fig. 3 they pop out naturally from, what I call, the Prime Template:

This partial sieve divides the number line up into repeating groups of size 30, starting at 25. They are numbered starting from 1 (the 0th Template starts at -5) at Template Number 1 (or T1 or  $T_1$ ). The first Template runs from 25 to 54, inclusive, and so on. All Templates begin with a number ending in 5. This study focuses on Sexuplets and Tuplets, so the “rogue” twin primes in the left portions of each Template are ignored. If



a number in parenthesis follows a TNumber it is showing the starting counting number at that TNumber, for example:  $T_1$  (25) means  $T_1$  starts at 25.

		Prime Template												
		T3 demonstrates alignment												
			9	1		7		1	3		7	9		3
		5	×	×		×		×	×		×	×		×
T3 (85-114):	85		90		95		100		105		110			
		Offsets to prime positions												
			9	1		7		1	3		7	9		3
		0	4	6		12		16	18		22	24		28
mod	0		4	6		12		16	18		22	24		28
counting	1		5	7		13		17	19		23	25		29

Several things are apparent after seeing the Template: sextuplets must always start with a prime number that ends with a 7. Twin primes will only be found with primes ending in x9/x1, x1/x3, x7/x9, no other ending digits are possible for twins. The twin x9/x1 can never be a remnant of a sextuplet.

For the most part, from here on (unless otherwise noted) number lines will represent TNumbers, not counting numbers. To convert counting numbers ( $N$ ) to TNumbers ( $T$ )

see equation (3), for the reverse see equation (4):

$$T = \left\lfloor \frac{N+5}{30} \right\rfloor = (N+5) \text{div} 30 \quad (3)$$

$$\begin{aligned} N_{\text{start}} &= (T \times 30) - 5 \\ N_{\text{end}} &= N_{\text{start}} + 29 = (T \times 30) + 24 \end{aligned} \quad (4)$$

What we can finally say about the primes 2/3/5 is that there is no need to worry about them further. They have given us a template to use which always starts off with a pristine Sextuplet. These primes come no farther into the calculations and structures that follow.

## 4.2 Conventions

### 4.2.1 Symbols for template diagrams and prime structures

Symbols are often used in files and diagrams to symbolize the Tuplet result at any particular Template:

- **H**: Sextuplet. The two vertical bars represent the end primes of the sextuplet, the horizontal the quadruplet (or double-twin).  
In the computer code it is represented by 0.
- **┌**: Left-sided Quintuplet.  
In the computer code it is represented by 1.
- **┐**: Right-sided Quintuplet.  
In the computer code it is represented by 2.
- **-**: Quadruplet.  
In the computer code it is represented by 3.
- **X**: Tuplet is destroyed.  
In the computer code it is represented by 4.
- **o**: Spacer; i.e., a skip or inflationary space is added in the diagrams
- **●**: equivalent to a Sexuplet.

The symbol **●** is a less busy equivalent to **H**. When you see either of these symbols in a table, diagram or file it means the symbol's effect is that the Sextuplet in that template survives and passes on to the next check.



### 4.2.2 Standards

- $C$ , equal to 30, is the constant size of the length of the Prime Template.
- $T_n$  is any TNumber
- $T_{\text{exp}}$  stands for TNumber expanded (which is done using equation 4 on the preceding page).
- forms of  $T_n(N)$  show the TNumbers starting value in the parentheses; e.g.  $T_1(25)$

## 4.3 Primes 7 through 29

I believe one word describes the primes 7-29 situation: chaos. Is it possible to find a “natural” pattern here that would be of use in studying Sextuplets?...

We now have a tool, the Prime Template, we can use to check the status of our starting pristine Sextuplet. The need is simple: starting at any TNumber we need to apply the effects of the seven primes 7, 11, 13, 17, 19, 23, and 29 at that Template. If the effect of the prime at that Template is a Sextuplet (meaning a sextuplet is still allowed, its allowed to “pass”) at each of these primes then the original pristine sextuplet is allowed; i.e., it survives. If any of the effects is a quintuplet, then the original sextuplet is altered to be a quintuplet. Likewise, if the effect of any is a quadruplet the sextuplet is altered to be a quadruplet (see section 4.4 on page 22).

So our first consideration is simple: we need some structure that can tell us what effect a prime will have at any particular Template Number. We need to map the effects of these primes into a structure that can be used to determine the prime’s effects at a TNumber. We will first analyze 7 to build up its “natural progression”.

Both equations and computer code are simpler to code using mod results (0 based counting), and it is preferred in this study to use mod crossings and positions.

Many of the details shown in the Prime 7 initial section will also apply to all the other primes 11-29.

Each prime 7-29 we will analyze has these useful properties: its value, its value squared, and the TNumber in which it becomes effective (see section 3.1 on page 3).

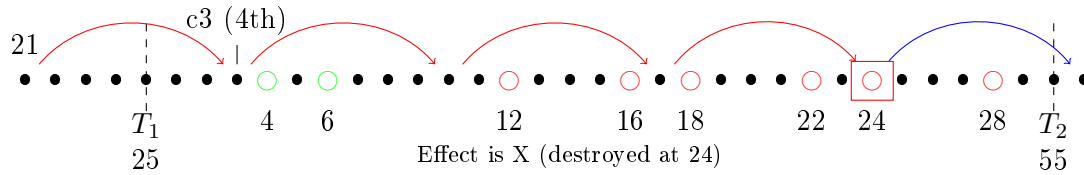
### 4.3.1 Prime 7

Its value is 7 and it becomes effective at  $7^2 = 49$ . So, evaluating 49 in equation 3 on the previous page gives us 7’s effective TNumber:  $T_1(25)$ .

We now only need to determine 7’s effects as it passes through  $T_1$  and the next 6 Templates,  $T_1(25)$  to  $T_7(205)$ , inclusive, because after that its effects will repeat. To do this we map out crossing effects against the Prime Template.

We build the crossing numbers and effects by following 7 as it passes through the Templates. By convention the crossing numbers are named after the position the prime lands on after crossing the Template border.

In the diagram below the dotted vertical lines denote the beginnings of Templates. All positions in the template are mod based. The “rogue twin” at the left (positions 4 and 6) are green colored; they are ignored in this Sextuplet study. If the prime, in this case 7, hits one of the Sextuplet positions it is emphasized with a surrounding box. The ends of the arrows point to the strike point. For clarity the beginnings of the arrows start from the last strike point, but they are not inclusive in the counting, showing that they span the next, in this case, 7 positions. Finally, the effect (See Symbol summary Symbols for template diagrams and prime structures on page 8) of this crossing is shown.



So, from this particular crossing of 7 we now know that if we find, at any TNumber we like, that the crossing number of 7 is c3, we know that the sextuplet at that TNumber is destroyed. A complete analysis of 7’s movements through Templates gives us a simple look up table for effects, and a chart of its “natural progression” through the TNumbers.

For those interested in seeing the complete prime 7 crossing number analysis see Complete crossing number analysis for prime 7 on page 56.

#### 4.3.2 Prime 7: LookUp Table and Natural Progression

As you inspect 7’s crossing numbers and effects in the table below you see that out of the 7 possibilities for 7, only 1 (c6) allows a sextuplet to survive, meaning only every 7th Template ever has a possibility to ultimately produce a sextuplet.

This shows that the difference between TNumbers that contain sextuplets, or differences of corresponding members of differing sextuplets, will always be evenly divisible by 7. This, then, shows that starting from  $T_3$  only every 7th Template has a possibility of producing a Sextuplet:  $T_3, T_{10}, T_{17}$  etc.

Given that the closest two Sextuplets can be to each other, by Template Number, is 7 then it follows that a “twin sextuplet” must be of the form  $T_n$  and  $T_{n+7}$ . See section Twin Sextuplets on page 22 for more information about twin Sextuplets.

Prime 7 effect table:

7 CrossNum	Effect	Next Crossing
c0	┐	→c5
c1	X	→c6
c2	X	→c0
c3	X	→c1
c4	X	→c2
c5	┌	→c3
c6	●	→c4

●○○○○○

Prime 7 natural progression:

Prime 7	c3	c1	c6	c4	c2	c0	c5	... c3 → ∞
Effect	X	X	●	X	X	┐	┌	...
$T_n$	$T_1$	$T_2$	$T_3$	$T_4$	$T_5$	$T_6$	$T_7$	...
$T_{\text{exp}}$	25	55	85	115	145	175	205	...
	0	1	2	3	4	5	6	

#### 4.3.3 Finding Crossing Numbers

While it might seem that a simple mod function will be all we'll need to determine crossing points at Template boundaries for primes 7-29, it is not the case. In order to match the naming convention for crossing numbers, which we will use for all the prime structures we build, we need a special form; a form that will give us back "3" to match our name of c3. In equations 5 and 6,  $p$  is the value of the prime in question,  $T_{\text{exp}}$  stands for TNumber expanded (which is done using equation 4),  $T_n$  is any TNumber greater than 0, and CN, crossing number, is returned in 0 based mod position:

$$\text{CN} = (p - T_{\text{exp}} \bmod p) \bmod p \quad (5)$$

$$\text{CN} = (p - ((T_n \times 30) - 5) \bmod p) \bmod p \quad (6)$$

Testing for the crossing number for 7 at  $T_1$ :

$$(7 - 25 \bmod 7) \bmod 7 = 3$$

$$(7 - ((1 \times 30) - 5) \bmod 7) \bmod 7 = 3$$

#### 4.3.4 Prime 11

This prime becomes effective at  $11^2 = 121$ , and so 11's effective TNumber is  $T_4$  (115).

There is one example diagram for 11 in section Crossing map for 1 cycle of prime 11 on page 57. These example diagrams should suffice if you want to reproduce the crossing numbers and natural progressions for the primes 7-29.

Prime 11 effect table:

11 CrossNum	Effect	Next Crossing
c0	X	→c3
c1	┼	→c4
c2	X	→c5
c3	●	→c6
c4	●	→c7
c5	X	→c8
c6	┼	→c9
c7	X	→c10
c8	●	→c0
c9	●	→c1
c10	●	→c2

○○○○●○

Prime 11 natural progression:

Prime 11	c6	c9	c1	c4	c7	c10	c2	c5	c8	c0	c3
Effect	┼	●	┼	●	X	●	X	X	●	X	●
$T_n$	$T_4$	$T_5$	$T_6$	$T_7$	$T_8$	$T_9$	$T_{10}$	$T_{11}$	$T_{12}$	$T_{13}$	$T_{14}$
$T_{\text{exp}}$	115	145	175	205	235	265	295	325	355	385	415
	0	1	2	3	4	5	6	7	8	9	10

### 4.3.5 Prime 13

This prime becomes effective at  $13^2 = 169$ , its effective TNumber is  $T_5$  (145).

Prime 13 effect table:

13 CrossNum	Effect	Next Crossing
c0	●	→c9
c1	●	→c10
c2	┐	→c11
c3	X	→c12
c4	●	→c0
c5	X	→c1
c6	●	→c2
c7	●	→c3
c8	●	→c4
c9	X	→c5
c10	●	→c6
c11	X	→c7
c12	└	→c8

●○○○○○

Prime 13 natural progression:

Prime 13	c11	c7	c3	c12	c8	c4	c0	c9	c5	c1	c10	c6	c2
Effect	X	●	X	└	●	●	●	X	X	●	●	●	┐
$T_n$	$T_5$	$T_6$	$T_7$	$T_8$	$T_9$	$T_{10}$	$T_{11}$	$T_{12}$	$T_{13}$	$T_{14}$	$T_{15}$	$T_{16}$	$T_{17}$
$T_{\text{exp}}$	145	175	205	235	265	295	325	355	385	415	445	475	505
	0	1	2	3	4	5	6	7	8	9	10	11	12

#### 4.3.6 Prime 17

This prime becomes effective at  $17^2 = 289$ , its effective TNumber is  $T_9$  (265).

Prime 17 effect table:

17 CrossNum	Effect	Next Crossing
c0	●	→c4
c1	X	→c5
c2	●	→c6
c3	●	→c7
c4	●	→c8
c5	X	→c9
c6	●	→c10
c7	X	→c11
c8	●	→c12
c9	●	→c13
c10	●	→c14
c11	┐	→c15
c12	└	→c16
c13	●	→c0
c14	●	→c1
c15	●	→c2
c16	X	→c3

○○○○●○

Prime 17 natural progression:

P 17a	c7	c11	c15	c2	c6	c10	c14	c1	c5	c9	c13	c0	→17b
Eff.	X	┐	●	●	●	●	●	X	X	●	●	●	→
$T_n$	$T_9$	$T_{10}$	$T_{11}$	$T_{12}$	$T_{13}$	$T_{14}$	$T_{15}$	$T_{16}$	$T_{17}$	$T_{18}$	$T_{19}$	$T_{20}$	→
$T_{\text{exp}}$	265	295	325	355	385	415	445	475	505	535	565	595	→
	0	1	2	3	4	5	6	7	8	9	10	11	

17b	c4	c8	c12	c16	c3
...	●	●	└	X	●
...	$T_{21}$	$T_{22}$	$T_{23}$	$T_{24}$	$T_{25}$
...	625	655	685	715	745
	12	13	14	15	16

#### 4.3.7 Prime 19

This prime becomes effective at  $19^2 = 361$ , its effective TNumber is  $T_{12}$  (355).

Prime 19 effect table:

19 CrossNum	Effect	Next Crossing
c0	●	→c8
c1	●	→c9
c2	●	→c10
c3	X	→c11
c4	●	→c12
c5	X	→c13
c6	●	→c14
c7	●	→c15
c8	●	→c16
c9	┐	→c17
c10	●	→c18
c11	●	→c0
c12	└	→c1
c13	●	→c2
c14	●	→c3
c15	●	→c4
c16	X	→c5
c17	●	→c6
c18	X	→c7

●○○○○○

Prime 19 natural progression:

P 19a	c6	c14	c3	c11	c0	c8	c16	c5	c13	c2	c10	c18	→19b
Eff.	●	●	X	●	●	●	X	X	●	●	●	X	→
$T_n$	$T_{12}$	$T_{13}$	$T_{14}$	$T_{15}$	$T_{16}$	$T_{17}$	$T_{18}$	$T_{19}$	$T_{20}$	$T_{21}$	$T_{22}$	$T_{23}$	→
$T_{\text{exp}}$	355	385	415	445	475	505	535	565	595	625	655	685	→
	0	1	2	3	4	5	6	7	8	9	10	11	

19b	c7	c15	c4	c12	c1	c9	c17
...	●	●	●	└	●	┐	●
...	$T_{24}$	$T_{25}$	$T_{26}$	$T_{27}$	$T_{28}$	$T_{29}$	$T_{30}$
...	715	745	775	805	835	865	895
	12	13	14	15	16	17	18

#### 4.3.8 Prime 23

This prime becomes effective at  $23^2 = 529$ , its effective TNumber is  $T_{17}$  (505).

Prime 23 effect table:

23 CrossNum	Effect	Next Crossing
c0	●	→c16
c1	X	→c17
c2	●	→c18
c3	●	→c19
c4	●	→c20
c5	┐	→c21
c6	●	→c22
c7	●	→c0
c8	●	→c1
c9	●	→c2
c10	●	→c3
c11	●	→c4
c12	└	→c5
c13	●	→c6
c14	●	→c7
c15	●	→c8
c16	X	→c9
c17	●	→c10
c18	X	→c11
c19	●	→c12
c20	●	→c13
c21	●	→c14
c22	X	→c15

○○○○●○

Prime 23 natural progression:

P 23a	c1	c17	c10	c3	c19	c12	c5	c21	c14	c7	c0	c16	→23b
Eff.	X	●	●	●	●	└	┐	●	●	●	●	X	→
$T_n$	$T_{17}$	$T_{18}$	$T_{19}$	$T_{20}$	$T_{21}$	$T_{22}$	$T_{23}$	$T_{24}$	$T_{25}$	$T_{26}$	$T_{27}$	$T_{28}$	→
$T_{\text{exp}}$	505	535	565	595	625	655	685	715	745	775	805	835	→
	0	1	2	3	4	5	6	7	8	9	10	11	

23b	c9	c2	c18	c11	c4	c20	c13	c6	c22	c15	c8
...	●	●	X	●	●	●	●	●	X	●	●
...	$T_{29}$	$T_{30}$	$T_{31}$	$T_{32}$	$T_{33}$	$T_{34}$	$T_{35}$	$T_{36}$	$T_{37}$	$T_{38}$	$T_{39}$
...	865	895	925	955	985	1015	1045	1075	1105	1135	1165
	12	13	14	15	16	17	18	19	20	21	22



#### 4.3.9 Prime 29

This prime becomes effective at  $29^2 = 841$ , its effective TNumber is  $T_{28}$  (835).

Prime 29 effect table:

29 CrossNum	Effect	Next Crossing
c0	●	→c28
c1	●	→c0
c2	●	→c1
c3	●	→c2
c4	●	→c3
c5	●	→c4
c6	●	→c5
c7	●	→c6
c8	●	→c7
c9	●	→c8
c10	●	→c9
c11	●	→c10
c12	┐	→c11
c13	●	→c12
c14	●	→c13
c15	●	→c14
c16	X	→c15
c17	●	→c16
c18	X	→c17
c19	●	→c18
c20	●	→c19
c21	●	→c20
c22	X	→c21
c23	●	→c22
c24	X	→c23
c25	●	→c24
c26	●	→c25
c27	●	→c26
c28	┐	→c27

○○○○●○

Prime 29 natural progression:

P 29a	c6	c5	c4	c3	c2	c1	c0	c28	c27	c26	c25	c24	→29b
Eff.	●	●	●	●	●	●	●	┐	●	●	●	X	→
$T_n$	$T_{28}$	$T_{29}$	$T_{30}$	$T_{31}$	$T_{32}$	$T_{33}$	$T_{34}$	$T_{35}$	$T_{36}$	$T_{37}$	$T_{38}$	$T_{39}$	→
$T_{\text{exp}}$	835	865	895	925	955	985	1015	1045	1075	1105	1135	1165	→
	0	1	2	3	4	5	6	7	8	9	10	11	

29b	c23	c22	c21	c20	c19	c18	c17	c16	c15	c14	c13	→29c
...	●	X	●	●	●	X	●	X	●	●	●	→
...	$T_{40}$	$T_{41}$	$T_{42}$	$T_{43}$	$T_{44}$	$T_{45}$	$T_{46}$	$T_{47}$	$T_{48}$	$T_{49}$	$T_{50}$	→
...	1195	1225	1255	1285	1315	1345	1375	1405	1435	1465	1495	→
	12	13	14	15	16	17	18	19	20	21	22	

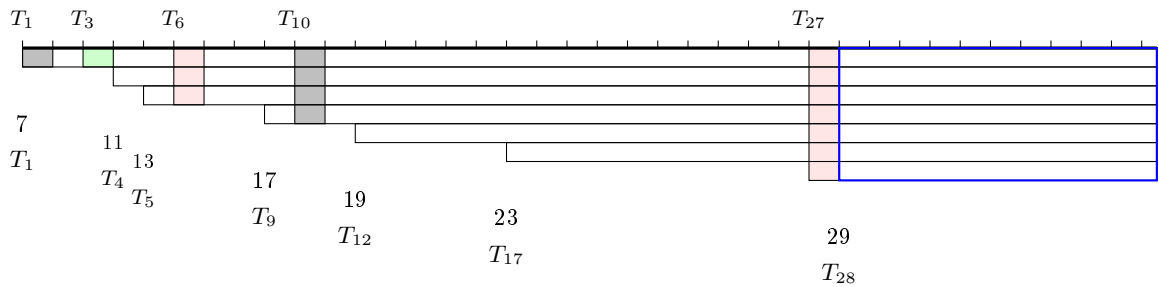
29c	c12	c11	c10	c9	c8	c7
...	┌	●	●	●	●	●
...	$T_{51}$	$T_{52}$	$T_{53}$	$T_{54}$	$T_{55}$	$T_{56}$
...	1525	1555	1585	1615	1645	1675
	23	24	25	26	27	28

#### 4.3.10 Usage of primes 7-29

In their most basic form they provide lookups to determine the effect each of these primes have on any Template you pick out of the infinitely many Templates there are. We will see shortly, in section Prime Basis below, how to reduce the range we choose from and how remove primes 7-29 from any further consideration in this study.

In the diagram the thick black line at the top represents the primes 2,3,5 structure. It is a line consisting of TNumbers going from  $T_1 \rightarrow T_\infty$ . The spacing of vertical dashes on this line represents the 30 numbers contained within each Template. Each of the primes 7-29 is shown at each's effective starting TNumber.

The diagram is read from top to bottom, so each TNumber begins at the 2,3,5 layer meaning each is a pristine Sextuplet. The gray areas show which primes are effecting that TNumber. We need to calculate the crossing number of the respective effecting prime (see Finding Crossing Numbers on page 11), look up the effect at that crossing number from the tables above, and then do "symbol math" (see Tuplet Math on page 22).



The crossing number of 7 at  $T_1$  is c3. 7's c3 effect is "X", meaning it destroys the sextuplet that comes from above. All the other Templates in the diagram, outside of  $T_3$ ,  $T_6$ ,  $T_{27}$ , are also destroyed, or "X"d, by one or another of the primes effecting them.

The crossing number of 7 at  $T_3$  is c6. 7's c6 effect is ●, equivalent to  $\text{H}$ . It allows the sextuplet to pass, and hence the sextuplet 97, 101, 103, 107, 109, 113 survived and resides in  $T_3$ .

For the more complex analysis of the larger TNumbers we will summarize the results in a running cumulative-result table.

For  $T_6$ :

$T_6$	CrossNum	Effect at CrossNum	Running Result
$T_6$ starts as		H	
prime 7 effect	0	┐	┐
prime 11 effect	1	┘	-
prime 13 effect	7	●	-

The starting sextuplet at  $T_6$  (175) is altered to be the quadruplet: 191, 193, 197, and 199.

Next for an example of sextuplet destruction  $T_{10}$ :

$T_{10}$	CrossNum	Effect at CrossNum	Running Result
$T_{10}$ starts as		H	
prime 7 effect	0	●	H
prime 11 effect	2	X	X

The sextuplet at  $T_{10}$  is destroyed by prime 11, no need to test primes 13 or 17.

And finally for  $T_{27}$ :

$T_{27}$	CrossNum	Effect at CrossNum	Running Result
$T_{27}$ starts as		H	
prime 7 effect	0	┐	┐
prime 11 effect	9	●	┐
prime 13 effect	1	●	┐
prime 17 effect	11	┐	┐
prime 19 effect	12	┘	-
prime 23 effect	0	●	-

$T_{27}$  (805) also finishes up as a quadruplet: 821, 823, 827, and 829 .

The TNumbers 1 to 27, inclusive, are special cases in this study, they do not fit into the general scheme that is yet to be described because of how the primes “layer” themselves under the TNumbers up until  $T_{28}$ .

In the diagram above the area denoted by the thick blue line indicates the start of prime 29’s influence at  $T_{28}$ . Every Tnumber after this will have to be analyzed by each of the primes 7 through 29, or at least up to the point where the Tuplet becomes destroyed. More importantly, however, is that we now have a rectangle beginning at  $T_{28}$  and extending to infinity. This is of use as we see in the next section.

#### 4.3.11 Prime Basis

The chaos and general sextuplet destructiveness of the primes 7-29 is simply a given. The power of 7 and 11 alone to destroy sextuplets is gargantuan. Out of an infinity of

choices where should we look for sextuplet survivors?

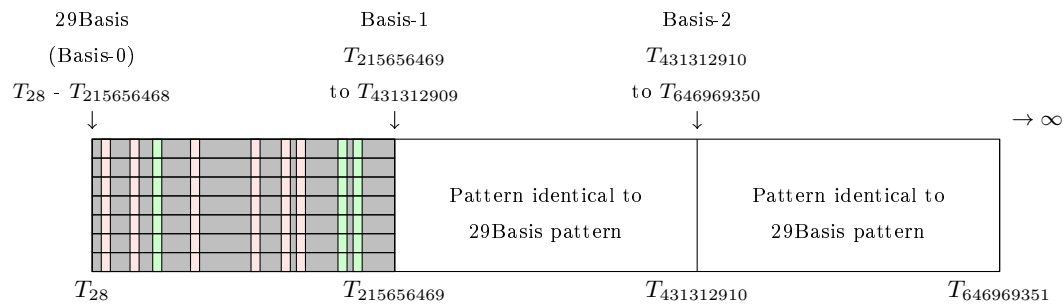
We will use the 29Basis to help us. The 29Basis, the only useful pattern for primes 7-29, is a catalog of the only locations, by TNumber, where sextuplets, and/or other Tuples, are possible. The 29Basis is functional out to infinity because it is re-usable.

The 29Basis catalog is produced by simply calculating, in order, *all the combinations* of prime 7 through 29 using the method outlined in section Usage of primes 7-29 on page 18.

This is not as bad as it sounds! The total combinations to calculate will be 7-29 primorial; i.e.,  $7 \times 11 \times 13 \times 17 \times 19 \times 23 \times 29 = 215656441$ .

We only need to iterate over 215,656,441 TNumbers. This is sufficient since the pattern, and results, will then repeat. This means the 29Basis is constructed over  $T_{28}$  to  $T_{215656468}$ , inclusive. When we reach  $T_{215656468}$  we can stop because the pattern repeats beginning with  $T_{215656469}$ .

In the diagram below the 29Basis, as well as its re-usable nature, is sketched out. In it we've performed the crossing number effect for each TNumber and green areas represent sextuplets which have survived, pink other surviving Tuples, and gray are destroyed 'tuplets. That 29basis then repeats forever.



We can now throw out the grays and keep the greens. Optionally, if one is also interested in quintuplets and quadruplets, keep the pinks. The calculation process only needs to be done once, and it takes a computer only a minute or two to calculate and write to a file (file size about 190Mb). The resulting file is the 29Basis: a catalog of the only TNumbers where Tuples are possible (the program I wrote will make this file for you, if you prefer not to code something yourself).

Once one has this catalog there is no further need to consider primes less than 31, the primes 7-29 have done their job and provided a usable pattern for us to use and made the discovery and study of sextuplets viable.

A completed 29Basis file has the following statistics. Remember that these 29Basis locations are only where Tuples *can* be, it will take the primes 31-59 to make the final decision if the Tuple will survive:

1,956,955 Sextuplets  
 5,010,341 Left sided Quintuplets  
 5,010,341 Right sided Quintuplets

5,528,488 Quadruplets

~17.5 million TNumbers out of the 215 million+ that we searched

The following constants define the limits of bases: Basis begin (b), Basis end (e), and Basis length (L). Remember that the begin and end are inclusive:

$$B_B = 28$$

$$B_E = 215656468$$

$$B_L = 215656441$$

The 29Basis starts at  $T_{28}$ , which begins with integer 835, and extends to and includes  $T_{215656468}$ , which ends with integer 6,469,694,064, a range which covers many needs. And it is very easy to use the 29Basis to find and study any number range we like. The catalog is infinitely re-usable because one only needs to add 215,656,441 to any TNumber from the 29basis file to move to the next basis, Basis-1 which has the range as shown in the figure above. If you want to study numbers in Basis-2 then add  $(215,656,441 \times 2)$  to the 29basis TNumber. Or, more generally, use the following relation where  $T_{bc}$  is a TNumber from the 29basis catalog and  $b$  is the basis number ( $b \geq 0$ ):

$$T_{bc} = T_{bc} + B_L b \quad (7)$$

Basis-0, then, is the 29Basis file TNumbers unaltered since  $b = 0$

Basis-1,  $b = 1$ , will analyze the 29basis TNumbers as being in the  $T_{215656469}$  to  $T_{431312909}$  range, and so on.

Following are the relationships that connect bases and TNumbers (if you want to use regular number line positive integers then convert them to their TNumbers first).

Find the TNumber range, beginning ( $T_b$ ) and ending ( $T_e$ ), for any Basis number b:

$$T_b = B_B + B_L b \quad (8)$$

$$T_e = B_E + B_L b \quad (9)$$

Given any TNumber,  $T_n$ , ( $n \geq B_B$ ) return the Basis number, b, it resides in:

$$b = (T_n - B_B) \text{div} B_L \quad (10)$$

One can, of course, search any range of numbers in any way one likes: by TNumber, by Basis, or by range of integers greater than 835. But the advantage of Basis based TNumber analysis is completeness, nothing can be missed, all numbers will be guaranteed to have been tested. If one tested by groups of 1 million, for instance, it is quite possible that some findings will be duplicated because of the peculiarities of integer to TNumber conversion. Or, it could be that a entire range was missed as it becomes difficult to accurately type large integers by hand. For these reasons, I recommend using Basis based analysis.

In summary so far: we've used the primes 2,3,5 and the primes 7-29 to build natural groupings in such a manner as to obviate the need to use primes 2-29. There is no need to consider any prime less than 31 for the remainder of this study.

#### 4.3.12 Twin Sextuplets

Given that the closest two Sextuplets can be to each other, by TNumber, is 7 (as discussed in section 4.3.2 on page 10), then it follows that a "twin sextuplet" must be of the form  $T_n$  and  $T_{n+7}$ .

How likely are they? Analysis of my 29Basis file shows there are 106,029 *possible* twin sextuplets. A quick look through a basis-0 and basis-1 sextuplet file found none, and so, if twin sextuplets exist in actuality, they must be in the range greater than  $T_{431312909}$ . This is an ongoing study as I have not found references to twin sextuplets on the internet.

Twin sextuplets will have the relationships as below, where  $T$  is any TNumber and  $T_2 > T_1$ , and  $N$  is any corresponding prime member of separate sextuplets and  $N_2 > N_1$ :

$$\frac{T_2 - T_1}{7} = 1 \text{ or } T_2 - T_1 = 7 \quad (11)$$

$$\frac{N_2 - N_1}{7} = 30 \text{ or } N_2 - N_1 = 210 \quad (12)$$

#### 4.4 Tuplet Math

For a review of symbol meanings see section Symbols for template diagrams and prime structures on page 8.

Each of our TNumbers starts out as a pristine Sextuplet. As time goes by and other primes cross into that TNumber they have effects which are added to what has come previously. The result can either be survival, change, or destruction. The tables below show a selection of symbol addition in detail, the idea is easy to see. The numbers in the header are the 0-based indices of the sextuplet positions in a Prime Template. The Symbol X denotes that the effect of a prime number crossing into that TNumber was to strike, i.e., remove, that position.

Four basic examples, once an X is inherited it stays with the TNumber. An X is when the prime strikes either 16, 18, 22, or 24 Prime Template index:

	Symbol	12				16		18				22		24				28
Sextuplet	<b>H</b>	o				o		o				o		o				o
+ Sextuplet	<b>H</b>	o				o		o				o		o				o
=	<b>H</b>	o				o		o				o		o				o

	Symbol	12			16		18			22		24			28
Sextuplet	<b>H</b>	o			o		o			o		o			o
+ {16 18 22 24}		o			X		o			o		o			o
=	destroyed	o			X		o			o		o			o

	Symbol	12			16		18			22		24			28
Sextuplet	<b>H</b>	o			o		o			o		o			o
+ R. Quintuplet	<b>⌊</b>	X			o		o			o		o			o
=	<b>⌊</b>	X			o		o			o		o			o

	Symbol	12			16		18			22		24			28
Sextuplet	<b>H</b>	o			o		o			o		o			o
+ L. Quintuplet	<b>⌋</b>	o			o		o			o		o			X
=	<b>⌋</b>	o			o		o			o		o			X
+ R. Quintuplet	<b>⌊</b>	X			o		o			o		o			o
=	<b>-</b>	X			o		o			o		o			X

#### 4.4.1 Summary of symbol addition:

A note about the quadruplet: They do not occur in nature. There is no crossing of any prime that produces a quadruplet effect. Crossing effects can only be 1) allowing a sextuplet to survive, 2) applying a right quintuplet effect, or 3) applying a left quintuplet effect. The “sum” can never return to a previous state when it is changed, it can only remain in the current state, be changed to another state in accordance with the rules below, or destroyed.

Quadruplets are the marriage of a right quintuplet and a left quintuplet effect, those natural quadruplets are starred green. While the quadruplet is represented in the tables for completeness, it is not always relevant in that no crossing effect can ever be a quadruplet, those cases are starred red. If a TNumber sum result reaches a quadruplet state nothing can change that state unless it is destroyed by a {16|18|22|24=X} strike.

The computer codes in current use that represent the effects are also shown.

current state		+ effect		=	
H	0	H	0	H	0
H	0	T	1	T	1
H	0	⊥	2	⊥	2
H	0	- ★	3	-	3
H	0	X	4	X	4
...		...		...	
T	1	H	0	T	1
T	1	T	1	T	1
T	1	⊥	2	- ★	3
T	1	- ★	3	-	3
T	1	X	4	X	4
...		...		...	
⊥	2	H	0	⊥	2
⊥	2	T	1	- ★	3
⊥	2	⊥	2	⊥	2
⊥	2	- ★	3	-	3
⊥	2	X	4	X	4
...		...		...	
-	3	{any}		-	3
X	4	{any}		X	4

## 4.5 Primes 31 through 59

The primes 31-59 are the deciders of the ultimate fate of any 29Basis Template's effect. These primes form a group that will represent all primes, but that are not necessarily prime at every level, and so it is better to call them now, what they really are: *potential primes*. To signify that they will either be noted as “potential prime”, “potPrime”,  $Q$ , or  $pP()$ .

The potential primes are: 31, 37, 41, 43, 47, 49, 53, 59

Those values are the base values of that potPrime family; i.e.,  $Q_{\text{base}}^{31} = 31$ ,  $Q_{\text{base}}^{37} = 37$ , and so on. They are the first “primes” of the form where their values mod 30 are: 1, 7, 11, 13, 17, 19, 23, and 29

When there is any need to identify a particular member of a potPrime family it will be denoted as  $Q^{31}$  or  $pP(31)$ ,  $Q^{37}$  or  $pP(37)$ , and so on.

What follows will be a detailed descriptions, and derivations, of the structures, patterns, and relationships of the potPrimes. If you just want to know how to use them for sextuplet generation then see Usage of primes 31-59 on page 35



#### 4.5.1 Potential Prime properties

The potPrimes are very regular, follow regular patterns, and are amenable to equations and structures. They can represent all primes  $\geq 31$  simply by adding products of 30 to each. For instance,  $31, 61, 91 \dots \pmod{30} = 1$ . Similarly,  $49, 79, 109 \dots \pmod{30} = 19$ , and so on.

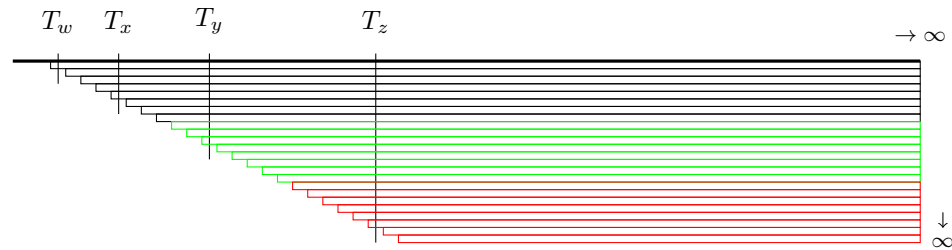
The relation below shows how any prime  $\geq 31$  can be constructed, where  $C$  is our constant 30,  $n \geq 0$ , and  $Q_{\text{base}}$  is the potPrime's base value :

$$Q_n = Q_{\text{base}} + Cn \quad (13)$$

Examples:  $Q_0^{37} = 37$ ,  $Q_2^{49} = 109$ , and so on.

Their natural progressions through Prime Templates are developed in the same fashion as they were for the primes 7-29 (4.3.1 on page 9).

The following diagram illustrates the structure we are building with these primes. It is diagrammatic and does not show the exponential nature of squares of succeeding primes:



The thick black line is the number line, in TNumbers, that, if coming from the 29basis, are already pre-processed by the primes 7-29.

The beginning of each rectangle represents the location where a potential prime becomes effective; that is, at its base value squared. The color groups correspond to the  $n$  in  $Q_n = Q_0 + Cn$  (equation 13), so black is  $n = 0$ , green  $n = 1$ , red  $n = 2$ , and so on to infinity.

The 8 rectangles of the black group are potPrimes 31, 37, 41,..., the green group to the 8 potPrimes of 61, 67, 71,..., and the red group to 91, 97, 101,...

We want to evaluate TNumbers coming from “above”, and to do this we must iterate through any potPrime that is “effective” at that point. For  $T_w$  it is potPrime 31 ( $Q_0^{31}$ ). For  $T_x$  it requires processing by potPrimes 31...47 before we can be certain we’ve confirmed its sextuplet-ness. For  $T_y$  it is the potPrimes 31...71, and for  $T_z$  31...109.

Our goal is translate this entire structure into equations that can give confirmation of sextuplet survival, or destruction, at any TNumber we like, and that such equations can help us investigate sextuplet discovery, and, perhaps, hints as to whether sextuplets are infinite.

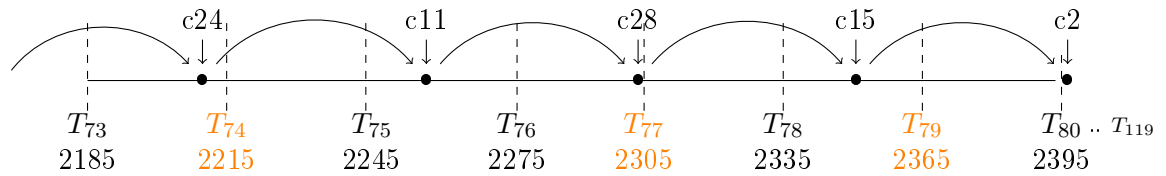
Following are the defining properties of potential primes:

#### STRAIGHTFORWARD CROSSING NUMBERS:

One big advantage is that the point that they strike when crossing is exactly that point; for example, if the crossing number is 12 then it has struck position 12 exactly. This is because all these primes are greater than the Template length: They can hit only one point in a Template and not multiple points like the primes 7-29. Therefore the crossing number and positional strike are equal. It also means that a crossing number of, for example, 12, the right handed quintuplet position, is the same for all potPrimes.

#### SKIPPING PRIME TEMPLATES:

In addition, again since each is  $> 30$ , there must be at least one or more TNumbers that are completely skipped for each potPrime. In fact, the number of skippings over each potPrime's pattern are, respectively, 1, 7, 11, 13, 17, 19, 23 and 29. The figure below for pP(47) illustrates this, pP(47)'s effective TNumber (remember effective TNumber is based on the prime's square which for 47 is 2209) is  $T_{73}$  (2185). The arcs encompass ranges of 47, while the distance between TNumbers is, of course, 30. The figure is diagrammatic, not to scale, and not complete (the last TNumber in 47's natural progression is  $T_{119}$ ):



One sees how  $T_{74}$ ,  $T_{77}$ , and  $T_{79}$  are skipped. In the summary tables of the potPrimes Details such skips are symbolized by “o”.

#### INFLATION:

These 8 potPrime families suffice for all calculations involving finding effects at any TNumber we choose because the natural progressions for each member of the potPrime family is identical to the base value's natural progression (with one caveat). For example, the natural progression of pP(61) is the same as it is for pP(31). The natural progression of pP(91) is identical to pP(61) is identical to pP(31). This is true for every  $Q_n$  in family  $Q$ .

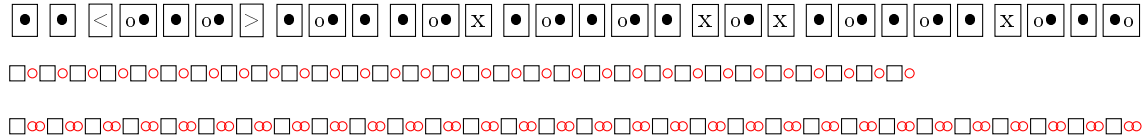
The caveat is that pP(61) is bigger than pP(31) by 30. It turns out, however, that this is compensated for by inserting a skip before every crossing in the natural progression; that is, the succeeding potPrime members in a family inflate the natural progression by a constant, smooth amount.

Every crossing for a potPrime gets an extra skip for every  $n > 0$ . For example,  $Q_{n=1}^{31}$  (equal to 61) will have one skip added for each of the crossings of the natural progression,  $Q_{n=2}^{31}$  (equal to 91), will have 2 skips added, and so on.

These smooth inflations are proven by mapping out pP(61)'s (and/or ...pP(91)'s, and/or pP(121)'s,...) natural progressions in the same fashion as we have used for all primes. If

one makes this effort in mappings then one will see the identical, smooth expansion as described. It is analogous to the expansion of the Universe: the expansion takes place at every location.

In the diagram below we look at the  $Q^{41}$  natural progression diagrammatically and show how expansion works. There are 30 boxes showing the Prime Template strikes 41 makes, the indexing of these boxes is  $0 \dots 29$ . An “o” inside a box indicates that 41 has skipped a Template before arriving in that box. The “<” stands for a left handed quintuplet strike, the “>” a right handed quintuplet strike, and “x” for a destroying strike. The black dot means it has no effect:



In the second and third rows, for space considerations, the boxes from the first row are summarized by blank boxes, but they contain exactly the same information one sees in row 1. Row 1 is  $n = 0$  (i.e.,  $Q_0^{41}$ ). Row 2 shows the natural progression of  $Q^{41}$  at  $n = 1$ , that is the potential prime 71. It leaps over an extra template at each jump because it is 30 bigger than 41. Row 3 is  $n = 2$ , potPrime 101, and it must leap over 2 templates each time. The contents of the boxes do not change, and so one sees the natural progressions do not change among members of a potPrime family, they just become inflated.

The diagram, row 1, also shows how the two cycles of 30 and 41 combined interact. The cycle can be looked in two ways: There are 41 30-cycles, or there are 30 41-cycles, before the pattern repeats. The potPrime 41 strikes exactly 30 Templates in the combined cycle because it skips some Templates. The 30 41's are the manner in which 41 soars from one Template to strike into the next (sometimes skipping one). I've already mentioned there are 30 boxes in the diagram. If you now count the symbols inside the boxes the total will be 41. This interaction cycle is the same for all  $Q$ .

By the way, an inflation space is never put before the first template crossing (position 0). That always lines up correctly because the potPrimes are interval-ized (discussed soon). When doing natural progressions by hand, it may appear that one needs to insert a skip space before the first template crossing, but this is illusion. Those phantom skip spaces can be added to the end of the sequence instead with no loss of meaning or functionality.

This inflation for pP(31)'s family is also true for every potPrime (pP(37), pP(41),...) which means that a single equation can be derived that gives the relevant effective starting TNumber for any potPrime we like, as far out as we like. That derivation follows below. It also means that the inflation can be summarized in tables, this is discussed next.

#### CROSSING EFFECT LOOKUPS:

Since we now have a family of primes describing crossing number effects out to infinity, a simple direct look up relationship, such as we had for primes 7-29, no longer suffices. This is particularly true since we want to use unifying equations and we know potPrime members natural progressions inflate making crossings a moving target.

Effect lookup is replaced by lookup tables that are derived from each respective potPrime's natural progression. It consists of a crossing offset and a multiplication factor which will then adjust any expanded potPrime (i.e.,  $Q_{n \geq 1}$ ) to give back its effect at any TNumber position in the number line. These lookup tables can be considered “constants” of each respective potPrime.

We will re-create the lookup table for  $Q^{41}$ . Natural progressions are, by definition, 30 positions long and map out the effects a potPrime has as it travels though its cycle striking into Prime Templates. The natural progressions are labeled in 0-based notation so the indices of the positions will be  $0 \dots 29$  and  $0 \dots 40$ . In the following figure the numbers above are the cumulative sum of symbols in the boxes at that box, the numbers below the index of that box:

$c$	0	1	2	4	5	7	8	9	11	12	13	15	16	17	19	20	22	23	24	26	27	28	30	31	33	34	35	37	38	40
	●	●	<	○●	●	○●	>	●	○●	●	●	○●	X	●	○●	●	○●	●	X	○●	X	●	○●	●	○●	●	X	○●	●	●○
$q$	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29

We only need to test 6 positions for any potPrime, the 4 destructors (x) and the 2 quintuplet strikes (“<” and “>”). I have traditionally used  $c$  for the crossing effect, and  $q$  for the multiplier in my tables.

The crossing effect,  $c$ , is *as it relates to* the potential prime. This means  $c$  mirrors the 41 cycle and so is constructed by counting, starting with 0, the symbols within the boxes, and noting that number at each of the symbols of interest. This puts “<” at 2, “>” at 8, and the x’s at 16, 24, 27, and 35. These positions are where the effect is actualized by the natural progression cycle of 41 striking sextuplet positions in the prime templates.

The multiplier,  $q$ , is as the natural progression as it relates to Template length and so is mirrored by the boxes. This means  $q$  takes on the values of the natural progression index and so can be read off directly from the natural progression indices. This puts “<” at 2, “>” at 6, and the 4 x’s at 12, 18, 20, and 26. These are the positions of the boxes, and we know each box will have  $n$  inflation spaces added in between. Therefore, these  $q$  describe the inflation of potPrimes at any natural progression index.

$c$	$q$	effect
2	2	<
8	6	>
16	12	X
24	18	X
27	20	X
35	26	X

This lookup table means we never have to expand any  $Q$ , or in any way worry about how to find an effect for any  $Q_{n \geq 0}$  at any TNumber. All we need is  $n$ , the same  $n$  we use in the relationship  $Q_n = Q_o + Cn$ .

### 4.5.2 Using Potential Prime Effect Lookup Tables

As an example we will use the table developed immediately above this section.

The following equation governs the usage of the lookup table, where  $i$  is the calculated offset,  $n \geq 0$ , and  $c, q$  are iterated from the table rows:

$$i = c + qn \quad (14)$$

The variable  $i$  is then used to compare to the relative offset,  $R$ , of any target TNumber we are testing (discussed in section 4.5.6 on page 35):

If  $i < R$  continue on to the next row and test again.

If  $i > R$  stop testing, the index is beyond the relative position of the TNumber we are testing.

If  $i = R$  stop testing, get the effect from the table and apply symbol math (4.4 on page 22) to the cumulative effect result.

The  $i = R$  condition is also where to check whether testing will continue on to the next potPrime for the target TNumber. If we are interested only in sextuplets then any  $i = R$  stops the testing for that target, the result can no longer be a sextuplet. If, however, we are interested in the other Tuples as well, then only when the effect is “X” do we not continue to the next potPrime.

The variable  $n$  is becoming indispensable to the net of relationships within a potPrime family. We will be deriving the equation for getting  $n$  after we derive an equation for getting a potPrime effective TNumber. Following that is a discussion of finding the relative offset of any TNumber.

### 4.5.3 Convert successful result into Tuple members

For an overview of the process of testing TNumbers see Usage of primes 31-59 on page 35.

If a target TNumber passes all tests then it contains a Tuple. Generally, if one is generating lists of Tuples, one wants to see the actual Tuple members in integer form.

To convert successful results into the Tuple members first convert the target TNumber,  $T_T$ , to its integer location  $I$ :  $I = (T_T \times 30) - 5$  (eq. 4 on page 8).

Each member,  $M_{1...6}$ , always has the same offset inside a Prime Template (see fig. 4, section 4.1 on page 7), so the process is simply to add that constant value to the TNumber’s integer value:

$$\begin{aligned}
M_1 &= I + 12 \\
M_2 &= I + 16 \\
M_3 &= I + 18 \\
M_4 &= I + 22 \\
M_5 &= I + 24 \\
M_6 &= I + 28
\end{aligned} \tag{15}$$

If the Tuplet is a left sided quintuplet then the 28 offset is omitted, if a right sided quintuplet the 12 is omitted, and both of these are omitted for quadruplets.

Example:  $T_{647}$  contains a sextuplet.  $(647 \times 30) - 5 = 19405$ , and so the sextuplet members are:

$$\begin{aligned}
19417 &= 19405 + 12 \\
19421 &= 19405 + 16 \\
19423 &= 19405 + 18 \\
19427 &= 19405 + 22 \\
19429 &= 19405 + 24 \\
19433 &= 19405 + 28
\end{aligned}$$

#### 4.5.4 Derivation for getting Potential Prime effective TNumber

For this derivation we will use  $Q^{31}$  as the example but the results are the same for all potPrime families. We will use  $p$  to represent the  $pP()$ 's base value ( $Q_{\text{base}}^{31} = Q_0^{31} = 31$ ),  $C = 30$  (the length of the Prime Template), and  $n \geq 0$ .

In order to use potPrimes to discover Tuplets we need to know at which TNumber each family's members become effective (see initial assertions, section 3.1 on page 3). If the potPrime member is effective it means we must process that potPrime to see how it effects the Sextuplet we are testing.

We've seen (equation 13 on page 25) that members are calculated by taking the  $pP()$  base value and adding 30 as many times as we like. The relationship is simple:  $p_n = p + Cn$ . For example, where  $n = 0, 1, 2, 3$  we get 31, 61, 91, and 121.

In order to align all these results properly to TNumbers we will need the interval concept from the initial assertions discussed in section 3.2 on page 4, from which we will use the final general form of the squares interval equation (equation 2 on page 5):  $x = 2p + C + 2Cn$ , and we will set its initial value to  $p$  and the interval to  $C$ . This will give us  $x$ , the number of intervals of size  $C$  between successive members of the potPrime family

squared if we modify it to use the previous  $n$ :  $x = 2p + C + 2C(n - 1)$ . We can see that the portion  $2p + C$  will be constant for each potPrime, for  $p = 31$  it is 92. And, since  $2C$  is also constant equaling 60, we can for now write the equation as:  $x = 92 + 60(n - 1)$ .

From this we can expect that the difference between the TNumbers where the squares of form  $(p + Cn)^2$  reside will be equal to  $92 + 60(n - 1)$ :

$n$	$p + Cn$	$(p + Cn)^2$	$T$	$T_{\text{current}} - T_{\text{prior}}$	$92 + 60(n - 1)$
0	31	961	32	n/a, start of series	n/a, $n$ must be $\geq 0$
1	61	3721	124	$124 - 32 = 92$	92
2	91	8281	276	$276 - 124 = 152$	152
3	121	14641	488	$488 - 276 = 212$	212

Indeed, the difference between TNumbers holding the values of successive squares of potPrimes is described by the equation, and the differences from  $n$  to  $n$  are 60 greater ( $2C$ ) each time. The potPrimes are now interval-ized and the extent of the regions of influence will always be an integer multiple of our interval value; that is, they are now interval-ized for TNumbers.

For example, there are exactly 92 intervals of size 30 (TNumbers) between  $T_{32}$  and  $T_{124}$ . The difference between TNumbers which contain the values of  $31^2$  and  $61^2$  is exactly 152 Templates, and so on.

We are now able to write an equation allowing us to calculate the effective TNumber between succeeding levels of  $n$  by using the previous effective TNumber. The first TNumber is the beginning of the series, which is the potPrimes starting TNumber generally symbolized by  $Q_{\text{start}}$ . For  $Q_{\text{start}}^{31}$  the value is  $T_{32} = 32$ . By the way, all of the constants associated with each potPrime are shown in each potPrime's "Details sections" which follow a few sections below.

$n$	$T_{\text{previous}} + 92 + 60(n - 1)$	predicted $T$ Number
0	given, constant	$T_{32} = 32$
1	$32 + 92 + 60(0)$	124
2	$124 + 92 + 60(1)$	276
3	$276 + 92 + 60(2)$	488

These do indeed match the calculated TNumbers in the previous table. We can now develop the fully generalized equation. To do so we will use a special form of equation so we can watch a wonderful pattern develop,  $T_{\text{eff}}$  is the TNumber at which the potPrime becomes effective for any  $n$ :

$$T_{\text{eff}} = Q_{\text{start}} + n(2p + C) + \sum_{n=1}^n (n(2C)) - n(2C) \quad (16)$$

We need to sum the  $+n(2C)$  term because those results are cumulative. We will stop using the literal 60 and return to  $2C$ , but will replace the constant  $2p + C$  with 92:

$$T_{\text{eff}} = 32 + n(92) + \sum_{n=1}^n (n(2C)) - n(2C)$$

The  $-n(2C)$  term adjusts for the effect of looking back one result, the hack of  $T_{\text{previous}}$  we used in the last table we constructed. Here are the results of our equation for up to  $n = 5$ :

$n$	$T_{\text{eff}} = 32 + n(92) + \sum_0^n (n(2C)) - n(2C)$	$T_{\text{eff}}$
0	$32 + 0(92) + 0(2C) - 0(2C)$	32
1	$32 + 1(92) + 1(2C) - 1(2C)$	124
2	$32 + 2(92) + 2(2C) + 1(2C) - 2(2C)$	276
3	$32 + 3(92) + 3(2C) + 2(2C) + 1(2C) - 3(2C)$	488
4	$32 + 4(92) + 4(2C) + 3(2C) + 2(2C) + 1(2C) - 4(2C)$	760
5	$32 + 5(92) + 5(2C) + 4(2C) + 3(2C) + 2(2C) + 1(2C) - 5(2C)$	1092

One sees that the summed term becomes the same problem as Carl Friedrich Gauss' (in)famous add the numbers from 1 to 100 school boy tale. The general form of Gauss' solution is, where the sought solution runs from 1 to  $n$ :  $\frac{n(n+1)}{2}$ . For Gauss' problem the answer is  $\frac{100(101)}{2} = \frac{10100}{2} = 5050$ .

For our problem,  $5(2C) + 4(2C) + 3(2C) + 2(2C) + 1(2C)$ , we factor out  $2C$ :  $(5 + 4 + 3 + 2 + 1)(2C)$ , and then use the Gauss formula,  $\left(\frac{5(6)}{2}\right)2C$ . or more generally  $\left(\frac{n(n+1)}{2}\right)2C = \left(\frac{n^2+n}{2}\right)2C$ .

Alternatively, the ending negative term can be removed by canceling the first term of the sum in which case we would use  $n - 1$  instead of  $n$ :  $\left(\frac{n-1(n-1+1)}{2}\right)2C = \left(\frac{n^2-n}{2}\right)2C$  in which case the negative term is left out of the final equation.

Putting our results back into equation 16 on the preceding page using symbols. Both the  $n$  and  $n - 1$  form are displayed:

$$T_{\text{eff}} = Q_{\text{start}} + 2Q_{\text{base}}n + Cn + \left(\frac{n^2 + n}{2}\right)2C - 2Cn$$

$$T_{\text{eff}} = Q_{\text{start}} + 2Q_{\text{base}}n + Cn + \left(\frac{n^2 - n}{2}\right)2C$$

Simplifying to the final form:

$$T_{\text{eff}} = Q_{\text{start}} + 2Q_{\text{base}}n + Cn^2 \quad (17)$$

Putting it in terms of pP(31) which we've used for the examples:

$$T_{\text{eff}} = Q_{\text{start}}^{31} + 2Q_{\text{base}}^{31}n + Cn^2$$

$$T_{\text{eff}} = 32 + 2(31)n + Cn^2 = 32 + 62n + Cn^2$$



We now have a general equation to find the effective TNumber for any family member of any of the potPrimes at any location in the number line. Given  $T_T$  is the target TNumber you are testing,  $n$  is the level currently being evaluated, and  $T_n$  is the  $T_{\text{eff}}$  at that  $n$ , then when  $T_n > T_T$  you know that potPrime member,  $Q_n$ , and greater,  $Q_{>n}$ , can be ignored, they will not affect the outcome of your sextuplet testing.

#### 4.5.5 Getting “n”

Rather than guessing at each TNumber we want to test by testing values of  $n$  until the effective TNumber exceeds our target TNumber, it would be preferable to know  $n$  ahead of time so we know exactly how many potPrimes to test.

We can in fact do this by solving for  $n$  in equation 17 on the previous page. We will, however, change it slightly:

$$T_T = Q_{\text{start}} + Cn^2 + 2Q_{\text{base}}n$$

The  $T_{\text{eff}}$  of the original equation is now  $T_T$  which represents the target TNumber; i.e., the TNumber we want to test. We will ultimately need to floor the result so the returned integer will be to the nearest  $n$  that will produce *only* effective TNumbers.

There are two forms for the derivation. The first requires the potPrime details of its starting TNumber and its base value. This results in a complex formula. We will also derive a simpler version which requires the potPrime details of its base value and a calculated adjustment. Both formulas, if calculated to the appropriate precision, give the same result.

Let  $p$  stand for  $Q_{\text{base}}$ ,  $T_T$  must be  $\geq 32$  (before  $T_{32}$  no potPrime *can* be in effect). We will need to complete the square at one point:

$$\begin{aligned} T_T &= Q_{\text{start}} + Cn^2 + 2pn \\ T_T - Q_{\text{start}} &= Cn^2 + 2pn \\ T_T - Q_{\text{start}} + \frac{p^2}{C} &= Cn^2 + 2pn + \frac{p^2}{C} \\ T_T - Q_{\text{start}} + \frac{p^2}{C} &= \left( \sqrt{C}n + \frac{p}{\sqrt{C}} \right)^2 \\ \sqrt{T_T - Q_{\text{start}} + \frac{p^2}{C}} &= \sqrt{C}n + \frac{p}{\sqrt{C}} \\ \left\lfloor \frac{\sqrt{T_T - Q_{\text{start}} + \frac{p^2}{C}} - \frac{p}{\sqrt{C}}}{\sqrt{C}} \right\rfloor &= n \end{aligned}$$

Replacing with standard symbols:

$$n = \left\lfloor \frac{\sqrt{T_T - Q_{\text{start}} + \frac{(Q_{\text{base}})^2}{C}} - \frac{Q_{\text{base}}}{\sqrt{C}}}{\sqrt{C}} \right\rfloor \quad (18)$$

If the result, before flooring is negative, then the pot prime is not active yet and that potPrime can be ignored. For example,  $Q^{37}$  becomes effective at  $T_{45}$ , if you try to find  $n$  for  $Q^{37}$  in the range of  $T_{32}$  to  $T_{44}$  the equation result is, before flooring, negative, and  $Q^{37}$  will have no effect at that  $T_T$ .

The complexity of equation (18) stems from, it turns out, the fact that  $Q_{\text{start}}$  is not in terms of  $p$  and  $C$ . This can be fixed,  $Q_{\text{start}}$  is calculated from equation 3 on page 8:  $\left\lfloor \frac{N+5}{30} \right\rfloor$  where  $N$  is  $(Q_{\text{base}})^2$ . Again letting  $p$  stand for  $Q_{\text{base}}$  this becomes  $\left\lfloor \frac{p^2+5}{30} \right\rfloor$ . Now we have it in terms of  $p$  and  $C$ , but since it is floored it will fail to give a proper result in edge cases.

If we could adjust this term to always give an integer result when divided by 30 we would have what we need. And this is only possible if we add a new piece of information. The squares of potPrime base values always either end with digit 1 or digit 9. Another way of saying this is  $p^2 \bmod 30 = 1$  or 19. If we adjust the expression properly the division by 30 will always be an integer value and the floor function can be removed.

For potPrimes = 1  $\bmod 30$  we can use  $\frac{p^2-1}{30}$  and for potPrimes = 19  $\bmod 30$  we can use  $\frac{p^2-19}{30}$ , no need to floor the results these divisions are exact integers. This means we can replace  $Q_{\text{start}}$  with  $\frac{p^2-a}{30}$ , where  $a$  is the adjustment factor. For this reason each potPrime has a property  $Q_{\text{adj}}$  which is either 1 or 19, depending.

Again let  $p$  stand for  $Q_{\text{base}}$  and using our generalized  $Q_{\text{start}}$ . The final form must be floored:

$$\begin{aligned} T_T &= \frac{p^2 - a}{C} + Cn^2 + 2pn \\ T_TC &= p^2 - a + C^2n^2 + 2pCn \\ T_TC + a &= p^2 + C^2n^2 + 2pCn \\ T_TC + a &= (p + Cn)^2 \\ \sqrt{T_TC + a} &= p + Cn \\ \left\lfloor \frac{\sqrt{T_TC + a} - p}{C} \right\rfloor &= n \end{aligned}$$

Replacing with standard symbols,  $Q_{\text{adj}}$  must be either 1 or 19 which comes from the result of  $(Q_{\text{base}})^2 \bmod 30$ :

$$n = \left\lfloor \frac{\sqrt{T_T C + Q_{\text{adj}}} - Q_{\text{base}}}{C} \right\rfloor \quad (19)$$

From equation (19) or 18 on the previous page we can now get the appropriate  $n$  at any TNumber which we can use to generate the appropriate number of potPrimes that we will need in order to thoroughly test a TNumber for Sextuplet survival, see Usage of primes 31-59 4.5.7.

It could be argued that there is no need to present two equations for the getting of  $n$ . However  $n$  is central to these structures and must be exact. I have found that it was very helpful to have two equations for testing, comparing results, and getting sanity checks. Perhaps you will find them helpful also.

#### 4.5.6 Getting relative offset for any TNumber

You have a TNumber that you would like to check to see if it has a sextuplet in it or not. To do that you will need to test it against the potPrime's Effect Lookup Tables for all  $n$  (4.5.2 on page 29). That testing method requires that the target TNumber's relative offset at that  $n$  is sent in to compare the Lookup test against.

Since the Lookup test returns its compare index as an index into the (often expanded) potPrime's natural progression, we need to map the target TNumber as a relative offset into the same (often expanded) potPrime natural progression.

Basically, this boils down to computing the number of complete cycles, in TNumbers, of that potPrime that are less than the target TNumber. Subtract that from the target TNumber to get back how far inside that last cycle the target is; that is, its relative offset to the pristine potPrime's natural progression. In other words, we need to normalize the target TNumber to the potPrime's natural progression at any  $n$ .

The following equation does that. The result,  $R$ , is the relative offset that the Lookup test requires to compare against,  $T_T$  is the target TNumber,  $\mathsf{T}(Q, n)$  is the result of the effective TNumber equation (17 on page 32) for the  $Q$  at that  $n$ ,  $n \geq 0$ , and  $\mathsf{T}(Q, n) \leq T_T$ :

$$R = T_T - \left( \left\lfloor \frac{T_T - \mathsf{T}(Q, n)}{Q_{\text{base}} + Cn} \right\rfloor (Q_{\text{base}} + Cn) + \mathsf{T}(Q, n) \right) \quad (20)$$

#### 4.5.7 Usage of primes 31-59

The idea of these structures I've described were developed with an eye to study formation and longevity of sextuplet primes. I've already identified several areas of interest regarding these structures, see section Analysis of Potential Primes on page 55.

But they are also useful for obtaining lists of sextuplets and other tuples. For instance, a Basis-0 analysis for only sextuplets ( $T_{28}$  to  $T_{215656468}$  range) shows that 1,168 Sextuplets survive in that range, while only 786 survive in the Basis-1 range.

In fact, to verify that all these relationships are true, it was necessary to code a program to do so. What follows can be done for any TNumber individually as needed with a calculator, or can be considered an outline for an algorithm to automatically generate lists of tuples. I'm assuming here that readers of this section may have very differing levels of math prowess and so will be giving explanatory details and examples. I would suggest, however, that each reader at least skim this paper to get the general ideas, terms, and concepts in grip.

The symbol  $C$  is, as always, the constant 30, the length of the Prime Template,  $n$  is always  $\geq 0$ .

**Step 1:** Select a TNumber to test,  $T_T$ , where  $T_T \geq 32$  (this is where the effects of primes 31-59 start).

You can select this randomly but you will have a very low chance of picking a TNumber that has a Tuple. For this reason I recommend that a copy of a 29basis file is obtained or generated (section 4.3.11 on page 19) and TNumbers selected from there.

If you don't have a 29basis handy then here are some interesting TNumbers to start with:  $T_{49}$  contains a right handed quintuplet,  $T_{535}$  a sextuplet,  $T_{630}$  a quadruplet,  $T_{647}$  a sextuplet.

**Step 2:** Get the  $n_{\max}$  for each potPrime for your selected  $T_T$  (equation 18 on page 34 [complex] or 19 on the preceding page [simple]).

$$n_{\max} = \left\lfloor \frac{\sqrt{T_T C + Q_{\text{adj}}} - Q_{\text{base}}}{C} \right\rfloor$$

For calculator calculations, and even computer programs for that matter, I prefer the simpler form even though it uses an extra potPrime constant. By the way, all constants associated with a potPrime are listed under their respective Detail sections.

An  $n_{\max}$  is needed for each potPrime: pP(31), pP(37), . . . . These  $n$ 's tell us how many members we need to use in that family. Because of the layered nature of potPrimes the  $n_{\max}$  of pP(31) will always be the absolute, or greatest,  $n$ ; the  $n_{\max}$ 's of the other potPrimes for that  $T_T$  can be equal to it or, at most, 1 less.

If the result, **before flooring**, is negative, then that potPrime is not effective for your chosen  $T_T$ , and that potPrime is ignored in the following steps. A result of zero is valid and must be used.

Using  $Q^{47}$  as an example:

$$n_{\max}^{47} = \left\lfloor \frac{\sqrt{T_T C + Q_{\text{adj}}^{47}} - Q_{\text{base}}^{47}}{C} \right\rfloor$$

$$n_{\max}^{47} = \left\lfloor \frac{\sqrt{T_T (30) + 19} - 47}{30} \right\rfloor$$

**Step 3, Looping:** You will loop over each potPrime from  $n = 0 \rightarrow n_{\max}$  (inclusive).

An  $n_{\max}$  of zero is valid and must be iterated. If you are programming an algorithm I recommend looping over all potPrimes at each  $n$ , rather than looping through all  $n$ 's for each potPrime in turn. It is simply more efficient because the smaller the potPrime the more likely it will destroy the Tuplet, and so one avoids some unnecessary processing.

**Step 3a:** Obtain the effective TNumber,  $T_{\text{eff}}$ , for each potPrime at each  $n$ , equation 17 on page 32, you will use this result in the next step:

$$T_{\text{eff}} = Q_{\text{start}} + 2Q_{\text{base}}n + Cn^2$$

Using  $Q^{47}$  as an example:

$$T_{\text{eff}} = Q_{\text{start}}^{47} + 2Q_{\text{base}}^{47}n + Cn^2$$

$$T_{\text{eff}} = 73 + 2(47)n + Cn^2$$

$$T_{\text{eff}} = 73 + 94n + 30n^2$$

**Step 3b:** for each potPrime at each  $n$  get the relative offset of your chosen  $T_T$  at that  $n$ , equation 20 on page 35, you will use this result in the next step. The  $\mathsf{T}(Q, n)$  is our result from step 3a,  $T_{\text{eff}}$ :

$$R = T_T - \left( \left\lfloor \frac{T_T - \mathsf{T}(Q, n)}{Q_{\text{base}} + Cn} \right\rfloor (Q_{\text{base}} + Cn) + \mathsf{T}(Q, n) \right)$$

Using  $Q^{47}$  as an example:

$$R = T_T - \left( \left\lfloor \frac{T_T - T_{\text{eff}}}{Q_{\text{base}}^{47} + Cn} \right\rfloor (Q_{\text{base}}^{47} + Cn) + T_{\text{eff}} \right)$$

$$R = T_T - \left( \left\lfloor \frac{T_T - T_{\text{eff}}}{47 + 30n} \right\rfloor (47 + 30n) + T_{\text{eff}} \right)$$

For computer programs: it always a good idea to validate results even though you are *sure* you have not written any bugs. Good validations here are that  $T_{\text{eff}} \leq T_T$ .

**Step 3c:** Use the  $R$  from the last step to test against your chosen  $T_T$ .

This process is detailed in section Using Potential Prime Effect Lookup Tables on page 29. Each potPrime has an effect lookup table with 6 entries. Each lookup is adjusted for inflation using the current  $n$ , and the result at that point is compared to your  $R$ . Depending on the comparison your  $T_T$  is either left untouched, altered, or destroyed.

Here is  $Q^{47}$ 's lookup table:

$c$	$q$	$Q^{47}$ Effect	Template crossing, mod
0	0	X	c24
3	2	┐	c28
19	12	X	c18
22	14	X	c22
38	24	└	c12
41	26	X	c16

Each row in turn is passed through the lookup equation (14 on page 29) to return a crossing,  $i$ , and then  $i$  is compared to  $R$ :

$$i = c + qn$$

If  $R = i$  then take the Effect from that row and apply symbol math to find out how it affects your  $T_T$  (section 4.4 on page 22). The comparison logic is explained in detail in the above referenced Using Potential Prime Effect Lookup Tables section, but in summary you test rows until  $i \geq R$  and make decisions based on that comparison.

**Step 4:** Convert a successful result into its Tuplet.

If your chosen  $T_T$  passes all the tests through all  $n$  for all potPrimes then it contains a Tuplet. The process to display its result in human readable form is explained in detail in section Convert successful result into Tuplet members on page 29.

#### 4.5.8 Elephant in the corner

I've already confessed that potPrimes are not necessarily prime numbers. For instance,  $Q_o^{49} = 49$  is not. Nor is  $Q_2^{31} = 91$ .

This means that tests are being made that simply need not be made. Certainly as  $n$  grows the number of composite potPrimes will greatly outnumber prime potPrimes, which means time wasted testing potPrimes that have already, in essence, been tested either by the 29basis file (primes 7-29) or by earlier  $n$ 's of preceeding potPrimes.

It does not hurt to test composite potPrimes, they simply have no effect on the results.

These prime structures built here are not designed to be efficient, they are designed to be complete. Certainly if a simple accurate test is available to test whether a potPrime is prime or not, it does not hurt to use it (as an aside, in the program I wrote to test

these structures, I did try to do simple-ish tests to bypass composite potPrimes, all it did was slow the program down).

The purpose of this study is to bring the primes  $\geq 31$  into order and to tie them together with equations that will perhaps be of use in elucidating properties of sextuplets that shed light on their survival and destruction, and whether they are infinite. These structures are systematically built such that primes do not need to be considered at all: just  $n$  needs to be considered.

Performing needless tests is a consequence of all this, and this only applies if you are going to program these structures into an application.

Yes, there is an elephant in the corner, but she is very friendly.

#### 4.5.9 General note regarding prime 31-59 Details

The key data for the potPrimes is the Effect Lookup Table. They are used to test the effect at  $c + qn$  (see on page 29). Lookup tables are constant for each potPrime and are derived from the natural progression data ( on page 27).

Prime details and natural progressions are also presented for completeness and reference, but have no particular use in discovering Tuplets if that is your main interest. They can be of interest when analyzing the prime structures developed in this study, or for deriving new relationships.

#### 4.5.10 Prime 31 Details

The base value is  $Q_{\text{base}}^{31} = Q_0^{31} = 31$ . This data applies to 31, 61, 91, ...; that is, where  $Q$  is any potential prime,  $(Q \bmod 30) = 1$ .

The base prime becomes effective at  $31^2 = 961$ , this makes the family's starting TNumber:  $Q_{\text{start}}^{31} = T_{32} = 32$ , this TNumber starts at integer 955 .

The symbol  $Q_{\text{adj}}^{31}$  is defined as:  $961 \bmod 30 = 1$ .

Effect Lookup Table  $Q^{31}$ ,  $c$  is crossing effect with respect to  $Q_{\text{base}}$ , and  $q$  is the inflation multiplier with respect to Template length (see on page 29).

$c$	$q$	$Q^{31}$ Effect	Template crossing, mod
6	6	┼	c12
10	10	X	c16
12	12	X	c18
16	16	X	c22
18	18	X	c24
22	22	┼	c28

Natural progression  $Q^{31}$ :

$Q$ 31a	c6	c7	c8	c9	c10	c11	c12	c13	c14	c15	$\rightarrow$ 31b
Effect	●	●	●	●	●	●	┐	●	●	●	$\rightarrow$
$T_n$	$T_{32}$	$T_{33}$	$T_{34}$	$T_{35}$	$T_{36}$	$T_{37}$	$T_{38}$	$T_{39}$	$T_{40}$	$T_{41}$	$\rightarrow$
$T_{\text{exp}}$	955	985	1015	1045	1075	1105	1135	1165	1195	1225	$\rightarrow$
$c$	0	1	2	3	4	5	6	7	8	9	$\rightarrow$
$q$	0	1	2	3	4	5	6	7	8	9	$\rightarrow$

31b	c16	c17	c18	c19	c20	c21	c22	c23	c24	c25	$\rightarrow$ 31c
...	X	●	X	●	●	●	X	●	X	●	$\rightarrow$
...	$T_{42}$	$T_{43}$	$T_{44}$	$T_{45}$	$T_{46}$	$T_{47}$	$T_{48}$	$T_{49}$	$T_{50}$	$T_{51}$	$\rightarrow$
...	1255	1285	1315	1345	1375	1405	1435	1465	1495	1525	$\rightarrow$
$c$	10	11	12	13	14	15	16	17	18	19	$\rightarrow$
$q$	10	11	12	13	14	15	16	17	18	19	$\rightarrow$

31c	c26	c27	c28	c29	c0	c1	c2	c3	c4	c5
...	●	●	┐	●	○●	●	●	●	●	●
...	$T_{52}$	$T_{53}$	$T_{54}$	$T_{55}$	$T_{56}$ $T_{57}$	$T_{58}$	$T_{59}$	$T_{60}$	$T_{61}$	$T_{62}$
...	1555	1585	1615	1645	1675 1705	1735	1765	1795	1825	1855
$c$	20	21	22	23	25	26	27	28	29	30
$q$	20	21	22	23	24	25	26	27	28	29

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Raw data  $Q^{31}$ , 1 skip space:



$Q^{31}$ CrossNum	Effect	Next Crossing
o c0	●	→c1
c1	●	→c2
c2	●	→c3
c3	●	→c4
c4	●	→c5
c5	●	→c6
c6	●	→c7
c7	●	→c8
c8	●	→c9
c9	●	→c10
c10	●	→c11
c11	●	→c12
c12	⊥	→c13
c13	●	→c14
c14	●	→c15
c15	●	→c16
c16	X	→c17
c17	●	→c18
c18	X	→c19
c19	●	→c20
c20	●	→c21
c21	●	→c22
c22	X	→c23
c23	●	→c24
c24	X	→c25
c25	●	→c26
c26	●	→c27
c27	●	→c28
c28	⊥	→c29
c29	●	→c0

#### 4.5.11 Prime 37 Details

The base value is  $Q_{\text{base}}^{37} = Q_0^{37} = 37$ . This data applies to 37, 67, 97, ...; that is, where  $Q$  is any potential prime,  $(Q \bmod 30) = 7$ .

The base prime becomes effective at  $37^2 = 1369$ , this makes the family's starting TNumber:  $Q_{\text{start}}^{37} = T_{45} = 45$ , this TNumber starts at integer 1345.

The symbol  $Q_{\text{adj}}^{37}$  is defined as:  $1369 \bmod 30 = 19$ .

Effect Lookup Table  $Q^{37}$ ,  $c$  is crossing effect with respect to  $Q_{\text{base}}$ , and  $q$  is the inflation multiplier with respect to Template length (see on page 29).

$c$	$q$	$Q^{37}$ Effect	Template crossing, mod
0	0	X	c24
5	4	X	c22
15	12	X	c18
20	16	X	c16
27	22	$\vdash$	c28
30	24	$\dashv$	c12

Natural progression  $Q^{37}$ :

$Q$ 37a	c24	c1	c8	c15	c22	c29	c6	c13	c20	c27	$\rightarrow$ 37b
Effect	X	$\circ\bullet$	$\bullet$	$\bullet$	X	$\bullet$	$\circ\bullet$	$\bullet$	$\bullet$	$\bullet$	$\rightarrow$
$T_n$	$T_{45}$	$T_{46}T_{47}$	$T_{48}$	$T_{49}$	$T_{50}$	$T_{51}$	$T_{52}$ $T_{53}$	$T_{54}$	$T_{55}$	$T_{56}$	$\rightarrow$
$T_{\text{exp}}$	1345	1375 1405	1435	1465	1495	1525	1555 1585	1615	1645	1675	$\rightarrow$
$c$	0	2	3	4	5	6	8	9	10	11	$\rightarrow$
$q$	0	1	2	3	4	5	6	7	8	9	$\rightarrow$

37b	c4	c11	c18	c25	c2	c9	c16	c23	c0	c7	$\rightarrow$ 37c
...	$\circ\bullet$	$\bullet$	X	$\bullet$	$\circ\bullet$	$\bullet$	X	$\bullet$	$\circ\bullet$	$\bullet$	$\rightarrow$
...	$T_{57}$ $T_{58}$	$T_{59}$	$T_{60}$	$T_{61}$	$T_{62}$ $T_{63}$	$T_{64}$	$T_{65}$	$T_{66}$	$T_{67}$ $T_{68}$	$T_{69}$	$\rightarrow$
...	1705 1735	1765	1795	1825	1855 1885	1915	1945	1975	2005 2035	2065	$\rightarrow$
$c$	13	14	15	16	18	19	20	21	23	24	$\rightarrow$
$q$	10	11	12	13	14	15	16	17	18	19	$\rightarrow$

37c	c14	c21	c28	c5	c12	c19	c26	c3	c10	c17
...	$\bullet$	$\bullet$	$\vdash$	$\circ\bullet$	$\dashv$	$\bullet$	$\bullet$	$\circ\bullet$	$\bullet$	$\bullet$
...	$T_{70}$	$T_{71}$	$T_{72}$	$T_{73}$ $T_{74}$	$T_{75}$	$T_{76}$	$T_{77}$	$T_{78}$ $T_{79}$	$T_{80}$	$T_{81}$
...	2095	2125	2155	2185 2215	2245	2275	2305	2335 2365	2395	2425
$c$	25	26	27	29	30	31	32	34	35	36
$q$	20	21	22	23	24	25	26	27	28	29

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Raw data  $Q^{37}$ , 7 skip spaces:

$Q^{37}$ CrossNum	Effect	Next Crossing
o c0	●	→c7
o c1	●	→c8
o c2	●	→c9
o c3	●	→c10
o c4	●	→c11
o c5	●	→c12
o c6	●	→c13
c7	●	→c14
c8	●	→c15
c9	●	→c16
c10	●	→c17
c11	●	→c18
c12	⊥	→c19
c13	●	→c20
c14	●	→c21
c15	●	→c22
c16	X	→c23
c17	●	→c24
c18	X	→c25
c19	●	→c26
c20	●	→c27
c21	●	→c28
c22	X	→c29
c23	●	→c0
c24	X	→c1
c25	●	→c2
c26	●	→c3
c27	●	→c4
c28	⊥	→c5
c29	●	→c6

#### 4.5.12 Prime 41 Details

The base value is  $Q_{\text{base}}^{41} = Q_0^{41} = 41$ . This data applies to 41, 71, 101, ...; that is, where  $Q$  is any potential prime,  $(Q \bmod 30) = 11$ .

The base prime becomes effective at  $41^2 = 1681$ , this makes the family's starting TNumber:  $Q_{\text{start}}^{41} = T_{56} = 56$ , this TNumber starts at integer 1675.

The symbol  $Q_{\text{adj}}^{41}$  is defined as:  $1681 \bmod 30 = 1$ .

Effect Lookup Table  $Q^{41}$ ,  $c$  is crossing effect with respect to  $Q_{\text{base}}$ , and  $q$  is the inflation multiplier with respect to Template length (see on page 29).

$c$	$q$	$Q^{41}$ Effect	Template crossing, mod
2	2	$\vdash$	c28
8	6	$\dashv$	c12
16	12	X	c18
24	18	X	c24
27	20	X	c16
35	26	X	c22

Natural progression  $Q^{41}$ .

NOTE: this is the first time you see a spacer added at the *end* of the natural progression. When mapping these by hand it appears that the spacer is placed before the first crossing, here c6. But this is illusion because the first crossing is starting from the family's starting Template. Placing this phantom spacer at the end is correct:

$Q$ 41a	c6	c17	c28	c9	c20	c1	c12	c23	c4	c15	$\rightarrow$ 41b
Effect	●	●	$\vdash$	○●	●	○●	$\dashv$	●	○●	●	$\rightarrow$
$T_n$	$T_{56}$	$T_{57}$	$T_{58}$	$T_{59}$ $T_{60}$	$T_{61}$	$T_{62}$ $T_{63}$	$T_{64}$	$T_{65}$	$T_{66}$ $T_{67}$	$T_{68}$	$\rightarrow$
$T_{\text{exp}}$	1675	1705	1735	1765 1795	1825	1855 1885	1915	1945	1975 2005	2035	$\rightarrow$
$c$	0	1	2	4	5	7	8	9	11	12	$\rightarrow$
$q$	0	1	2	3	4	5	6	7	8	9	$\rightarrow$

41b	c26	c7	c18	c29	c10	c21	c2	c13	c24	c5	$\rightarrow$ 41c
...	●	○●	X	●	○●	●	○●	●	X	○●	$\rightarrow$
...	$T_{69}$	$T_{70}$ $T_{71}$	$T_{72}$	$T_{73}$	$T_{74}$ $T_{75}$	$T_{76}$	$T_{77}$ $T_{78}$	$T_{79}$	$T_{80}$	$T_{81}$ $T_{82}$	$\rightarrow$
...	2065	2095 2125	2155	2185	2215 2245	2275	2305 2335	2365	2395	2425 2455	$\rightarrow$
$c$	13	15	16	17	19	20	22	23	24	26	$\rightarrow$
$q$	10	11	12	13	14	15	16	17	18	19	$\rightarrow$

41c	c16	c27	c8	c19	c0	c11	c22	c3	c14	c25
...	X	●	○●	●	○●	●	X	○●	●	●○
...	$T_{83}$	$T_{84}$	$T_{85}$ $T_{86}$	$T_{87}$	$T_{88}$ $T_{89}$	$T_{90}$	$T_{91}$	$T_{92}$ $T_{93}$	$T_{94}$	$T_{95}$ $T_{96}$
...	2485	2515	2545 2575	2605	2635 2665	2695	2725	2755 2785	2815	2845 2875
$c$	27	28	30	31	33	34	35	37	38	40
$q$	20	21	22	23	24	25	26	27	28	29

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Raw data  $Q^{41}$ , 11 skip spaces:

$Q$ 41 CrossNum	Effect	Next Crossing
o c0	●	→c11
o c1	●	→c12
o c2	●	→c13
o c3	●	→c14
o c4	●	→c15
o c5	●	→c16
o c6	●	→c17
o c7	●	→c18
o c8	●	→c19
o c9	●	→c20
o c10	●	→c21
c11	●	→c22
c12	⊥	→c23
c13	●	→c24
c14	●	→c25
c15	●	→c26
c16	X	→c27
c17	●	→c28
c18	X	→c29
c19	●	→c0
c20	●	→c1
c21	●	→c2
c22	X	→c3
c23	●	→c4
c24	X	→c5
c25	●	→c6
c26	●	→c7
c27	●	→c8
c28	⊥	→c9
c29	●	→c10

#### 4.5.13 Prime 43 Details

The base value is  $Q_{\text{base}}^{43} = Q_0^{43} = 43$ . This data applies to 43, 73, 103, ...; that is, where  $Q$  is any potential prime,  $(Q \bmod 30) = 13$ .

The base prime becomes effective at  $43^2 = 1849$ , this makes the family's starting TNumber:  $Q_{\text{start}}^{43} = T_{61} = 61$ , this TNumber starts at integer 1825.

The symbol  $Q_{\text{adj}}^{43}$  is defined as:  $1849 \bmod 30 = 19$ .

Effect Lookup Table  $Q^{43}$ ,  $c$  is crossing effect with respect to  $Q_{\text{base}}$ , and  $q$  is the inflation multiplier with respect to Template length (see on page 29).

$c$	$q$	$Q^{43}$ Effect	Template crossing, mod
0	0	X	c24
6	4	X	c16
9	6	$\dashv$	c12
23	16	X	c22
26	18	X	c18
40	28	$\vdash$	c28

Natural progression  $Q^{43}$ .

$Q$ 43a	c24	c7	c20	c3	c16	c29	c12	c25	c8	c21	$\rightarrow$ 43b
Effect	X	$\circ\bullet$	$\bullet$	$\circ\bullet$	X	$\bullet$	$\circ\vdash$	$\bullet$	$\circ\bullet$	$\bullet$	$\rightarrow$
$T_n$	$T_{61}$	$T_{62}$ $T_{63}$	$T_{64}$	$T_{65}$ $T_{66}$	$T_{67}$	$T_{68}$	$T_{69}$ $T_{70}$	$T_{71}$	$T_{72}$ $T_{73}$	$T_{74}$	$\rightarrow$
$T_{\text{exp}}$	1825	1855 1885	1915	1945 1975	2005	2035	2065 2095	2125	2155 2185	2215	$\rightarrow$
$c$	0	2	3	5	6	7	9	10	12	13	$\rightarrow$
$q$	0	1	2	3	4	5	6	7	8	9	$\rightarrow$

43b	c4	c17	c0	c13	c26	c9	c22	c5	c18	c1	$\rightarrow$ 43c
...	$\circ\bullet$	$\bullet$	$\circ\bullet$	$\bullet$	$\bullet$	$\circ\bullet$	X	$\circ\bullet$	X	$\circ\bullet$	$\rightarrow$
...	$T_{75}$ $T_{76}$	$T_{77}$	$T_{78}$ $T_{79}$	$T_{80}$	$T_{81}$	$T_{82}$ $T_{83}$	$T_{84}$	$T_{85}$ $T_{86}$	$T_{87}$	$T_{88}$ $T_{89}$	$\rightarrow$
...	2245 2275	2305	2335 2365	2395	2425	2455 2485	2515	2545 2575	2605	2635 2665	$\rightarrow$
$c$	15	16	18	19	20	22	23	25	26	28	$\rightarrow$
$q$	10	11	12	13	14	15	16	17	18	19	$\rightarrow$

43c	c14	c27	c10	c23	c6	c19	c2	c15	c28	c11
...	$\bullet$	$\bullet$	$\circ\bullet$	$\bullet$	$\circ\bullet$	$\bullet$	$\circ\bullet$	$\bullet$	$\vdash$	$\circ\bullet$
...	$T_{90}$	$T_{91}$	$T_{92}$ $T_{93}$	$T_{94}$	$T_{95}$ $T_{96}$	$T_{97}$	$T_{98}$ $T_{99}$	$T_{100}$	$T_{101}$	$T_{102}$ $T_{103}$
...	2695	2725	2755 2785	2815	2845 2875	2905	2935 2965	2995	3025	3055 3085
$c$	29	30	32	33	35	36	38	39	40	42
$q$	20	21	22	23	24	25	26	27	28	29

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Raw data  $Q^{43}$ , 13 skip spaces:

$Q$ 43 CrossNum	Effect	Next Crossing
o c0	●	→c13
o c1	●	→c14
o c2	●	→c15
o c3	●	→c16
o c4	●	→c17
o c5	●	→c18
o c6	●	→c19
o c7	●	→c20
o c8	●	→c21
o c9	●	→c22
o c10	●	→c23
o c11	●	→c24
o c12	⊥	→c25
c13	●	→c26
c14	●	→c27
c15	●	→c28
c16	X	→c29
c17	●	→c0
c18	X	→c1
c19	●	→c2
c20	●	→c3
c21	●	→c4
c22	X	→c5
c23	●	→c6
c24	X	→c7
c25	●	→c8
c26	●	→c9
c27	●	→c10
c28	⊥	→c11
c29	●	→c12

#### 4.5.14 Prime 47 Details

The base value is  $Q_{\text{base}}^{47} = Q_0^{47} = 47$ . This data applies to 47, 77, 107, ...; that is, where  $Q$  is any potential prime,  $(Q \bmod 30) = 17$ .

The base prime becomes effective at  $47^2 = 2209$ , this makes the family's starting TNumber:  $Q_{\text{start}}^{47} = T_{73} = 73$ , this TNumber starts at integer 2185.

The symbol  $Q_{\text{adj}}^{47}$  is defined as:  $2209 \bmod 30 = 19$ .

Effect Lookup Table  $Q^{47}$ ,  $c$  is crossing effect with respect to  $Q_{\text{base}}$ , and  $q$  is the inflation multiplier with respect to Template length (see on page 29).

$c$	$q$	$Q^{47}$ Effect	Template crossing, mod
0	0	X	c24
3	2	$\vdash$	c28
19	12	X	c18
22	14	X	c22
38	24	$\dashv$	c12
41	26	X	c16

Natural progression  $Q^{47}$ .

$Q$ 47a	c24	c11	c28	c15	c2	c19	c6	c23	c10	c27	$\rightarrow$ 47b
Effect	X	$\circ\bullet$	$\vdash$	$\circ\bullet$	$\circ\bullet$	$\bullet$	$\circ\bullet$	$\bullet$	$\circ\bullet$	$\bullet$	$\rightarrow$
$T_n$	$T_{73}$	$T_{74}$ $T_{75}$	$T_{76}$	$T_{77}$ $T_{78}$	$T_{79}$ $T_{80}$	$T_{81}$	$T_{82}$ $T_{83}$	$T_{84}$	$T_{85}$ $T_{86}$	$T_{87}$	$\rightarrow$
$T_{\text{exp}}$	2185	2215 2245	2275	2305 2335	2365 2395	2425	2455 2485	2515	2545 2575	2605	$\rightarrow$
$c$	0	2	3	5	7	8	10	11	13	14	$\rightarrow$
$q$	0	1	2	3	4	5	6	7	8	9	$\rightarrow$

47b	c14	c1	c18	c5	c22	c9	c26	c13	c0	c17	$\rightarrow$ 47c
...	$\circ\bullet$	$\circ\bullet$	X	$\circ\bullet$	X	$\circ\bullet$	$\bullet$	$\circ\bullet$	$\circ\bullet$	$\bullet$	$\rightarrow$
...	$T_{88}$ $T_{89}$	$T_{90}$ $T_{91}$	$T_{92}$	$T_{93}$ $T_{94}$	$T_{95}$	$T_{96}$ $T_{97}$	$T_{98}$	$T_{99}$ $T_{100}$	$T_{101}$ $T_{102}$	$T_{103}$	$\rightarrow$
...	2635 2665	2695 2725	2755	2785 2815	2845	2875 2905	2935	2965 2995	3025 3055	3085	$\rightarrow$
$c$	16	18	19	21	22	24	25	27	29	30	$\rightarrow$
$q$	10	11	12	13	14	15	16	17	18	19	$\rightarrow$

47c	c4	c21	c8	c25	c12	c29	c16	c3	c20	c7
...	$\circ\bullet$	$\bullet$	$\circ\bullet$	$\bullet$	$\circ\vdash$	$\bullet$	$\circ X$	$\circ\bullet$	$\bullet$	$\circ\bullet$
...	$T_{104}T_{105}T_{106}$		$T_{107}$ $T_{108}$	$T_{109}$	$T_{110}$ $T_{111}$	$T_{112}$	$T_{113}$ $T_{114}$	$T_{115}$ $T_{116}$	$T_{117}$	$T_{118}$ $T_{119}$
...	3115 3145	3175	3205 3235	3265	3295 3325	3355	3385 3415	3445 3475	3505	3535 3565
$c$	32	33	35	36	38	39	41	43	44	46
$q$	20	21	22	23	24	25	26	27	28	29

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Raw data  $Q^{47}$ , 17 skip spaces:



$Q$ 47 CrossNum	Effect	Next Crossing
o c0	●	→c17
o c1	●	→c18
o c2	●	→c19
o c3	●	→c20
o c4	●	→c21
o c5	●	→c22
o c6	●	→c23
o c7	●	→c24
o c8	●	→c25
o c9	●	→c26
o c10	●	→c27
o c11	●	→c28
o c12	⊥	→c29
o c13	●	→c0
o c14	●	→c1
o c15	●	→c2
o c16	X	→c3
c17	●	→c4
c18	X	→c5
c19	●	→c6
c20	●	→c7
c21	●	→c8
c22	X	→c9
c23	●	→c10
c24	X	→c11
c25	●	→c12
c26	●	→c13
c27	●	→c14
c28	⊥	→c15
c29	●	→c16

#### 4.5.15 Prime 49 Details

The base value is  $Q_{\text{base}}^{49} = Q_0^{49} = 49$ . This data applies to 49, 79, 109, ...; that is, where  $Q$  is any potential prime,  $(Q \bmod 30) = 19$ .

The base prime becomes effective at  $49^2 = 2401$ , this makes the family's starting TNumber:  $Q_{\text{start}}^{49} = T_{80} = 80$ , this TNumber starts at integer 2395.

The symbol  $Q_{\text{adj}}^{49}$  is defined as:  $2401 \bmod 30 = 1$ .

Effect Lookup Table  $Q^{49}$ ,  $c$  is crossing effect with respect to  $Q_{\text{base}}$ , and  $q$  is the inflation multiplier with respect to Template length (see on page 29).

$c$	$q$	$Q^{49}$ Effect	Template crossing, mod
6	4	X	c22
16	10	X	c16
19	12	X	c24
29	18	X	c18
39	24	$\dashv$	c12
45	28	$\vdash$	c28

Natural progression  $Q^{49}$ .

$Q$ 49a	c6	c25	c14	c3	c22	c11	c0	c19	c8	c27	$\rightarrow$ 49b
Effect	●	●	○●	○●	X	○●	○●	●	○●	●	$\rightarrow$
$T_n$	$T_{80}$	$T_{81}$	$T_{82}$ $T_{83}$	$T_{84}$ $T_{85}$	$T_{86}$	$T_{87}$ $T_{88}$	$T_{89}$ $T_{90}$	$T_{91}$	$T_{92}$ $T_{93}$	$T_{94}$	$\rightarrow$
$T_{\text{exp}}$	2395	2425	2455 2485	2515 2545	2575	2605 2635	2665 2695	2725	2755 2785	2815	$\rightarrow$
$c$	0	1	3	5	6	8	10	11	13	14	$\rightarrow$
$q$	0	1	2	3	4	5	6	7	8	9	$\rightarrow$

49b	c16	c5	c24	c13	c2	c21	c10	c29	c18	c7	$\rightarrow$ 49c
...	○X	○●	X	○●	○●	●	○●	●	○X	○●	$\rightarrow$
...	$T_{95}$ $T_{96}$	$T_{97}$ $T_{98}$	$T_{99}$	$T_{100}$ $T_{101}$	$T_{102}$ $T_{103}$	$T_{104}$	$T_{105}$ $T_{106}$	$T_{107}$	$T_{108}$ $T_{109}$	$T_{110}$ $T_{111}$	$\rightarrow$
...	2845 2875	2905 2935	2965	2995 3025	3055 3085	3115	3145 3175	3205	3235 3265	3295 3325	$\rightarrow$
$c$	16	18	19	21	23	24	26	27	29	31	$\rightarrow$
$q$	10	11	12	13	14	15	16	17	18	19	$\rightarrow$

49c	c26	c15	c4	c23	c12	c1	c20	c9	c28	c17
...	●	○●	○●	●	○ $\dashv$	○●	●	○●	$\vdash$	○●○
...	$T_{112}$	$T_{113}$ $T_{114}$	$T_{115}$ $T_{116}$	$T_{117}$	$T_{118}$ $T_{119}$	$T_{120}$ $T_{121}$	$T_{122}$	$T_{123}$ $T_{124}$	$T_{125}$	$T_{126}$ $T_{127}$ $T_{128}$
...	3355	3385 3415	3445 3475	3505	3535 3565	3595 3625	3655	3685 3715	3745	3775 3805 3835
$c$	32	34	36	37	39	41	42	44	45	48
$q$	20	21	22	23	24	25	26	27	28	29

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Raw data  $Q^{49}$ , 19 skip spaces:

$Q$ 49 CrossNum	Effect	Next Crossing
o c0	●	→c19
o c1	●	→c20
o c2	●	→c21
o c3	●	→c22
o c4	●	→c23
o c5	●	→c24
o c6	●	→c25
o c7	●	→c26
o c8	●	→c27
o c9	●	→c28
o c10	●	→c29
o c11	●	→c0
o c12	⊥	→c1
o c13	●	→c2
o c14	●	→c3
o c15	●	→c4
o c16	X	→c5
o c17	●	→c6
o c18	X	→c7
c19	●	→c8
c20	●	→c9
c21	●	→c10
c22	X	→c11
c23	●	→c12
c24	X	→c13
c25	●	→c14
c26	●	→c15
c27	●	→c16
c28	⊥	→c17
c29	●	→c18

#### 4.5.16 Prime 53 Details

The base value is  $Q_{\text{base}}^{53} = Q_0^{53} = 53$ . This data applies to 53, 83, 113, ...; that is, where  $Q$  is any potential prime,  $(Q \bmod 30) = 23$ .

The base prime becomes effective at  $53^2 = 2809$ , this makes the family's starting TNumber:  $Q_{\text{start}}^{53} = T_{93} = 93$ , this TNumber starts at integer 2785.

The symbol  $Q_{\text{adj}}^{53}$  is defined as:  $2809 \bmod 30 = 19$ .

Effect Lookup Table  $Q^{53}$ ,  $c$  is crossing effect with respect to  $Q_{\text{base}}$ , and  $q$  is the inflation multiplier with respect to Template length (see on page 29).

$c$	$q$	$Q^{53}$ Effect	Template crossing, mod
0	0	X	c24
11	6	$\dashv$	c12
14	8	$\vdash$	c28
25	14	X	c16
32	18	X	c18
46	26	X	c22

Natural progression  $Q^{53}$ .

$Q$ 53a	c24	c17	c10	c3	c26	c19	c12	c5	c28	c21	$\rightarrow$ 53b
Effect	X	$\circ\bullet$	$\circ\bullet$	$\circ\bullet$	$\bullet$	$\circ\bullet$	$\circ\vdash$	$\circ\bullet$	$\vdash$	$\circ\bullet$	$\rightarrow$
$T_n$	$T_{93}$	$T_{94}$ $T_{95}$	$T_{96}$ $T_{97}$	$T_{98}$ $T_{99}$	$T_{100}$	$T_{101}$ $T_{102}$	$T_{103}$ $T_{104}$	$T_{105}$ $T_{106}$	$T_{107}$	$T_{108}$ $T_{109}$	$\rightarrow$
$T_{\text{exp}}$	2785	2815 2845	2875 2905	2935 2965	2995	3025 3055	3085 3115	3145 3175	3205	3235 3265	$\rightarrow$
$c$	0	2	4	6	7	9	11	13	14	16	$\rightarrow$
$q$	0	1	2	3	4	5	6	7	8	9	$\rightarrow$

53b	c14	c7	c0	c23	c16	c9	c2	c25	c18	c11	$\rightarrow$ 53c
...	$\circ\bullet$	$\circ\bullet$	$\circ\bullet$	$\bullet$	$\circ X$	$\circ\bullet$	$\circ\bullet$	$\bullet$	$\circ X$	$\circ\bullet$	$\rightarrow$
...	$T_{110}$ $T_{111}$	$T_{112}$ $T_{113}$	$T_{114}$ $T_{115}$	$T_{116}$	$T_{117}$ $T_{118}$	$T_{119}T_{120}$	$T_{121}$ $T_{122}$	$T_{123}$	$T_{124}$ $T_{125}$	$T_{126}$ $T_{127}$	$\rightarrow$
...	3295 3325	3355 3385	3415 3445	3475	3505 3535	3565 3595	3625 3655	3685	3715 3745	3775 3805	$\rightarrow$
$c$	18	20	22	23	25	27	29	30	32	34	$\rightarrow$
$q$	10	11	12	13	14	15	16	17	18	19	$\rightarrow$

53c	c4	c27	c20	c13	c6	c29	c22	c15	c8	c1
...	$\circ\bullet$	$\bullet$	$\circ\bullet$	$\circ\bullet$	$\circ\bullet$	$\bullet$	$\circ X$	$\circ\bullet$	$\circ\bullet$	$\circ\bullet$
...	$T_{128}$ $T_{129}$	$T_{130}$	$T_{131}$ $T_{132}$	$T_{133}$ $T_{134}$	$T_{135}$ $T_{136}$	$T_{137}$	$T_{138}$ $T_{139}$	$T_{140}$ $T_{141}$	$T_{142}$ $T_{143}$	$T_{144}$ $T_{145}$
...	3835 3865	3895	3925 3955	3985 4015	4045 4075	4105	4135 4165	4195 4225	4255 4285	4315 4345
$c$	36	37	39	41	43	44	46	48	50	52
$q$	20	21	22	23	24	25	26	27	28	29

$\circ\circ\circ\circ\bullet\circ$

Raw data  $Q^{53}$ , 23 skip spaces:

$Q$ 53 CrossNum	Effect	Next Crossing
o c0	●	→c23
o c1	●	→c24
o c2	●	→c25
o c3	●	→c26
o c4	●	→c27
o c5	●	→c28
o c6	●	→c29
o c7	●	→c0
o c8	●	→c1
o c9	●	→c2
o c10	●	→c3
o c11	●	→c4
o c12	⊥	→c5
o c13	●	→c6
o c14	●	→c7
o c15	●	→c8
o c16	X	→c9
o c17	●	→c10
o c18	X	→c11
o c19	●	→c12
o c20	●	→c13
o c21	●	→c14
o c22	X	→c15
c23	●	→c16
c24	X	→c17
c25	●	→c18
c26	●	→c19
c27	●	→c20
c28	⊥	→c21
c29	●	→c22

#### 4.5.17 Prime 59 Details

The base value is  $Q_{\text{base}}^{59} = Q_0^{59} = 59$ . This data applies to 59, 89, 119, ...; that is, where  $Q$  is any potential prime,  $(Q \bmod 30) = 29$ .

The base prime becomes effective at  $59^2 = 3481$ , this makes the family's starting TNumber:  $Q_{\text{start}}^{59} = T_{116} = 116$ , this TNumber starts at integer 3475.

The symbol  $Q_{\text{adj}}^{59}$  is defined as:  $3481 \bmod 30 = 1$ .











Effect Lookup Table  $Q^{59}$ ,  $c$  is crossing effect with respect to  $Q_{\text{base}}$ , and  $q$  is the inflation multiplier with respect to Template length (see on page 29).

$c$	$q$	$Q^{59}$ Effect	Template crossing, mod
15	8	$\vdash$	c28
23	12	X	c24
27	14	X	c22
35	18	X	c18
39	20	X	c16
47	24	$\dashv$	c12

Natural progression  $Q^{59}$ .

$Q$ 59a	c6	c5	c4	c3	c2	c1	c0	c29	c28	c27	$\rightarrow$ 59b
Effect	●	○●	○●	○●	○●	○●	○●	●	○ $\vdash$	○●	$\rightarrow$
$T_n$	$T_{116}$	$T_{117}$ $T_{118}$	$T_{119}$ $T_{120}$	$T_{121}$ $T_{122}$	$T_{123}T_{124}$ $T_{125}$ $T_{126}$	$T_{127}$ $T_{128}$	$T_{129}$	$T_{130}T_{131}$	$T_{132}$ $T_{133}$	$\rightarrow$	$\rightarrow$
$T_{\text{exp}}$	3475	3505 3535	3565 3595	3625 3655	3685 3715	3745 3775	3805 3835	3865	3895 3925	3955 3985	$\rightarrow$
$c$	0	2	4	6	8	10	12	13	15	17	$\rightarrow$
$q$	0	1	2	3	4	5	6	7	8	9	$\rightarrow$

59b	c26	c25	c24	c23	c22	c21	c20	c19	c18	c17	$\rightarrow$ 59c
...	○●	○●	○X	○●	○X	○●	○●	○●	○X	○●	$\rightarrow$
...	$T_{134}$ $T_{135}$	$T_{136}$ $T_{137}$	$T_{138}$ $T_{139}$	$T_{140}T_{141}$ $T_{142}$ $T_{143}$	$T_{144}T_{145}$ $T_{146}$ $T_{147}$	$T_{148}$ $T_{149}$	$T_{150}$ $T_{151}$	$T_{152}$ $T_{153}$	$\rightarrow$	$\rightarrow$	$\rightarrow$
...	4015 4045	4075 4105	4135 4165	4195 4225	4255 4285	4315 4345	4375 4405	4435 4465	4495 4525	4555 4585	$\rightarrow$
$c$	19	21	23	25	27	29	31	33	35	37	$\rightarrow$
$q$	10	11	12	13	14	15	16	17	18	19	$\rightarrow$

59c	c16	c15	c14	c13	c12	c11	c10	c9	c8	c7
...										
...	$T_{154}$ $T_{155}$	$T_{156}T_{157}$ $T_{158}$ $T_{159}$	$T_{160}$ $T_{161}$	$T_{162}$ $T_{163}$	$T_{164}$ $T_{165}$	$T_{166}$ $T_{167}$	$T_{168}$ $T_{169}$	$T_{170}$ $T_{171}$	$T_{172}$ $T_{173}$ $T_{174}$	
...	4615 4645	4675 4705	4735 4765	4795 4825	4855 4885	4915 4945	4975 5005	5035 5065	5095 5125	5155 5185 5215
$c$	39	41	43	45	47	49	51	53	55	58
$q$	20	21	22	23	24	25	26	27	28	29

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Raw data  $Q^{59}$ , 29 skip spaces:

$Q$ 59 CrossNum	Effect	Next Crossing
o c0	●	→c29
o c1	●	→c0
o c2	●	→c1
o c3	●	→c2
o c4	●	→c3
o c5	●	→c4
o c6	●	→c5
o c7	●	→c6
o c8	●	→c7
o c9	●	→c8
o c10	●	→c9
o c11	●	→c10
o c12	⊥	→c11
o c13	●	→c12
o c14	●	→c13
o c15	●	→c14
o c16	X	→c15
o c17	●	→c16
o c18	X	→c17
o c19	●	→c18
o c20	●	→c19
o c21	●	→c20
o c22	X	→c21
o c23	●	→c22
o c24	X	→c23
o c25	●	→c24
o c26	●	→c25
o c27	●	→c26
o c28	⊥	→c27
c29	●	→c28

## 5 Analysis of Potential Primes

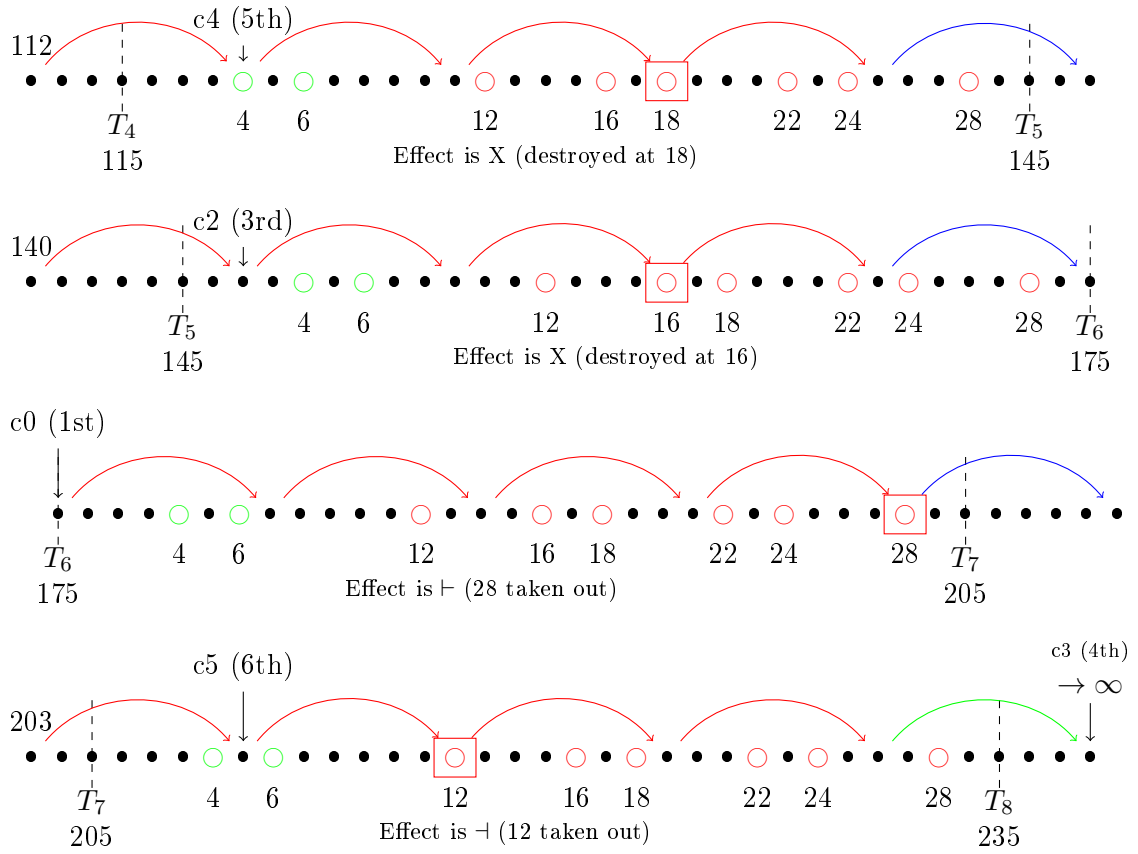
This section is under development. The original publishing in Feb. 2021 was done so that the basic structure of the potPrimes was available for study and to complement the computer code.

There are several interesting questions that arise when the potential primes are analyzed. They will be published here as time permits.

Check back at the download site for updated pdf.







## 6.2 Crossing map for 1 cycle of prime 11

A last example diagram showing how prime 11 would be analyzed in a similar fashion starting at its effective TNumber  $T_4$ . All other primes 11-29 were analyzed in the same way and their crossing numbers and natural progressions shown in their respective Detail sections. A similar analysis also produces maps for primes 31-59.

