Cicadas Know Their Primes

by
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Cicadas may appear eccentric and eerie as they crawl in overwhelming numbers on the ground with their beady eyes and loud rattle. But this is no zombie play. It is the awakening of periodical cicadas.

Whilst cicadas spend most of their lives underground sucking root juices, they climb to the ground together, singing their signature mating calls, laying their eggs on tree branches, and dying within few weeks of their emergence. After the egg hatches, the nymphs drop from the tree and burrow underground and the cycle repeats.

When they emerge on ground, they are easy pickings. Birds consume them massively and so do others — squirrels, cats, turtles, fish, spiders and even humans!

The real question is how do they yet survive?
Most Cicadas that emerge on the surface every 1 or 2 years were devoured by waiting predators. You may assume that the longer they spend underground, the longer they are safe and the longer they will survive. But it may come to you as a surprise that cicadas who surface every 13 years have a greater probability of surviving than cicadas who might surface every 16 years.

The genus known as Magicicada or periodical cicadas have the longest known insect life cycle. They emerge after their long juvenile period of every 13th or 17th year making it difficult for predators to predict their emergence from underground nests.

The most fascinating part here is what is the specific advantage of evolving a lifecycle of 13 or 17 years rather than 4, 6, 10, 14, or 15. You've probably already noticed that 13 and 17 are prime numbers.

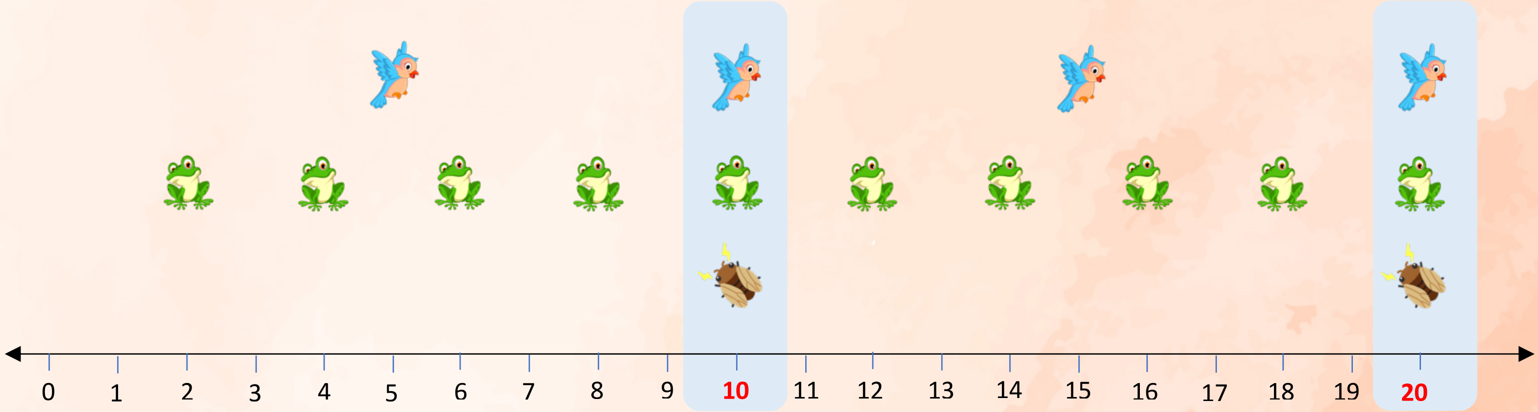
What are Prime Numbers?
Prime number is a positive integer > 1 that has exactly two distinct positive integral divisors: 1 and the number itself. It cannot be factored by other numbers.
For example: Factors of 17 is 1 and 17, hence 17 is a prime number.

Properties of Prime Numbers:

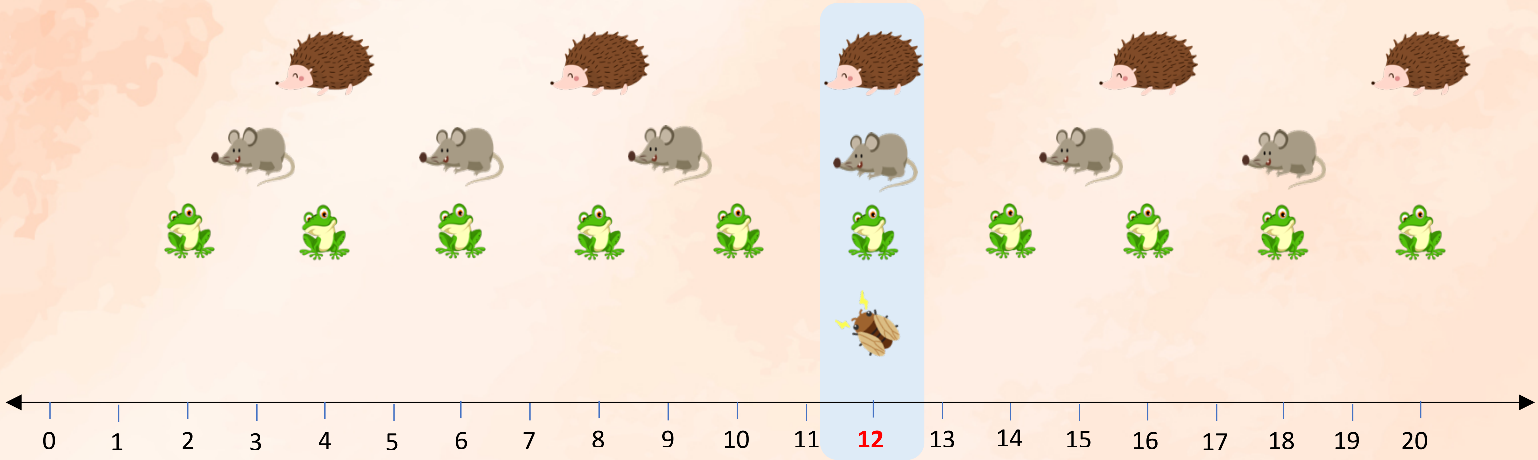
1) Every positive integer greater than 1 can be divided by at least one prime number
2) Every even positive integer greater than 2 can be expressed as the sum of two primes
3) Every number can be expressed as a product of prime numbers
4) When a set of integers or numbers has only 1 as common factor then they are co-primes. Hence, two prime numbers are always co-prime to each other. GCD of prime numbers is always 1. Integers: a and b are prime if GCD(a,b) = 1

But why would this relatively simple bug care about math?

Predators have their own distinctive cycle of growth just like cicadas. For instance, the life cycle of a beetle is 3 years which means this beetle specie needs three years to complete one generation from egg to become adults. Consequently, the cicadas will become vulnerable every 3rd, 6th, 9th, 12 years and so on as it would be feasted by the adult beetle; its predator.
Let's say cicadas settles for 10 years pattern
Then, they will be susceptible to predators whose population boomed on a 1, 2, 5 or 10 year cycle



You see, cicadas' predators have shorter life cycles, and they feast on the cicadas on a year that is a MULTIPLE of their life cycle.

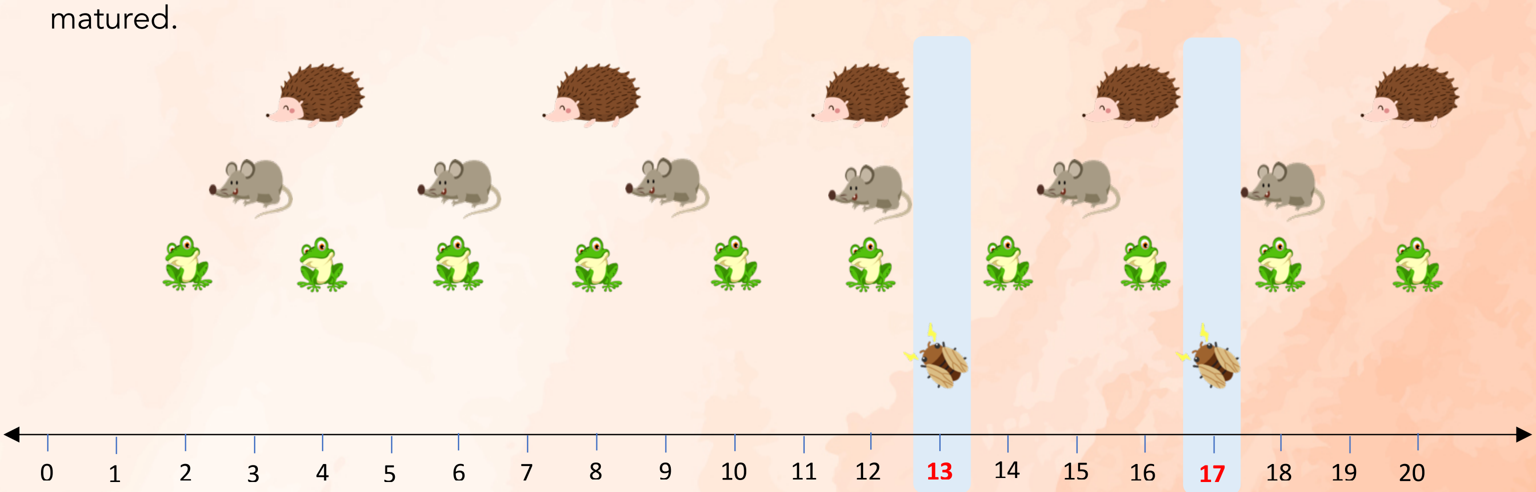


In the case of a cicada who surfaces every 12 years, the number 12 has many factors (1,2,3,4,6,12), so any predator whose life cycle is one of these factors can easily intercept the cicadas.

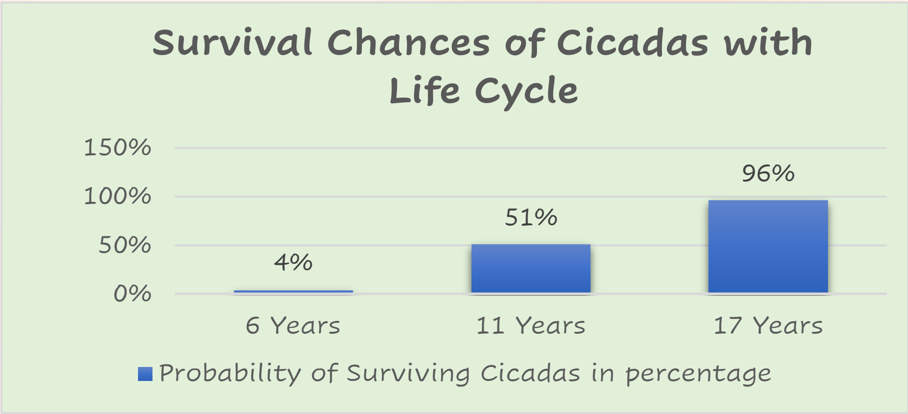
The predator with a 2-year life cycle will hunt the cicadas in every sixth generation (2 X 6 = 12)
The predator with a 3-year life cycle will hunt the cicadas in every fourth generation (3 X 4 = 12)
The predator with a 4-year life cycle will hunt the cicadas in every third generation (4 X 3 = 12)

So how could cicadas evade from being eaten by its predators each time they emerge?

The best solution is wait underground for prime number years.
Prime numbers seldom overlap with the life cycle of the potential predators.
For 13-year cicadas, the predators with life cycle between 2 to 12 will miss the window of hunting since 13 is a prime number and as prime numbers only have a factor of 1 and 13, the 13-year cicadas will only meet a predator of a 1 or 13-year life cycle. For example: a 6-year life cycle predator will miss the 13-year life cycle cicada since 6 X 2 =12, 6 X 3 =18. Second generation of the predator will be early by a year and third generation will be late by 5 years. The same strategy will work for the 17-year cycle cicadas. Hence, they'll have a greater probability of thriving. By emerging every 13th or 17th year they minimise the deadly coincidence of appearing right when their predator has matured.

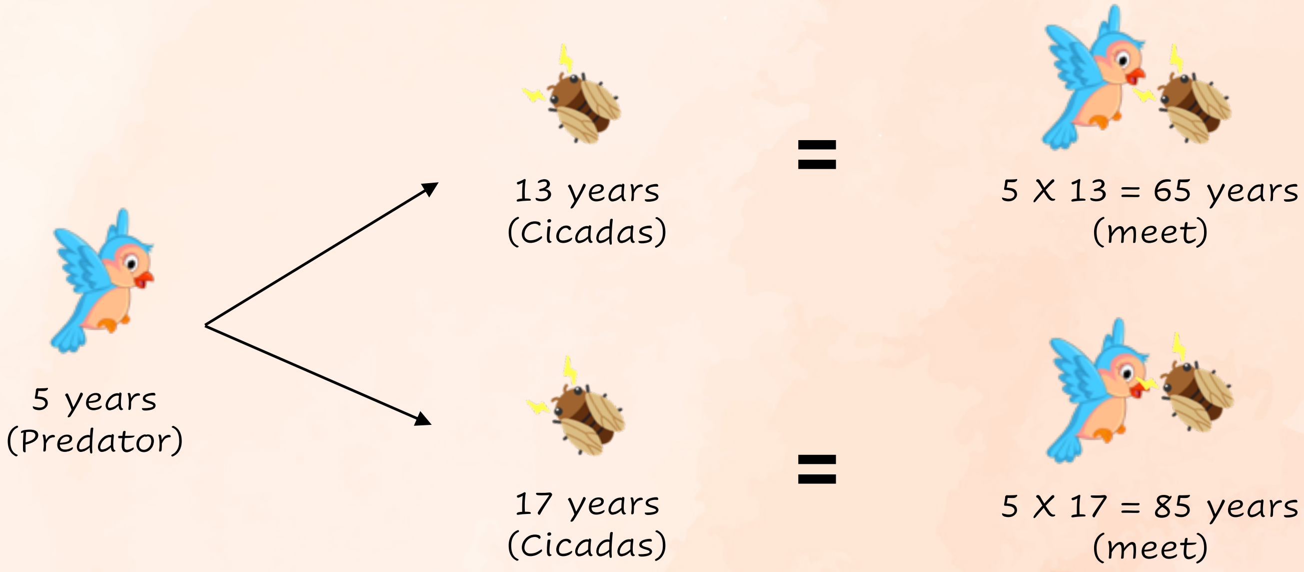


The graph demonstrates how prime numbers like 13 and 17 do not align with 2, 3 and 4-year periodicity and the same will hold true if we added even longer repeated periods of predator's life cycle like 5, 6 or 8 years to the graph. This suggests that even after significant hunting by predators



and cicada's low defence mechanism, having a long lifecycle based on a prime number is more likely to give a higher survival chance to the cicada to breed.

A predator whose life cycle is every 5 years will meet cicadas in :



Cicadas with 13 and 17-year life cycles surface less often with other breeds of cicadas than the cicadas whose life cycles are non-prime numbers.
Let's say, when a 15-year cicada brood emerges, it will emerge at the same time as 3-year and 5-year cicadas (the factors of 15 are 3 and 5). Thus, it will interbreed with 3-year and 5-year brood cicadas and produce mongrel offspring. The greater the number of cicadas with common multiples, more diverse the hybrids will be.

Suppose there are two breeds of cicadas with overlapping habitats whose lifecycles are 12 and 16 years respectively.

Multiples of 12:

12	24	36	48	60	72	84	96	108	120	132	144

Multiples of 16:

16	32	48	64	80	96	112	128	144	160

The common multiples of 12 and 16 are 48, 96, 144 ....and their LCM (least common multiple) is 48
Thus, they would encounter each other every 48 years. The numbers 12 and 16 have small common multiples which makes intersection more frequent
Contrarily, the numbers 13 and 17 have large LCM making the intersection less frequent

13 years × 17 years = 221 years

Thus, they would encounter each other every 221 years.
Cicadas with prime numbered cycles have reduced chances for hybridization significantly than non-prime numbered cycles. This enables them to stay well-synchronized internally.

2015 was a special year for periodical cicadas where both breeds emerged at the same time.
2015 + 221 years = 2236
Both breeds emerging in the year 2015 will next emerge simultaneously in the year 2236

So, cicadas use prime numbers pattern to minimise the chance of encounters.

Now the question here arises 'Why do cicadas not emerge in other prime number years?'
The reason being if cicadas emerge too early, the hungry predators would be waiting for them to devour, and if they emerge too late, predators would have had enough time to digest their kith and kin and would be ready by then to devour their next meal. Hence, 13-year and 17-year life cycle is considerably apt for them to survive.

Now is this just random coincidence that we see the mathematical significance while cicadas just fall into it by sheer chance, or did they calculate this unusual survival strategy?
Experts speculate that they have an internal molecular clock to keep the track. We simply do not know ...

But one thing is evident, prime numbers give periodical cicadas higher chances of survival.