

## Things that are Unchanged Assembly

We are always hearing that we live in turbulent and changing times. It has become a cliché that the world is in a state of continuous transformation and management of change is high on the list of the problems that every human faces. This morning, I am going to disagree. Whilst I don't deny that there is change, I would like to use this assembly to suggest that some of the most important things don't change, because they can't. They can't because the rules of the universe – by which I mean mathematics - require that they stay the same.

One of the key areas of change is said to be the digital revolution. The pace of change has been extra-ordinary, even in my lifetime. I can remember my father bringing home one of the first pocket calculators. It was in the mid-1970's – it was a baffling device to us. It will be hard to imagine for some in the room, but for almost all my time at school until the early 1980's we did not have computers. When I started teaching in 1990, email did not exist for the general public. It only became known in the mid-1990's. In fact, it was so exciting and strange that its use prompted the 1998 romantic film *You've Got Mail*, starring Tom Hanks and Meg Ryan.

That sounds like a lot of change, but it stopped there. The email we use today is essentially the same as that I first tried in the 90's. It hasn't improved a jot. In fact, given the overwhelming number of emails and spam we get each day, pinging into our smartphones, the process is immeasurably worse. So, email has been unchanged for more than 25 years, in the white-hot crucible of the digital revolution. What else hasn't changed?

Well, what about the bicycle? J K Starley invented the Rover Safety Bicycle in 1885 – every bicycle since has used the same design. Whilst this new bicycle design was revolutionary at the time – it replaced the obviously useless penny farthing – the revolution stopped there. The design was either unimprovable or no-one saw the need for further innovation. There, we have seen no change for 140 years.

House-building has been unchanged in over 2000 years. We build houses in the same way the Romans did, and house design remains influenced by Roman thinking. They even invented the tower block. In Rome, people lived in high-rise buildings called 'insulae' – which translates as 'islands'. There is a funny poem by the Roman poet Martial complaining of a schoolteacher who teaches his pupils in a neighbouring high-rise, where he lives. He shouts at his pupils, which disturbs the poet, who offers to pay the teacher's tuition fees to stop teaching, sit still and shut up. All the common problems of modern city life that are around today, have remained unchanged for over two millennia.

Let's go even further back. Some things haven't changed for millions of years. Crocodiles are ancient. They first evolved around 200 million years ago, in the late Triassic. They are broadly unchanged since then. To give context, our own species is a couple of hundred thousand years old and the first hominid, from which we evolved, appeared only about 2 million years ago. Crocodiles are a thousand times older than humans. But they aren't the most ancient of largely unchanged species. Trees are one of the oldest living organisms on Earth. Trees have been around for approximately 400 million years. But even they are not the oldest unchanged organism.

Sharks have been here longer than trees. Sharks have been swimming in the oceans for over 450 million years unchanged, taking them all the way back to the Silurian period. Both trees and sharks are much older than the first dinosaurs, who evolved around 250 million years ago.

Some other designs have gone unchanged, because they are unimprovable. The Peregrine falcon is the fastest bird in the world; in fact, it's the fastest animal of all. The peregrine hunts by flying high above its prey – typically smaller birds. It then goes into a steep dive, hitting a top speed of 242 mph. The shock of the impact kills the peregrine's prey instantly. The bird's entire anatomy is perfectly adapted to the extreme speeds it can achieve and its stealthy swoop on its prey. Therefore, we should not be surprised to see its aerodynamics have been adopted unchanged by stealthy military planes.



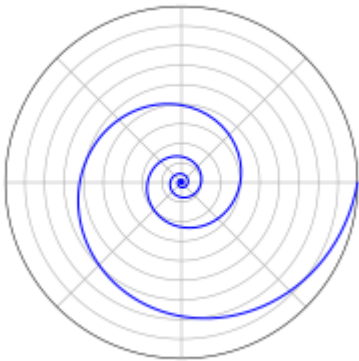
So far, we have gone in search of things that have remained unchanged and found that change is not inevitable or universal. But we have confined ourselves to looking for designs that are unchanged. Some things are unchanged for a deeper reason. Deep forces echo through mathematics, music and nature.

Some things are unchanged because of the nature of things themselves. Where does music come from? It seems to be a fundamental of human nature that our species creates music. In fact, earlier species of human also made music. The Divje Babe (Die-ve-ay Babe) flute - a cave bear femur pierced by spaced holes - was unearthed in 1995. It is around 60,000 years old and was made (and played) by Neanderthals. Some claim that the bone's holes were "consistent with four notes of the diatonic scale" (do, re, mi, fa) based on the spacing of those four holes. A reconstruction of the instrument was able to play 3½ octaves of the diatonic scale.

This is what it sounds like [Neanderthal Bone Flute Music](#) (play first 50 seconds).

Why would Neanderthals, 60,000 years ago, play music that is recognisable to us today? Because music and mathematics are connected and mathematics doesn't change – it describes the rules of the universe.

Here is a logarithmic spiral:



It occurs throughout nature, in hurricanes, galaxies and Nautilus shells

Music works in the same way. Here we are describing something called a Harmonic Spiral.

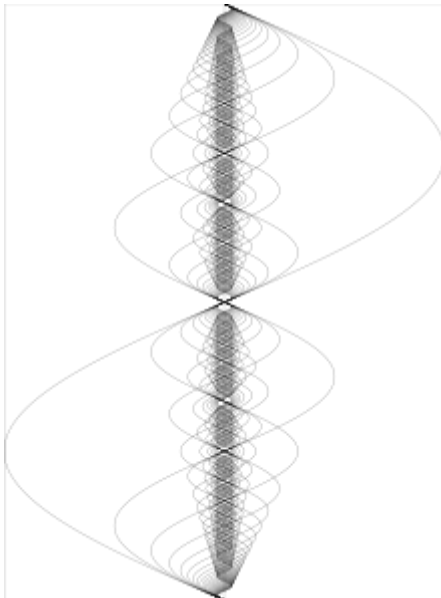
*Have a look at the opening animation from this site: <https://loophole-letters.vercel.app/harmonic-spirals>*

Here we see maths forming music. But it gets even more complicated and interesting.

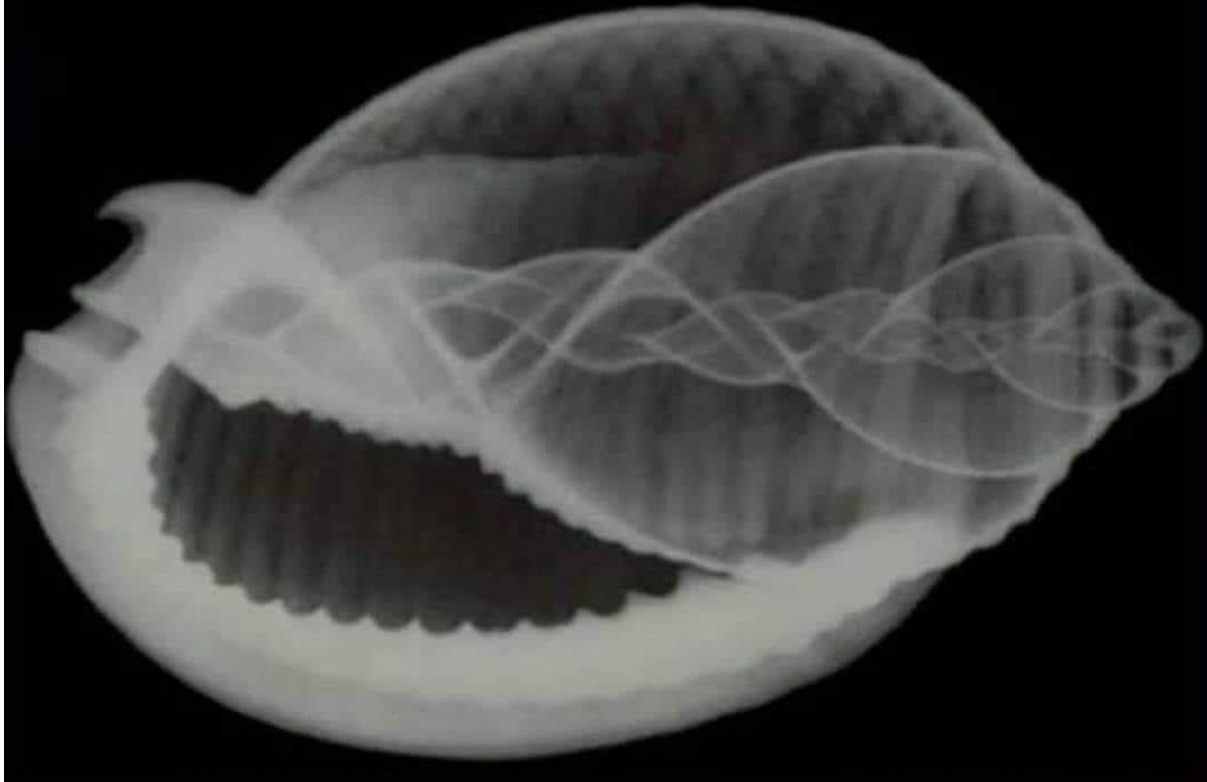
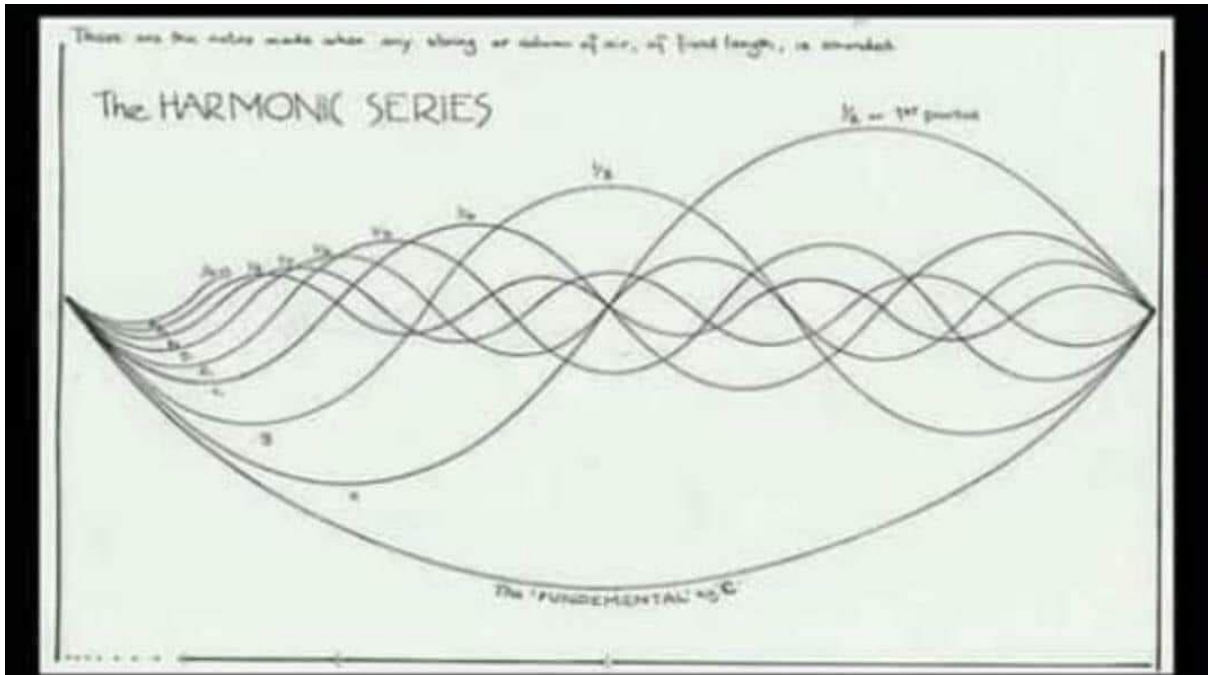
In mathematics, the harmonic series is the infinite series formed by summing all positive unit fractions:

$$\sum_{n=1}^{\infty} \frac{1}{n} = 1 + \frac{1}{2} + \frac{1}{3} + \frac{1}{4} + \frac{1}{5} + \dots$$

This forms the wave:



This wave can be used to create music, octaves, and harmonies; it can also be used to generate beautiful proportions in architecture and art. And it also appears in nature: laid on its side, you can see it appear in the internal structure of a shell:



But it gets even deeper. The Riemann Hypothesis is one of the most important unsolved problems in mathematics.

The Riemann zeta function  $\zeta(s)$  is a function whose argument  $s$  may be any complex number other than 1, and whose values are also complex. I don't pretend to understand it. But it looks like this

$$\zeta(s) = \sum_{n=1}^{\infty} \frac{1}{n^s} = \frac{1}{1^s} + \frac{1}{2^s} + \frac{1}{3^s} + \dots$$

Riemann constructed a hypothesis about how this function will behave. If you can prove the hypothesis, you will win a prize of \$1m - and more importantly, you will understand the distribution of prime numbers and have transformed our understanding of mathematics. The harmonic series is a version of the Riemann zeta function where  $s = 1$ . In other words, music is built into the fabric of the universe, as is proportion and beauty. It cannot change – it is as unchangeable as a mathematical proof. It is like prime numbers. No wonder it was as pure and true to the Neanderthals as it is to us. Truly, ancient people were right to speak of the music of the spheres.

So, it just isn't the case that everything is rushing into a madcap world of change and constant turmoil. Many things stay the same, some because they are just the best way of doing things, others because the nature of the universe requires it.

I find it extraordinary that music and beauty fall into that second category – that the nature of mathematics and the universe requires them.

‘When old age shall this generation waste,  
     Thou shalt remain, in midst of other woe  
 Than ours, a friend to man, to whom thou say'st,  
     "Beauty is truth, truth beauty,—that is all  
     Ye know on earth, and all ye need to know.’

*Keats' Ode on a Grecian Urn*