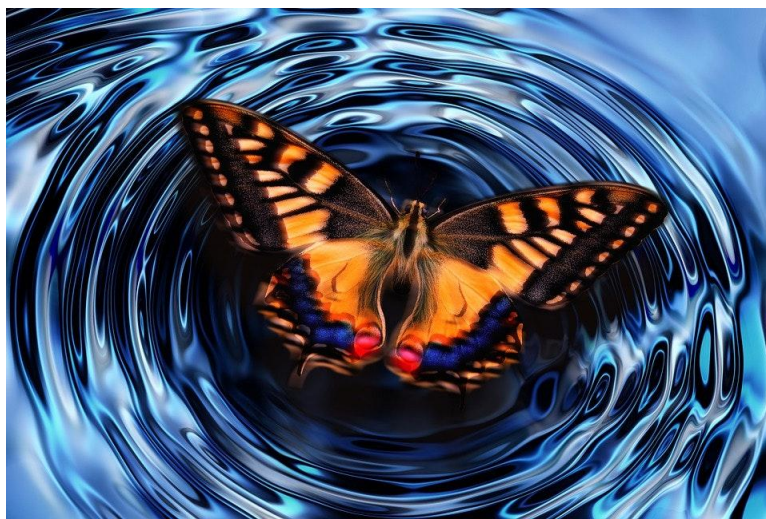


The Butterfly Effect

Have you ever wondered what difference it would make if you stepped into a different carriage on the tube? Sometimes, the smallest changes can have the biggest consequences. A slight difference at the start of a process can grow larger and larger over time, eventually leading to a completely different result. By stepping into carriage one rather than carriage three you have altered the people you meet, things you hear and many more things you may not even realise. For example, you might arrive somewhere a minute earlier or later, which could change who you see or the interactions you have without even realising.

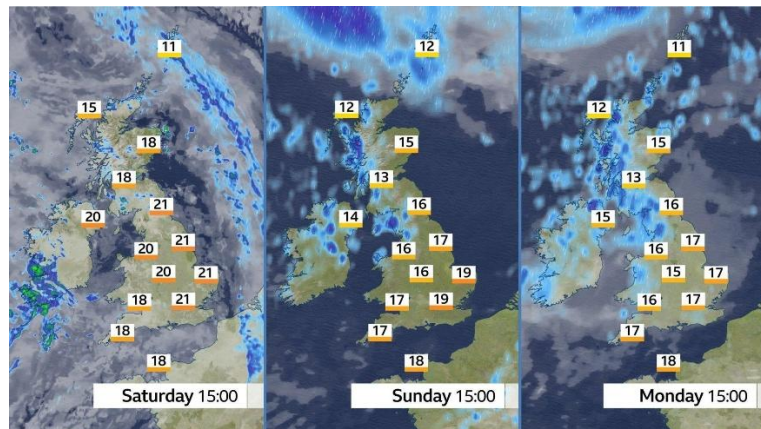


Ripples created by a butterfly showing small actions can create a large change.

This idea is known as the butterfly effect, an important concept in the chaos theory. It occurs in systems (things that change over time according to rules) that are sensitive to their conditions, meaning even a tiny change at the beginning can grow and evolve over time. Although these systems follow clear mathematical rules and are not random, their outcomes can become extremely difficult to predict. This is why a butterfly flapping its wings in one part of the world is often used as a metaphor for causing a hurricane far away, giving its name.

A change that may seem small to begin with is carried through and increases with every step taken. Over time as the differences increase, they become more noticeable and have a much larger effect. This is why even simple systems can have unpredictable results. This idea can be compared to making a drink of squash. Imagine you have two glasses of water and slowly you add a tiny bit more squash to one then the other. If you took a sip at first, you would not notice but gradually as you added more the difference in the taste would become clearer. This is comparable to the butterfly effect as in the same way, minor differences can grow over time. It shows how something that appears unimportant to begin with can turn into a visible change.

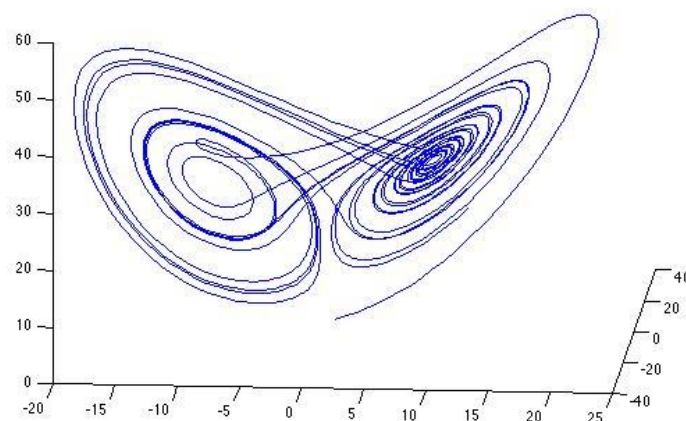
A common example of the butterfly effect is in weather forecasting. When we predict the weather, it is commonly based on measurements such as temperature and different pressures / speeds in the air. As these slight differences increase, they can lead to completely different forecasts. This is why weather predictions are often accurate in the short term, but much less dependable over longer periods, which explains why it always seems to rain at the worst possible times. Therefore, even the smallest of changes can affect the prediction given for a few days later.



Small differences in weather patterns can develop over time.

You're likely thinking how does this relate to maths? Well, I will give you a simple maths example. Take the number 0.500, multiply by 1 and subtract 3 that gives -2.5. Then do the same but with $0.501 \times 1 - 3 = -2.499$. At first, the answers look almost the same. In more complex maths systems where a rule is repeated many times, even a tiny difference at the start can quickly grow into something much bigger and lead to completely different results. This is chaos, the act of a tiny change growing into a huge difference.

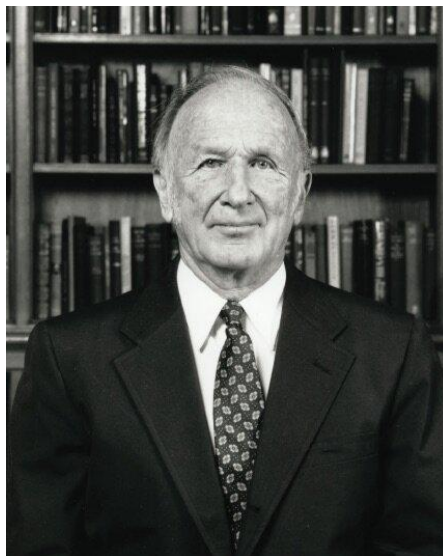
$$r=28, b=8/3$$



A mathematical model small differences in starting conditions leading to very different outcomes.

Another example you could see mathematically is simple addition. It is a much less complex way of viewing it. For example, if you start with the number 3 and then someone else starts with 3.3 (like the last example) the difference is very small. But if you continue to add the same number over and over the gap increases and is easier to spot. This shows how an insignificant change at the beginning can grow over time.

Even everyday life can be used as an example in the butterfly effect. For example, a small decision such as taking a different route home or talking to a new person may bring different opportunities or experiences. At the time these may not matter but overall, these decisions can impact our whole lives. The theory of the butterfly effect was discovered by Edward Lorenz, a scientist who was studying weather patterns. He realised that even tiny differences in his calculations led to very different results, which showed how sensitive systems are. This discovery helped people understand why predicting things like the weather can be challenging.



Edward Lorenz, the scientist who discovered the butterfly effect.

The chaos theory studies processes that follow rules (can be mathematical) but are hard to predict as the processes that take place are very sensitive to conditions (small changes at the start growing bigger over time). I'm explaining this to you as I think it's important to note that the butterfly effect is part of the chaos theory and even though many of the processes may look random they most certainly aren't. The smallest change at the start of a process expands over time which is exactly what the butterfly effect shows. Although these processes follow clear rules, the results can still seem unpredictable because the differences continue to increase.

To conclude, the butterfly effect reminds us of the weight tiny differences in our day to day lives carry. While we cannot control everything, we can understand that our actions may have bigger effects over time. From stepping onto a different tube carriage, changing the amount of squash or the tiny differences we spot in the weather. As I have explained and you can experiment with in maths eventually an insignificant change can alter the outcome completely. So, when you are in your maths lesson or decide to alter your playlist remember the tiniest action can have the

largest effect. Overall, it teaches us that even the smallest choices can matter more than we expect.