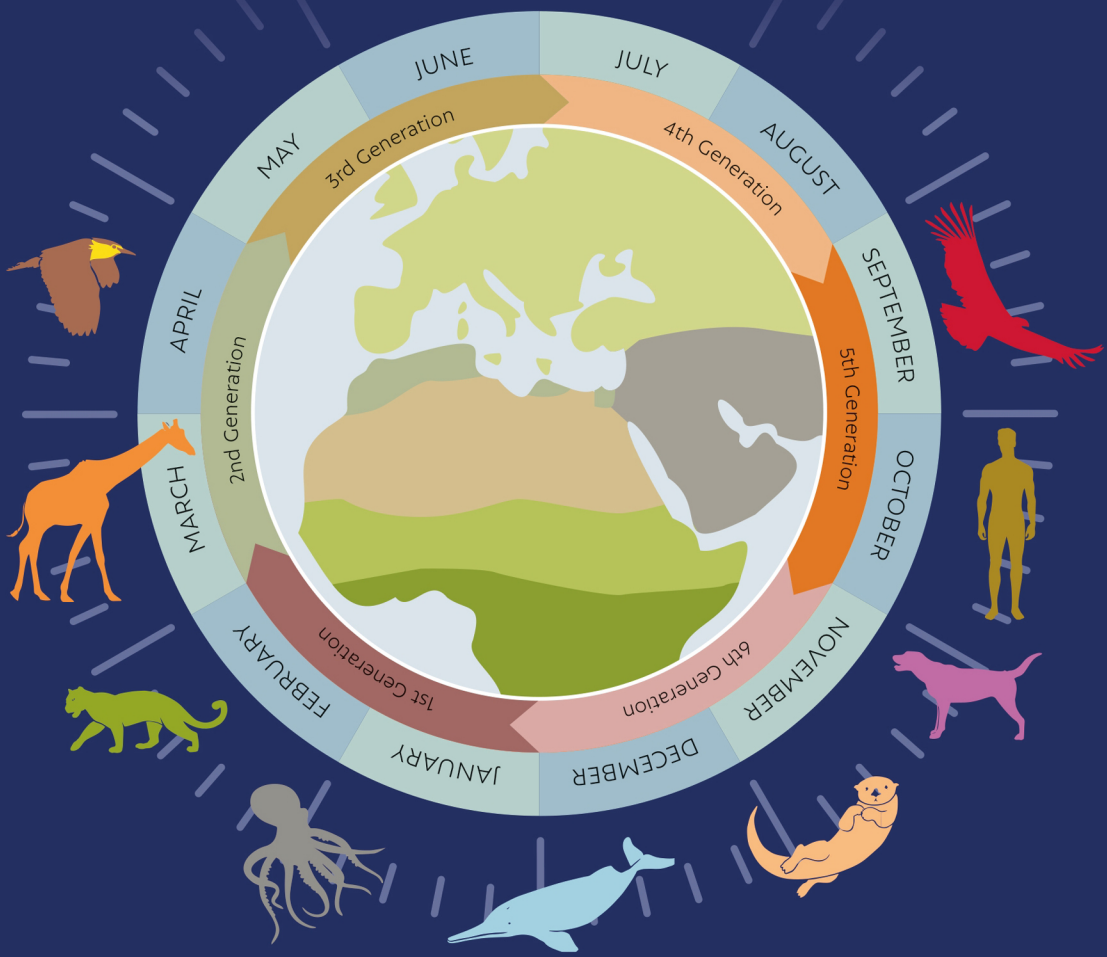
HELEN PILCHER

HOW NATURE KEEPS TIME

UNDERSTANDING LIFE EVENTS IN THE NATURAL WORLD



BLOOMSBURY

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INTRODUCTION

IT'S ALL ABOUT TIME

According to advocates of the Big Bang theory, time began with a cataclysmic explosion that occurred around 13.8 billion years ago. It led to the creation of energy and matter and, ultimately, the planet that we live on.

Today, Earth is brimming with life and events that unfold through the lens of time. In this book, we explore the time spans that are occupied by these natural events, in order to find out exactly how nature keeps time. Each chapter represents a different type of time span.

Evolutionary time spans trace planetary-scale narratives, such as the transition of life from the sea onto land, the snuffing out of species and the emergence of a primate so powerful it has the capacity to destroy Earth.

Ecological time spans describe the dynamic nature of ecosystems. Beavers, for example, can engineer their classic freshwater ecosystem within weeks, while the decaying remains of a blue whale can create a deep-sea ecosystem that can support life across decades.

Lifespans are the space between the start and end of life. An adult mayfly lives for less than a day, yet the oldest living individual tree is more than 4,500 years old.

Growth spans, meanwhile, chart the development that occurs during this time. At one extreme, the Greenland shark takes 150 years to reach sexual maturity, at the other, axolotls retain their juvenile form for life.

Behavioural time spans measure the way that organisms respond to their environment. They can occur across long time periods, such as the migration of the painted lady butterfly, or shorter time frames, like the millisecond traps of the carnivorous bladderwort plant.

Finally, biological time spans are dependent on physiological processes, such as metabolism and hormone production. From the number of breaths taken per minute, to the time taken to poo and wee, these intervals chart the innate processes that help organisms to function and survive. Let's explore how nature keeps time.

The life of a painted lady butterfly can last just a few weeks, but in that time it can travel thousands of kilometres.

HAVE A GOOD TIME

From the sweet bouquet of a wildflower meadow, to the soulful song of a blackbird at dusk, the natural world has the power to make us feel good. We know this intuitively, but in recent years, scientific studies have lent empirical weight to the idea of a 'natural health service' that can benefit us all.

Spending time in green spaces has proven to benefit both physical and mental wellbeing. People who live in greener neighbourhoods have a lower risk of developing cardiovascular disease, obesity and diabetes. They also report lower levels of stress, better sleep patterns, and higher levels of health and wellbeing.

The potential benefits of spending time in nature are so great, that some doctors now offer 'green prescriptions', in which patients are actively encouraged to interact with nature. One scheme, in New Zealand, found that after six months, two-thirds of patients issued the prescription felt healthier and were more active.

The rise of urban living

300,000 years ago

Homo sapiens evolve.

6,000 years ago

First cities are built.

Eco-therapy, where people participate in outdoor activities, such as gardening or group walks, is also being explored as a possible treatment for some types of depression.

It sounds great, but we all have busy lives. So, what is the optimum 'dose' of nature that we should be taking? Once again, science has the answers. A 2019 study of almost 20,000 individuals, found the benefits of spending just two hours a week in green spaces is enough to boost feelings of both happiness and health. Whether it is one long walk, or several shorter outings, spending time in nature increases physical and mental wellbeing, and the results apply to everyone, regardless of age, gender or levels of health and disability.

We are all used to public health messaging telling us to eat five portions of fruit and vegetables per day, or exercise for 150 minutes per week, but perhaps now, it's time to shout about the health benefits of nature, too.

WHY DOES NATURE MAKE US FEEL GOOD?

According to the conservationist, Edward O. Wilson, it's because we are part of the natural world. As our species evolved, our brains became primed to respond positively to natural features, such as rivers, forests and grasslands, that boosted the survival of our ancestors. Proposed in 1984, Wilson called this idea the 'biophilia' hypothesis.

10 years ago

More people live in cities than in rural areas.

2050

Seventy per cent of people will live in cities.

NATURE'S CLOCKS

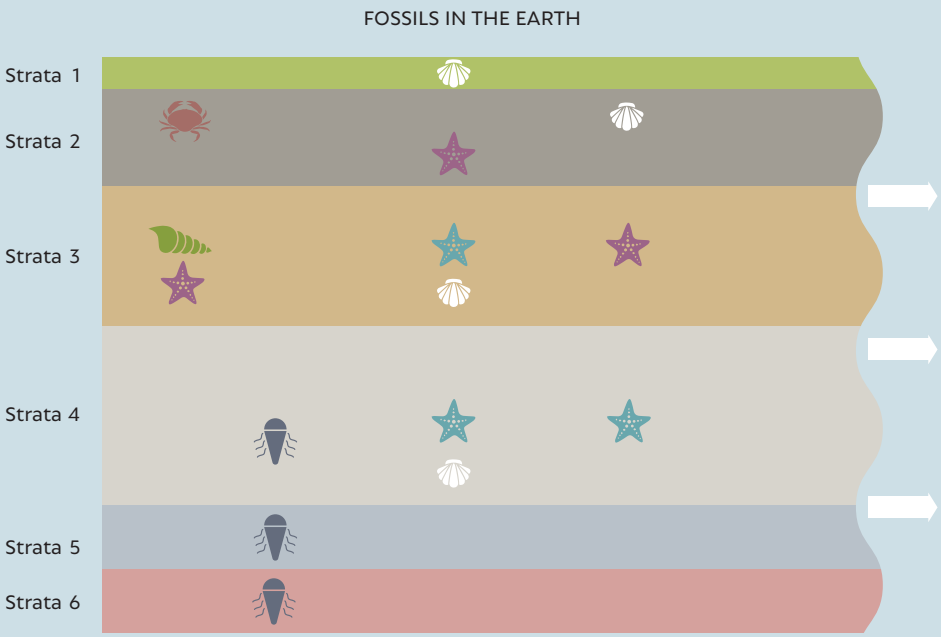
From the mechanical clock to the digital wristwatch, humans have been devising increasingly accurate timepieces for centuries, but the natural world has an impressive array of its own time keepers. Some are tuned to the big picture, recording key events across millions of years, whilst others are tuned to the small scale, documenting the changes that occur within a single, brief life. They may not have the accuracy of an atomic clock, which has an error of just one second in up to 100 million years, but what they lack in sensitivity, nature's clocks more than make up for in context and colour.

The fossil record, for example, tells the dazzling story of life on Earth. Sediments are laid down, layer upon layer, and inside each one, are the fossilised remains of some of the organisms that lived during that time period. The study of these layers is called stratigraphy. It helps palaeontologists to determine the relative age of fossils.

HOW TO GAUGE THE AGE OF A FOSSIL

Layers of sedimentary rock are called strata. The strata at the bottom were deposited first, which means that they are older than the layers above them. Such information can help us to understand the age of

Examples of fossils found in rock



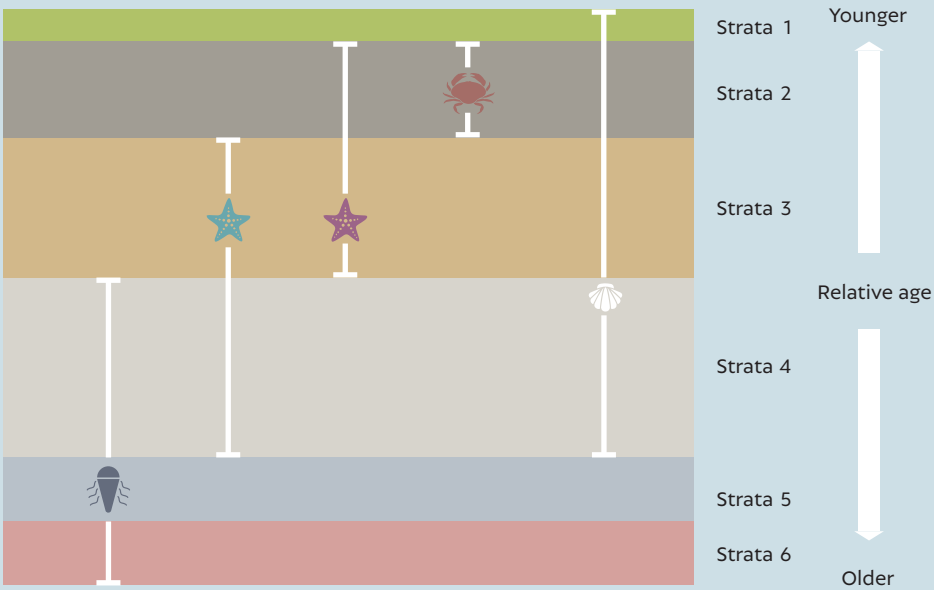
fossils. In the chart below, the grey trilobite found in strata 4, 5 and 6 must be older than the green shell, as the green shell is only located in strata 3. However, the green shell is older than the red crab, which is only found in strata 2.

RADIOMETRIC DATING

Stratigraphy can give us an idea of a fossil's relative age, but to find out its absolute age in 'millions of years', other methods are needed. Radiometric dating, which is one of these techniques, relies on the fact that some rocks contain unstable radioactive atoms, which decay at a predictable rate.

Scientists may study radioactive uranium, potassium or carbon. By measuring the amount of unstable radioactive atoms left in a rock, and comparing it to the quantity of stable atoms that have been produced, scientists can estimate the amount of time that has passed since the rock formed.

EXAMPLES OF THE AGE SPAN OF KNOWN FOSSILS



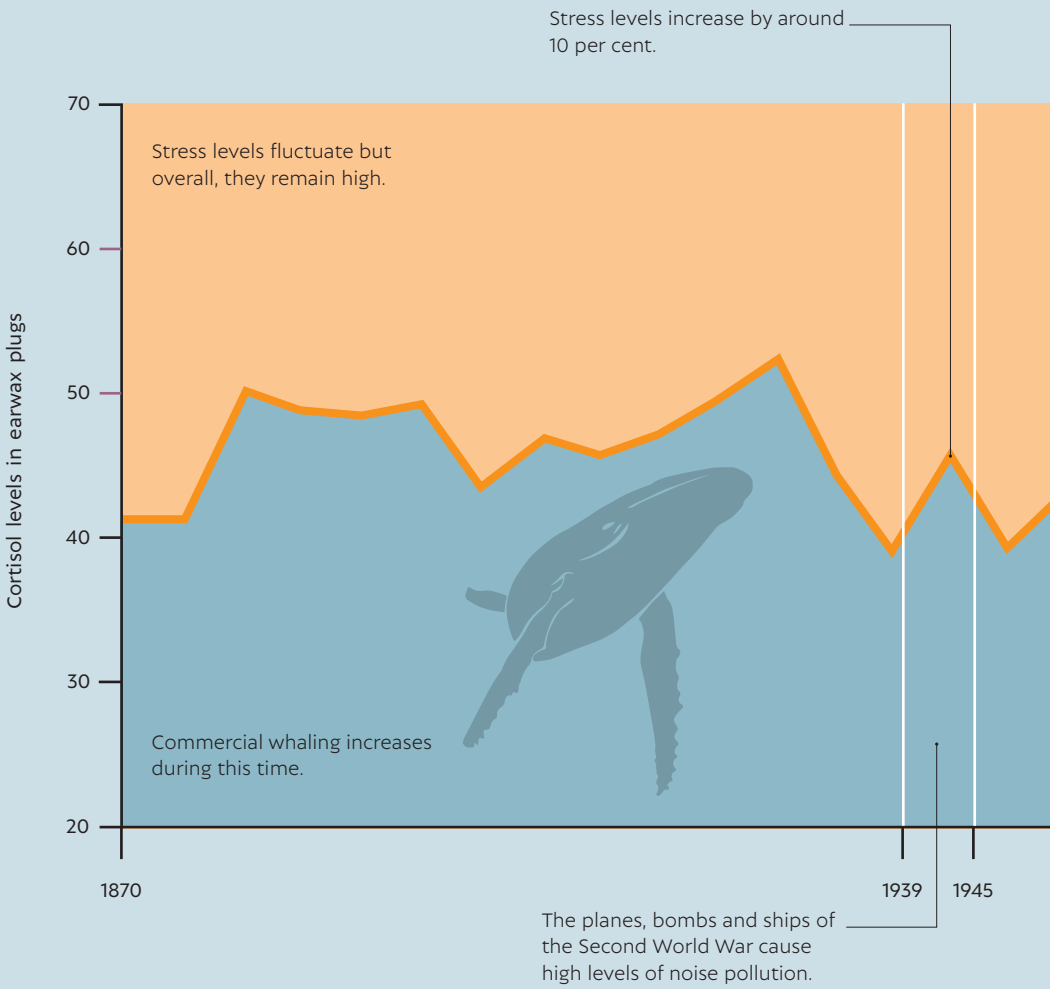
LIVING CLOCKS

Most of us are familiar with the idea that tree rings can be used to measure time. The alternating circles of light and dark give information, not only about the age of the tree, but also about the conditions that it experienced through its life.

The same is true for whale earwax. Throughout their life, whales build up layers of lipid-dense wax inside their ear canals. If a whale is found soon after it dies, then the long, thin plugs of earwax can be extracted. When the plug is sawn in half, a series of light and dark bands can be seen, which are counted to give an indication of age, so whale ear plugs can act like a clock.

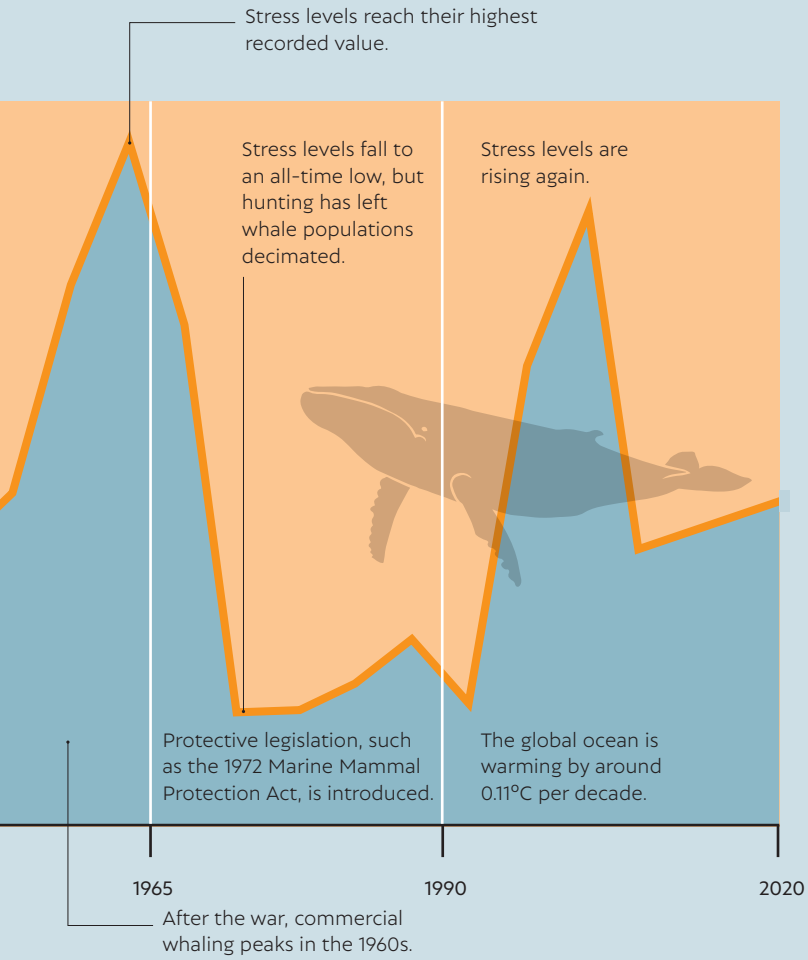
They can also tell us about the whale's life. Whales often live very long lives, during which they inevitably experience stress. When a whale is stressed, it produces a hormone called cortisol.

Human activity affects whale stress



During its lifetime, the levels of cortisol go up and down. These changes are captured in the whale's earwax. Scientists can take samples from different points along the earplugs, and then analyse them to identify the cortisol level. Each sample represents a different time in the whale's life. By combining this information, it is possible to tell how the animal's stress levels changed over time.

In a study from 2018, scientists pooled earwax data from 20 whales, spanning over 150 years. Peak cortisol levels, when the animals were really stressed, coincided with periods of negative human activity, such as commercial hunting, war and human activity. Now, as the global oceans warm, their stress levels are rising again, so the study shows how detrimental our actions can be to these gentle giants.



LIFE IN SLOW MOTION

They say that time flies when you're having fun, but we all know how much it can drag when there's housework to be done. The idea that time can seemingly speed up or slow down is familiar to us all, but experiments have revealed that some species can alter their perception of time to suit their needs.

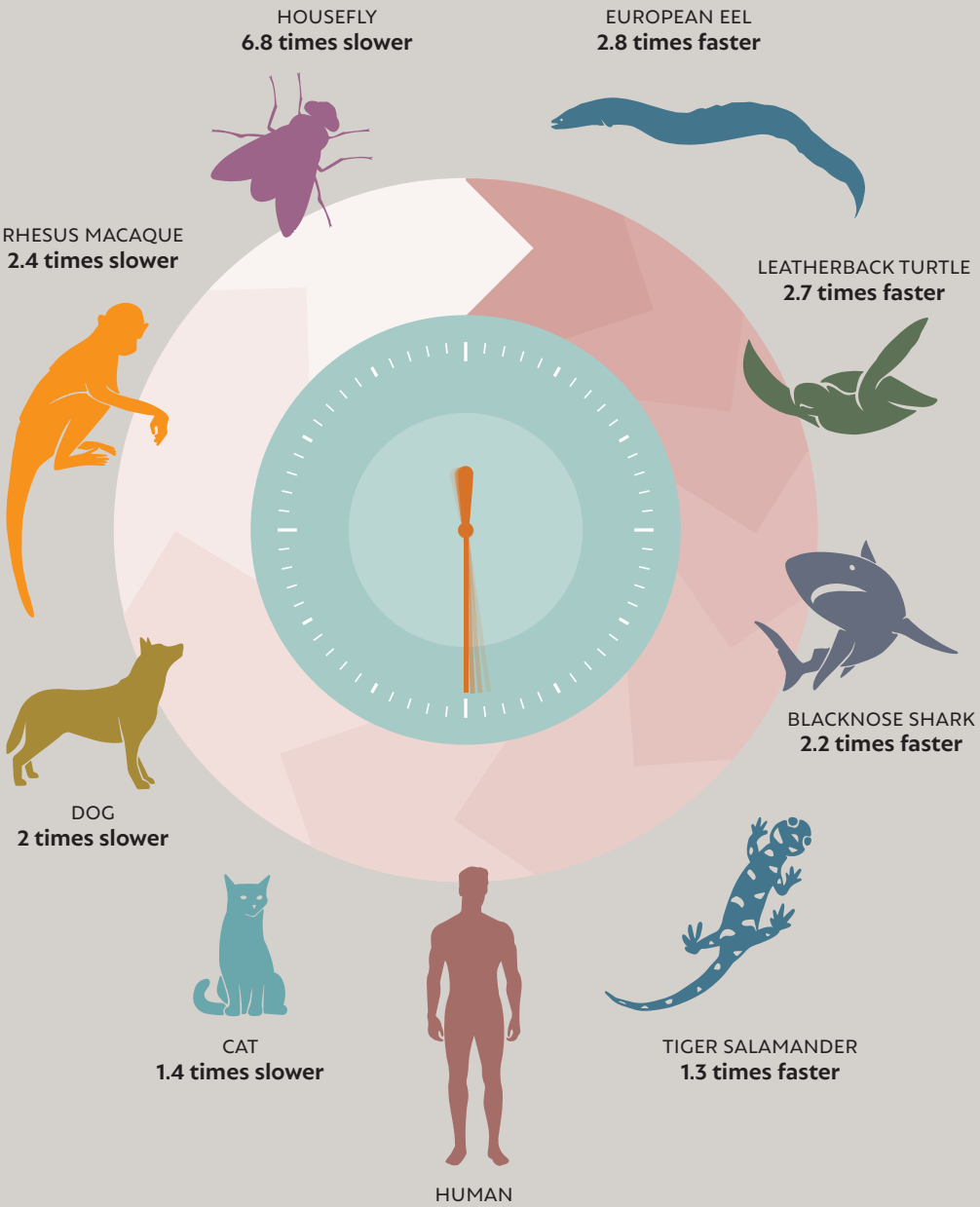
Time perception depends on the speed at which the brain is able to process incoming information. It can be measured by showing animals pulses of light, which start slowly and then speed up. There comes a point where the light is flashing so quickly, that it looks like a continuous blur. This is called the 'critical flicker fusion frequency.' Carefully placed brain electrodes can determine the moment this transition occurs.

Studies show that smaller, speedier animals can detect higher frequencies of flickering lights than larger animals with slower metabolisms. Flies, for example, can perceive light flickering up to four times faster than we can. Just like the fictional character Neo dodging bullets in *The Matrix*, actions and events may seem to unfold more slowly, and whilst it may explain the infuriating ability of flies to dodge a rolled-up newspaper, it also makes us ask 'why?'

From an evolutionary perspective, it makes sense for animals that need to move quickly – to avoid being eaten or to catch fast-moving prey – to perceive time more slowly and react swiftly. It also makes sense for these same animals to be able to change their perception of time when speedy reactions are no longer needed, for example, when resting.

In line with this, scientists have discovered that some swordfish boost blood flow to the brain before they set off hunting. This slows their perception of time, and boosts the number of frames they can process per second. When not hunting, time goes by more quickly, as the amount of information they can process per second decreases.

How times moves relative to human time perception



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EVOLUTIONARY SPANS

INTRODUCTION

There has been life on planet Earth for more than 3.5 billion years, and during this time, our planet has been home to hundreds of millions of species. Today, it is estimated that about 9 million different species inhabit Earth, and that more than 98 per cent of all species that have ever lived are now extinct.

The Earth has witnessed the emergence of life, in its original single-celled form, and then the explosion of diversity that occurred after single cells started collaborating, spawning the emergence of multi-cellular organisms. Our planet stood by as living things crept out of the oceans and started to thrive on land. It was then the ancestors of whales and dolphins left the land, and returned to water. The Earth has seen the rise of plants, the demise of the dinosaurs and the emergence of our own species. In its time, our planet has been home to fungi as tall as trees, beavers the size of bears and dragonflies as big as barn owls.

So many fascinating life forms have evolved through evolution, which is the process that enables living things to change over time. Sometimes, evolution occurs over unimaginably enormous time spans, with changes so subtle and slow, they can be hard to appreciate. Other times, it can be measured across much shorter time spans, sometimes even witnessed within a single human lifespan. As we will discover, life can evolve across millions and billions of years, but it can also change over decades and even within a single year.

The ancestor of whales was a land-dwelling mammal that returned to the sea around 50 million years ago.