The Statesman
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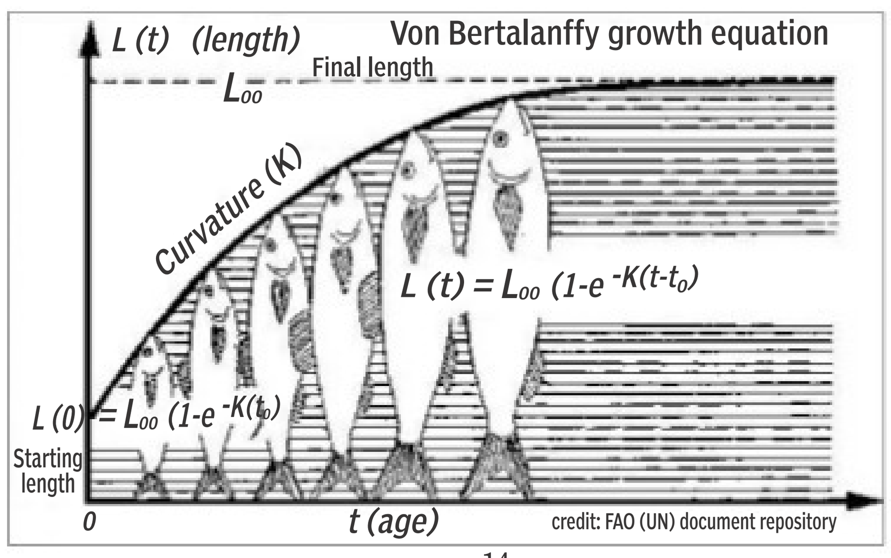
Oldest denizen of the sea

NO WELL-BRED SCIENTIST CAN ASK A LADY SHARK HOW OLD SHE IS, WRITES S ANANTHANARAYANAN

This problem, however, goes beyond good manners because it is challenging to tell the age of some living things that last more than a human lifetime. The legendary Redwood trees are hundreds to thousands of years old but we can work out their age from the "growth rings" once the tree is felled, or even from records of people long dead who were familiar with the tree.

But how do you tell the age of an animal that shows no annual growth markings and does not stay in one place, like a Redwood tree? Julius Nielsen, Rasmus B Hedeholm, Jan Heinemeier, Peter G Bushnell, Jørgen S Christiansen, Jesper Olsen, Christopher Bronk Ramsey, Richard W Brill, Malene Simon, Kirstine F Steffensen and John F Steffensen from institutes and universities in Denmark, Greenland, Norway, the USA and UK report in the journal *Science* that they have used a combination of radioactive dating and the growth rate of shark tissue to find that there are female sharks in the sea that are more than 270 years old!



That radioactive dating could be used to tell the age of a contemporary living thing may come as a surprise. This established technique of finding the age of long dead fossils, archaeological specimens and so on is based on the decay of the nuclei of radioactive carbon. The normal carbon nucleus, which is stable, consists of six protons and six neutrons, or 12 particles in all. But there is also a tiny percentage of atoms whose nuclei have eight neutrons instead of six. The atom, however, is still carbon, as chemical properties depend on the number of protons, which is the same. But this form of carbon, known as C^{14}, is unstable and one of the neutrons, sooner or later, radioactively changes to a proton and with seven protons the atom becomes one of nitrogen.

We can imagine that any living thing that contains carbon would keep showing radioactivity, whose rate would gradually slow down as the number of atoms of C^{14} gets depleted. The fact, however, is that in the atmosphere and the environment there is also generation of C^{14} atoms, by the action of cosmic rays, and there is a balance. And as living things keep exchanging carbon atoms with the environment through the intake of food and exhalation of breath, the percentage of C^{14} stays constant in living things, too. But once the organism dies, the exchange stops and as the C^{14} content depletes the level of radioactivity starts to fall.

Age of a living thing

This is the way we can tell how long ago it was that a once living thing died, the skeleton of a dinosaur, or the wood used to build a temple, for instance. But how do you use this to tell how long an animal has been living before it died? This is also possible, thanks to a part of the body that forms just before the animal was born, and crystallises, or stops participating in metabolism, so that the C^{14} content in that part starts depleting and keeping count of passing time, almost from the moment of birth. Julius Nielsen and others, the authors of the paper in Science, used this method to estimate the age of the Greenland shark that inhabits the North Atlantic and grows to be over five metres long. As the shark shows a very slow rate of growth, less than a centimetre every year, it clearly grows to this length over a very long lifetime! "The biology of the Greenland shark, however, is poorly understood and longevity and age at first reproduction are completely unknown," the authors say.

The part of the body that acts as the timekeeper in the Greenland shark is a bit of crystallised protein within the eye lens. "In vertebrates, the eye lens nucleus is composed of metabolically inert crystalline proteins, which in the centre (ie, the embryonic nucleus) is formed during prenatal development," the authors say. This tissue thus has C^{14} content that was the same as its surrounding at the time of the shark's birth, but has been depleting by radioactivity ever since. Measuring the level of radioactivity at the time of the shark's death then provides information of how long ago it was that the shark was born.

The team was able to inspect the eye lens centre of 28 female Greenland sharks measuring from 81 cm to 502 cm (the females being larger than male Greenland sharks), that were accidentally caught in the course of fishing during 2010-2013. Analyses of the eye lens material showed that the source of the carbon was the diet of the mother and the date of the crystallised centre was nearly the same as the birth of the young shark. The ages estimated by the level of radioactivity were seen to agree with the idea that smaller sharks were likely to be younger sharks. This was also in agreement with expected high levels of radioactivity in carbon ingested during the period of thermonuclear tests in the late 1950s to the early 1960s — the three smallest sharks were found to have radioactivity levels that corresponded to post-nuclear test environmental levels, in two, and a spike corresponding to the test period, in one case, which placed the age of that shark at approximately 50 years in 2012. The remaining 25 sharks showed lower levels, indicating greater age, and corresponding to larger sizes.

The earth's most durable living things

NAME	LONGEVITY
1. Hexactinellid sponge (*Scolymastra joubini*)	15.000years
2. Great Basin bristiecone pine (*Pinus longaeva*)	4.713
3. Epibenthic sponge (*Cinachyra antartica*)	1.550
4. Ocean quahog clam (Arctica islandica)	507
5. Greenland shark (*Somniosus microcephalus*)	392
6. Bowhead whale (*Balaena mysticetus*)	211
7. Rougheye rockfish (*sebastes aleutianus*)	205
8. Red sea urchin (*Strongylocentrotus franciscanus*)	200
9. Galapagos tortoise (*Geochelone nigra*)	177
10. Shortraker rockfish (*Sebastes borealis*)	157

From the journal, Science, crediting Human Ageing Genomic Resources' AnAge database

Another marker to help corroborate the findings was the Suess effect, or the change in the atmospheric C^{14}/C^{13} levels as a result of large-scale burning of fossil fuels during the last century, which is imprinted in the marine food web. Accordingly, sharks that were less than three metres long and estimated to be less than 100 years old showed lower levels of C^{13}, in keeping with the atmospheric trend.

The estimation of age was adjusted for known variation in the environment carbon levels in the last 400 years as well as the effect of the mixing of waters from different parts of the ocean. The statistical method used for this calibration uses a presumed age distribution that was derived from a formula known as the Von Bertalanffy equation to relate fish size, whose increase gradually slows down, with age.

Oldest member

The findings, hence, place the longest Greenland sharks at 392 years, with an error margin of 120 years, or at least 272 years old. This is more than the lifetime of the Bowhead whale, which is estimated to live for 211 years. While the only longer-lived animal is the quahog, a species of clam that lives for 507 years, the Greenland shark is the longest-lived vertebrate. Being 272 years, which is the lower bound of the estimated age, places the birth of the largest Greenland sharks at around 1740, the time of the declining Mughal empire, Nadir Shah's sacking of Delhi and the beginning of the steam engine and the industrial revolution!

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PLUS POINTS

For free

Care to learn more about 400-foot tsunamis on Mars? Now you can, after the National Aeronautics and Space Administration announced it was making all its publicly funded research available online for free. The agency has set up a new public web portal called Pubspace, where you can find Nasa-funded research articles on everything from the chances of life on one of Saturn's moons to the effects of space station living on the hair follicles of astronauts.

In 2013, the White House Office of Science and Technology Policy directed Nasa and other agencies to increase access to their research, which in the past was often available (if it was available online at all) only via a paywall. Now, it is Nasa policy that any research articles funded by the agency have to be posted on Pubspace within a year of publication. There are some exceptions, such as research that relates to national security. Nonetheless, there are currently a little over 850 articles available on the website with many more to come.

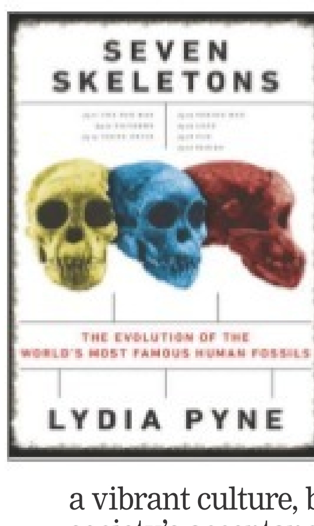
"Making our research data easier to access will greatly magnify the impact of our research," Nasa chief scientist Ellen Stofan said in a statement. "As scientists and engineers, we work by building upon a foundation laid by others."

The move is part of a trend in the worldwide scientific community towards making knowledge more readily available. In May, European Union member states agreed on an initiative to try to make all European scientific papers freely available by 2020. In the meantime, you can enjoy Nasa-funded insights into keeping fit in space, the ages of the lunar seas and much more.

THE INDEPENDENT

Neanderthal in the mirror

On 3 August 1908, the first near-complete Neanderthal skeleton was discovered in a cave near the village of La Chapelle-aux-Saints in south central France during a survey of the region's Paleolithic archaeological sites. For decades prior, prehistorians had collected bits and pieces of curious but not-quite-human fossils from museums and excavations alike — the odd skull here, a scrap of tooth there. In 1863, the mélange of bones was finally given its own species designation, Homo neanderthalensis. Forty-five years later, the La Chapelle discovery was the first Neanderthal specimen found in an original archaeological context and the first to be expertly excavated and carefully studied. Because the body was arranged in a flexed, foetal position and carefully placed in the floor of the cave, excavators argued that fossil - nicknamed the Old Man - had been purposefully buried by his Neanderthal contemporaries.



Today, we're rather used to the idea that Neanderthals had a vibrant culture, but science and society's acceptance of each new piece of the Neanderthal story is an uphill battle, thanks to the Old Man's early days in the public's eye. We now have archaeological evidence that Neanderthals built structures, that they had sophisticated hunting strategies, fire-starting technologies and art; and, of course, that they buried their dead. Analyses of Neanderthal DNA show us more and more similarities between ourselves and Neanderthals, with every indication that modern humans and Neanderthals interbred in their evolutionary history. Every "human" behaviour we can claim to separate ourselves from our Pleistocene relatives, we eventually find in Neanderthals, blurring the line between human and not.

Decades of researchers have studied the Old Man since Boule's original analysis. Every new iteration of the Neanderthal's story humanises him, turning the fossil from a dim troglodyte into a dignified paleo patriarch. The more we study the Old Man, the more the differences between our species melt away.

THE SCIENTIST

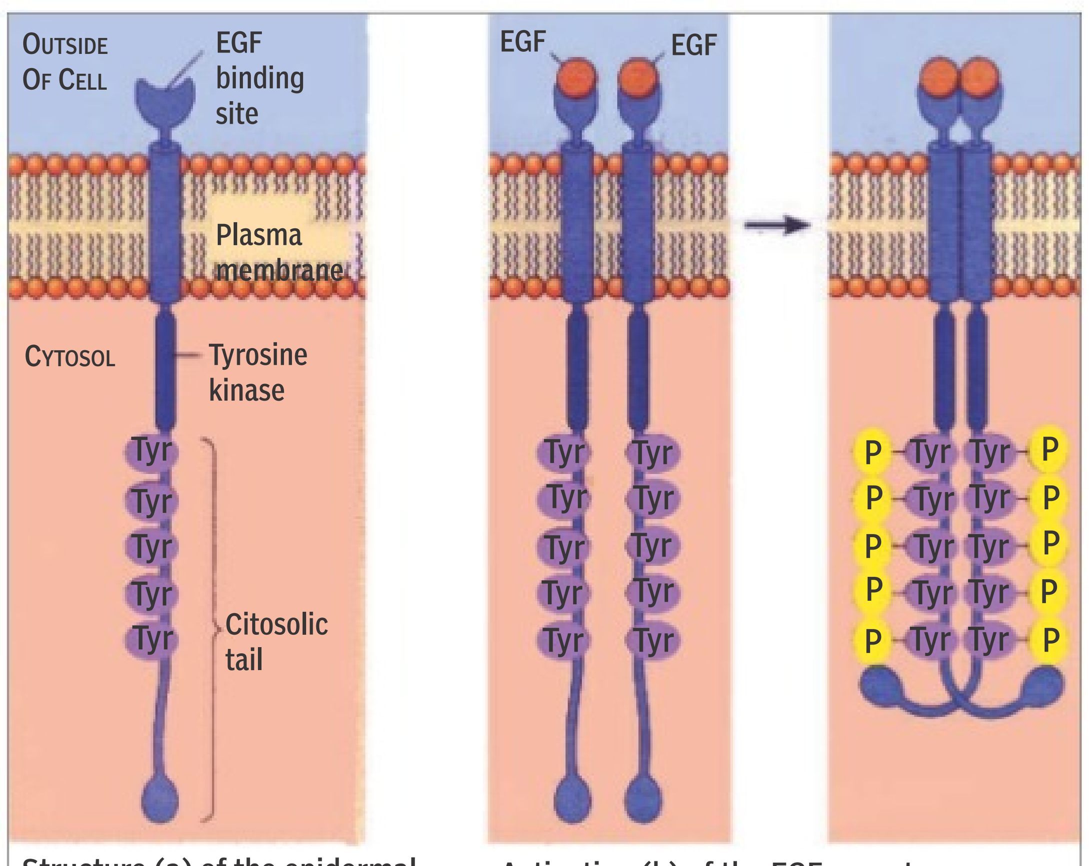
SIGNALLING PATHWAYS

TAPAN KUMAR MAITRA EXPLAINS A TRANSDUCTION CASCADE INVOLVING RAS AND MAP KINASE

Receptor tyrosine kinases use a different method of initiating signal transduction from that seen with G protein-linked receptors. Many of the key events in RTK signalling were identified using mutants in model organisms such as *Drosophila* and *Caenorhabditis elegans*.

Once autophosphorylation of tyrosine residues on the cytosolic portion of the receptor occurs in response to ligand binding, the receptor recruits a number of cytosolic proteins to interact with itself. Each of these proteins binds to the receptor at a phosphorylated tyrosine residue. To bind to the receptor, each cytosolic protein must contain a stretch of amino acids that recognises the phosphotyrosine and a few neighbouring amino acids on the receptor. The portion of a protein that recognises one of these phosphorylated tyrosines is called an *SH2 domain*. The term *SH2* (Src homology domain 2) was originally used because proteins with SH2 domains have sequences of amino acids that are strikingly similar to a portion of the Src protein.

Recruitment of different SH2 domain-containing proteins activates different signal transduction pathways. As a result, receptor tyrosine kinases can activate several different pathways at the same time, including the inositol-phospholipid-calcium second messenger pathway and the *Ras* pathway, which ultimately activates the expression of genes involved in growth or development.



Structure (a) of the epidermal growth factor (EGF) receptor — Activation (b) of the EGF receptor

The receptor for Epidermal Growth Factor (a) is typical of many receptor tyrosine kinases. These receptors often have only one transmembrane segment. The extracellular portion of the receptor binds to the ligand (EGF in this case). Inside the cell, a portion of the receptor has tyrosine kinase activity. The remainder of the receptor contains a series of tyrosine residues that are substrates for the tyrosine kinase (b). The activation of receptor tyrosine kinases starts with the binding of a messenger (EGF, in this case), causing receptor aggregation or clustering. Once the receptors aggregate, they cross-phosphorylate each other at a number of tyrosine amino acid residues. The formation of tyrosine phosphate (TyrP) residues on the receptor creates binding sites for cytosolic proteins that contain SH2 domains.

Ras is important in regulating the growth of cells. Unlike the heterotrimeric G proteins associated with G protein-linked receptors, Ras comprises a single subunit. Ras and other *small monomeric G proteins* are important signalling molecules. Like other types of G proteins, Ras can be bound to either GDP or GTP, but it is active only when bound to GTP. In the absence of receptor stimulation, Ras is normally in the GDP-bound state. For Ras to become active, it must release GDP and acquire a molecule of GTP. For this to take place, Ras needs the help of another type of protein called a *Guanine-nucleotide Exchange Factor*.

The GEF that activates Ras is Sos (so called because it was originally identified from a genetic mutation in fruit flies called Son of Sevenless that results in the failure of cells in the compound eye to develop properly. For Sos to become active, it must bind indirectly to the receptor tyrosine kinase through another protein called *GRB2*, which contains an SH2 domain. Thus, to activate Ras, the receptor becomes tyrosine phosphorylated, and GRB2 and Sos form a complex that binds to the receptor, activating Sos, which then stimulates Ras to release GDP and acquire GTP, which converts Ras to its active state.

Once Ras is active, it triggers a cascade of cellular events collectively referred to as the Ras pathway. One important event in the pathway is the activation of *Mitogen-Activated Protein Kinases*, when cells receive a stimulus to grow and divide (such a signal is sometimes called a *mitogen*. One of the functions of MAPKs is to phosphorylate a nuclear protein called *Jun*, which assembles along with other proteins into a transcription factor called *AP-1*, which appears to stimulate the production of proteins that are needed for cells to grow and divide.

Once Ras is in its active state, it must be inactivated by hydrolysis of the GTP bound to it to avoid continued stimulation of the Ras pathway. GTP hydrolysis is facilitated by an activating protein called that can accelerate inactivation of Ras a hundredfold.

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'Scary' new man-made epoch

DECLARING THAT WE NOW LIVE IN THE 'ANTHROPOCENE' WOULD REFLECT THE IMPACT OF ARTIFICIAL CHANGES TO THE EARTH'S CLIMATE, CHEMISTRY, LIFEFORMS AND THE ROCKS OF THE FUTURE, WRITES IAN JOHNSTON

A worldwide hunt for a "line in the rock" that shows the beginning of a new geological epoch defined by humanity's extraordinary impact on planet Earth is expected to get underway in the next few weeks. The idea that we are now living in the Anthropocene epoch has been gaining ground in recent years. The surge in global temperatures by an average of one degree Celsius in little over a century, the burning of vast amounts of fossil fuels, the extinction of many animal species, the widespread use of nitrogen fertilisers, the deluge of plastic rubbish and a number of other factors have all caused changes that will remain visible in rocks for millions of years.

Later this month, an expert working group — set up to investigate whether these changes are so significant that the 11,500-year-old Holocene epoch is now at an end — will present its latest findings to the 35TH International Geological Congress in South Africa. They then plan to search for what is known as a "golden spike" — a physical point in the geological record that shows where one epoch changed to another — which could win over any remaining doubters among the geology community. This would set in train a process that could see a formal declaration that we are living in the Anthropocene by the International Union of Geological Sciences in just two years.

Dr Colin Waters, secretary of the Anthropocene Working Group who will address the IGC, said, "The key thing to us is the scale of the changes that have happened. It's of comparable scale with what happened with the Holocene and the transition from the last ice age."

A key factor in defining the boundaries of the different chapters in earth's geological history has been climate as our planet moved from the ice age to warm periods. In the past, humans had "no input into that and all the changes have been because of that natural oscillation", said Dr Watson, a geologist at the British Geological Survey. "But really in the last century we have had such a huge impact that we're actually taking the planet away from that natural oscillation and changing the trend for global temperatures from what should have been a cooling trend to a warming trend," he said.

The mid-20th century has emerged as the favourite time for the beginning of the Anthropocene, partly because of the number of different indications that will be written into our planet. Radioactive particles from the open-air nuclear bomb blasts, which began in 1945, were scattered all over the planet. The same is true of smoke from the burning of fossil fuels, which increased dramatically after World War II. Discarded plastic, which is expected to last for thousands of years, and blooms of algae — caused by chemical fertilisers washed and blown into rivers, lakes and the sea — are already caught up in sediments that will make the rocks of the future. Pesticides have also left their own chemical signature.

Global warming has melted glaciers, enabling plants to grow and creating a sharp dividing line in the sediment, and raised the temperature and altered the acidity of the oceans. It is also thought the golden spike might be found in corals that have suffered widespread bleaching because of the warmer water. They have also been damaged by trawlers' nets and pollution.

In a paper in the journal Science earlier this year, Dr Waters and others said an age range of 1945 to 1964 had been proposed for the start of the Anthropocene. The working group's convener, Professor Jan Zalasiewicz, a palaeobiologist at Leicester University, said, "There's a majority of opinion on the working group to say the Anthropocene is real." However, there is still a debate about when it started and some experts believe it is premature to formally declare a new epoch.

Earth's city lights seen from space highlight the impact humans have on the planet.

"The feeling is that it would be better, most geologists would be more comfortable, if there was a 'golden spike', a physical reference point in the strata," Professor Zalasiewicz said. "We'll suggest (to the Congress) that we begin the process of looking around the world for a set of sections that could be sediments in lake beds, peat bogs, glaciers... where there are a set of signals to show the beginning of the Anthropocene. And then we'll choose one of these to say 'this is the reference point, this marks the beginning of the Anthropocene'."

THE INDEPENDENT