Topics

- LUCA
- Omega Centauri
- As thoughts become digitised, who will protect our neurorights?
- Mount Etna,
- Mains

By saurabh Pandey

THE HINDU

Target Mains -2024/25 -

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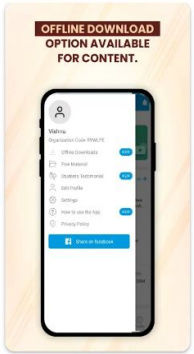

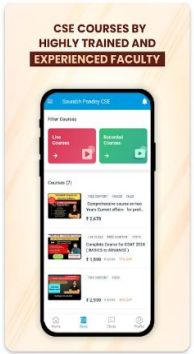

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BY SAURABH PANDEY SIR

Glimpses of LUCA, the life-form from which all other life descended

As mysteries go, a close second to the origin of life is how life-forms started to evolve. Researchers believe bacteria, archaea, and eukarya all originated from the last universal common ancestor. There is no fossil evidence of its existence, but the fact that modern genomes share so many features provides some clues

Sridhar Sivasubbu
Vinod Scaria

The origin of life on earth is one of the world's most enduring mysteries. There are a number of competing theories, but all of them lack conclusive proof. Nonetheless, scientists widely believe a combination of geological, climatic, and chemical processes gave rise to the building blocks of life.

In the 1920s, Alexander Oparin and J. B. S. Haldane independently proposed their origin theories – the first of their kind. In 1924 and 1929, Oparin and Haldane, respectively, suggested the first molecules making up the earliest life forms gradually self-organised from a "primordial soup" in a young earth's tempestuous, prebiotic environment. This idea is today called the Oparin-Haldane hypothesis.

Researchers have also conducted biochemistry experiments and found evidence to support this hypothesis. A particularly famous one was the Miller-Urey experiment in 1952, in which University of Chicago researchers Stanley Miller and Harold Urey showed that in the right conditions, inorganic compounds could give rise to complex organic compounds. Miller and Urey mixed methane, ammonia, and water, and when they applied a strong electric current – like a lightning strike might have – the mixture contained amino acids, the building blocks of proteins. They reported their discovery the very next year in the journal *Science*.

While we have evidence today that the earth's environment then may not have been much like what the experiment presumed to mimic, the very fact that amino acids could be created in a broth of inorganic molecules was groundbreaking.

Other researchers have proposed other theories about the origin of life. A particularly prominent one is that meteorites from space could have brought the building blocks of life, sustained by discoveries on the earth as well as out there. In August 2019, French and Italian scientists reported discovering extra-terrestrial organic material 3.3 billion years old, whereas Japan's Hayabusa 2 mission to the asteroid Ryugu indicated the presence of more than 20 amino acids there.

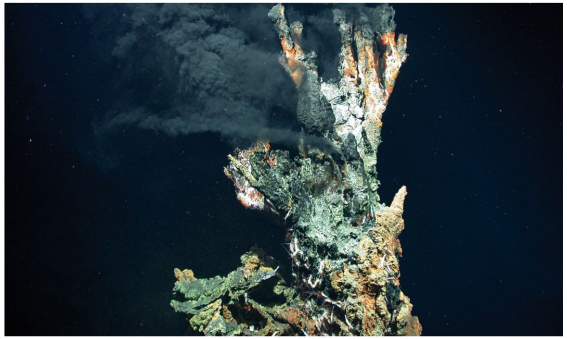
LUCA and the molecular clock

As mysteries go, a close second to the origin of life is how life-forms evolved to produce the rich diversity we see around us today. Researchers believe all three branches of life – bacteria, archaea, and eukarya – originated from a single cell, called the last universal common ancestor (LUCA). There is no fossil evidence to support the existence of LUCA, but the fact that modern genomes share so many features provides some insights. An important concept that allows scientists to reconstruct the 'tree of life' is the theory of the molecular clock. Molecular biologist Emile Zuckerkandl and biochemist Linus Pauling proposed it in the 1960s, and biologist Motoo Kimura subsequently improved it.

According to a simplified version of the theory, the rate at which mutations are added or removed from a population's genome is proportional to the rate of acquiring new mutations, which is constant. Later studies also found that the mutation rate varies between species. Using these two facts, researchers developed a way to estimate how much time could have passed between two evolutionary events.

To calibrate the molecular clock to a particular rate of mutations, researchers establish links between a genome and known events, such as the 'date' on which the first mammal evolved or the age of certain fossils. These links act like temporal benchmarks.

Thanks to the large number of genome sequences and fossils of various organisms, as well as the computing power available today, researchers routinely use the molecular clock to understand the evolution of various life-forms on earth through time.



The 'Candelabra' hydrothermal vent on the Mid-Atlantic Ridge, which is 3.3 km underwater. In the past, scientists have found evidence of ancient life forms in the precipitates around such vents. MARUM (CC BY 4.0)

> Scientists widely believe a combination of geological, climatic, and chemical processes gave rise to the building blocks of life

Which is older: LUCA or fossils?

In a recent paper in the journal *Nature Ecology and Evolution*, researchers at the University of Bristol and Exeter in the U.K. constructed a phylogenetic tree of 350 bacterial and 350 archaeal genomes. Then, using a molecular clock, the team estimated when LUCA could have originated: around 4.2 billion years ago, just 300 million years after the earth itself formed.

The team also reported that LUCA may have had a small genome, of some 2.5 million bases and encoding around 2,600 proteins, all just enough to help it survive in a unique environmental niche. The team also suggested the metabolites produced by LUCA – compounds produced as a result of its metabolism – could have created a 'secondary' ecosystem in which other microbes could have emerged.

Importantly, the origin of LUCA by 4.2 billion years significantly predates previous suggestions about the origin of life on earth. For context, researchers have found fossil records of the earliest life-forms in the Pilbara Craton in western Australia, one of the few places on the planet where archaean rocks are exposed aboveground and accessible. Studies of these fossils have suggested that life that lived on the rocks emerged around 3.4 billion years ago. The current study, on the other hand, pushes this date back by almost a billion years, almost on the heels of the birth of our planet itself.

The researchers also found some reasons to believe LUCA may have had genes responsible for immunity, suggesting it had to fight off viruses.

Taken together, the findings are tremendously significant, not just for understanding how life emerged and evolved on the earth: they also speak to our ability to look for similar forms of life across the universe. The insights into evolution they provide will also give a significant fillip to human ambitions to engineer synthetic organisms for various industrial, chemical, and biological processes on the earth, as well as to create or moderate ecosystems on other planets in the future.

(The authors are senior consultants at Vishwanath Cancer Care Foundation, and adjunct professors at IIT Kanpur and Dr. D.Y. Patil Vidyapeeth, and distinguished visitors at Ashoka University.)

THE GIST

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LUCA

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-

QUESTION CORNER

The ABO classification system

How are blood groups differentiated?

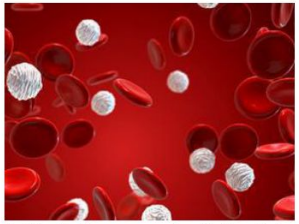
A: Human blood consists of red blood corpuscles as a constituent, which give it its red colour. On the surfaces of these red cells are present one or both of two types of antigens (proteins), designated A and B. Other than these, two antibodies, designated as antibody-A and antibody-B, present in the serum are also involved in the classification of human blood. (Serum, a constituent of blood, is a straw-coloured liquid that can be seen after removing all the other blood cells from a sample.)

Antibodies have the property of clumping red cells. When antigen-A is present on the red cells, the serum contains only antibody-B, which will clump red cells with antigen-B on their surface. Then the blood is classified as group A.

When antigen-B is present on the red cells, the serum contains only antibody-A, which clumps red cells with antigen-A. As a result, the blood is classified as group B.

In some people, both antigens A and B are present on all the red cells, so their serum does not contain any of the antibodies. They belong to the AB group. Their blood cells don't clump whether they receive A group or B group blood. That is, A and B are compatible with the AB group.

The fourth type, O, has neither of the antigens on its red cells but has both antibodies in the serum.



Red blood cells carry oxygen from the lungs to the body's tissues. White cells monitor for potential threats and respond to infections. GETTY IMAGES

In order to keep red cells from clumping, those with A group blood can receive only A and O group blood, and those with B group blood can only receive B and O group blood. But the AB group can receive blood from any of the groups. Thus, it is called the universal recipient. Similarly, those with O-group blood are universal donors.

This system of classification is called the ABO system. Blood groups are also classified by the Rhesus system (Rh). The Rh factor leads to one type in which the Rh factor is present (Rhesus positive) and another in which it is not (Rhesus negative).

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ABO Blood group

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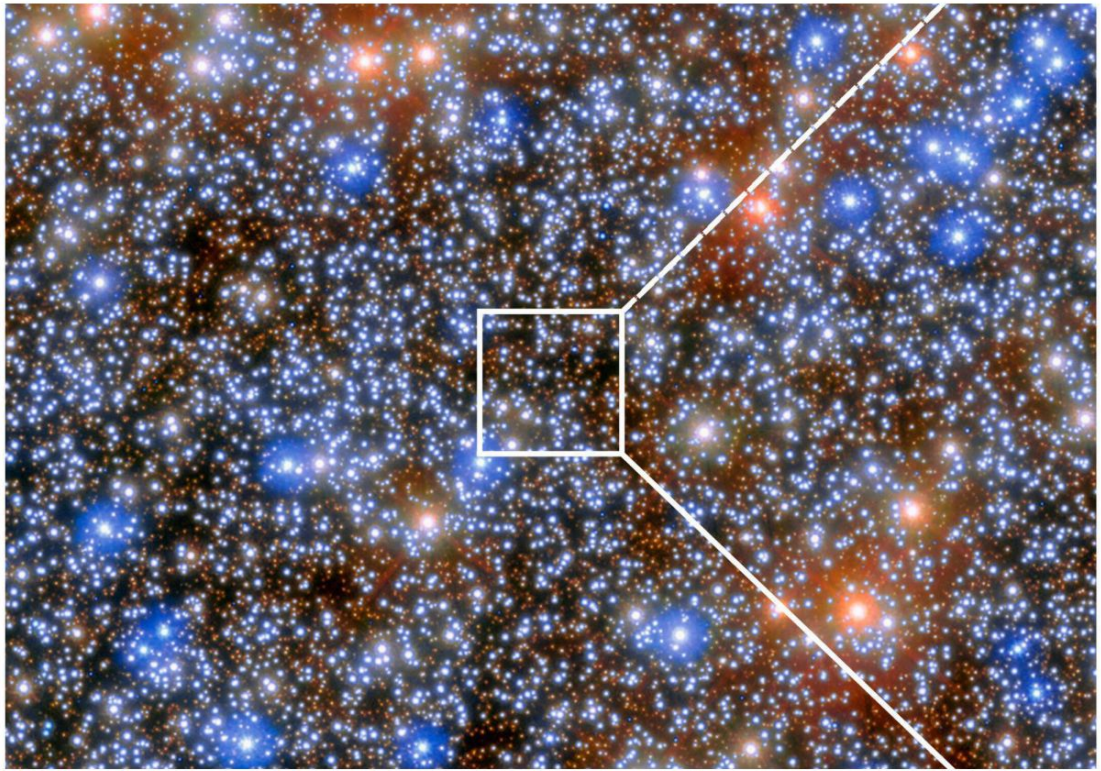
BIG SHOT



This image captured by the Hubble Telescope, and released last week, shows the star cluster Omega Centauri. One of the enduring mysteries of the cosmos has been the strange absence of medium-sized black holes between the very small and very big extremes. On July 10, astronomers said they had found the best evidence yet of the existence of one of these "missing link" black holes, located within the square in this image. THE HINDU

Omega Centauri

- Omega Centauri is a globular cluster in the constellation of Centaurus that was first identified as a non-stellar object by Edmond Halley in 1677.
- Located at a distance of 17,090 light-years (5,240 parsecs), it is the largest-known globular cluster in the Milky Way at a diameter of roughly 150 light-years.

- It is estimated to contain approximately 10 million stars, with a total mass of 4 million solar masses, making it the most massive known globular cluster in the Milky Way.
- Omega Centauri is very different from most other galactic globular clusters to the extent that it is thought to have originated as the core remnant of a disrupted dwarf galaxy

ISTOCKPHOTO

As thoughts become digitised, who will protect our neurorights?

The right to safeguard one's mental statuses and thoughts from surveillance are precious fundamental rights but technological advancements may cheapen them in some contexts. The digitisation of neuro-data raises great opportunities as well as concerns

Krishna Ravi Srinivas

Neurotechnologies have come a long way since the development of electroencephalography (EEG). Invented a hundred years ago, the EEG has had a significant impact on our knowledge of the human brain and various treatments of brain disorders. Many researchers expect that soon there will be wearable EEGs that could directly assist human cognitive functions. Elon Musk's Neuralink has also kindled hope about using brain-computer links to help physically impaired people restore some lost function.

The 1990s was popularly known as the 'decade of the brain' as research on neuroscience and neurotechnologies received a big boost from various governments. The European Union's 'Human Brain Project' and the subsequent 'BRAIN' initiative were some of the major initiatives. Today, research in these areas is also supported by private companies, especially in the life sciences sector, and is also more extensive than before, including brain pathophysiology, deep-brain stimulation, and neuromarketing.

Neurotechnologies range from Magnetic Resonance Imaging (MRI) that health workers routinely use to the rarer Brain-Computer Interfaces (BCI). In the last few decades, the type of sensory information these technologies have become able to record has expanded considerably. Sophisticated biosensors that can record a person's physiological activities, behavioural responses, and emotions are no longer fiction.

How is neurodata valuable?

The digitisation of neuro-data raises great opportunities as well as concerns. Not all neurotech users are care-seekers, as smartwatches, apps, and 'embeddables' are integrated more into day-to-day activities. After users' devices collect these data, there will be an option to transmit them to healthcare providers and private companies, who will have an incentive to integrate them in a larger knowledge framework to offer, say, real-time tracking of health indicators and personalised suggestions.

This also increases the risk of surveillance – from multiple sources for different purposes. For example, a manager can monitor the movements and mental states of an employee to track alertness, fatigue, and other indicators. This data can be shared with various state and non-state actors, including other employers and physicians. This can be a boon but can also help these actors exert more control over individuals' behaviour. Digitised health data also has great commercial value in advertising and marketing (including neuromarketing).

Surging investment by the private sector in neurotechnologies has also raised concerns about their governance and regulation. There are unique ethical concerns here because these neurotechnologies can probe individuals' physiological and psychological states.

Ultimately the right to think freely and mental privacy can be imperilled. In the garb of monitoring and assessing efficiency, different entities may be able to track and monitor the movements and behaviour of diverse sections of the population, individually and collectively.

What is neuroethics?

The right to think freely and the right to safeguard one's mental statuses and thoughts from surveillance and monitoring are precious fundamental rights but technological advancements may cheapen them in some contexts. Experts strive to adopt ethical standards such that humankind benefits most from the use of neurotechnologies while minimising harm. This is the principal concern of neuroethics. It has emerged as an important field of research and action in the last two decades.

Various institutions and funding agencies have tried to identify and enforce ethical principles for neuro-X research and development. In 2015, the U.S. Presidential Commission on Bioethics published a two-volume report entitled 'Gray Matters'. It focused its analysis on three "controversial topics that illustrate the ethical tensions and societal implications of advancing neuroscience and technology: cognitive enhancement, consent capacity, and neuroscience and the legal system".

In 2019, the Organisation for Economic Co-operation and Development (OECD) recommended nine principles to ensure the ethical development and use of neurotechnologies based on the concept of responsible innovation. Two of them were "safeguarding personal brain data" and "anticipating and monitoring potential unintended use and/or misuse".

UNESCO published a paper in 2022 in which it said: "As [neurotech] actively interacts with, and alters the human brain, this technology also raises issues of human identity, freedom of thought, autonomy, privacy and flourishing. The risk of unauthorised access to the sensitive information stored in the brain is a case in point. Already today, neural data is increasingly sought after for commercial purposes, such as digital phenotyping, emotional information, neurogaming and neuromarketing. Neuromarketing units have been developed by industry to evaluate, and even alter consumer preferences – raising serious concerns about mental privacy. These risks can also pose serious problems when dealing with non-democratic governments."

In 2023, researchers at the Institute of Neuroethics in Atlanta in the U.S. reviewed several guideline documents and ethical frameworks published by institutions, think-tanks, governments, etc. worldwide. Among other things, they wrote, these texts ask researchers to "proactively consider and communicate potential implications of scientific advances" and "to improve and meaningfully incorporate ethics in training and the conduct of research".

What are your neurorights?

Internationally accepted human rights principles and the Universal Declaration of Human Rights provide some inkling as to individuals' neurorights. But the extent to which they are enforceable depends on the laws in each jurisdiction.

In 2021, Chile became the first country to legally recognise its citizens' neurorights when its Senate agreed to amend the constitution. As a result, according to a 2022 article in the journal *AI & Society*, technological developments in the country must "respect people's physical and mental integrity" and its laws should "protect brain activity and information related to it". In the U.S., Colorado enacted a law in April 2024 to protect individuals' neurological privacy while California is deliberating a similar instrument.

But some legal scholars have said the current rights framework is adequate and that laws specific to neurorights may be limited in scope. For example, in a paper published last year in the journal *AJOB Neuroscience*, Pennsylvania State University scholars discussed whether neuro-privacy is meaningfully separate from data privacy.

An important challenge to developing suitable neuroethical standards is that the underlying technologies are evolving rapidly. The contexts in which people use these technologies are also diverse, beset by disparate expectations and cultural norms. For now, UNESCO has appointed an expert group to develop the "first global framework on the ethics of neurotechnology", expected to be adopted by the end of 2025. While this framework is not likely to result in a treaty or a binding convention, it could have a major impact on governments' guidance documents and policy narratives. Apart from UNESCO, various intergovernmental organisations are also actively working on the human rights dimension of neurotechnologies.

Krishna Ravi Srinivas is adjunct professor of law, NALSAR University of Law Hyderabad; consultant, RIS, New Delhi; and associate faculty fellow, CeRAI, IIT Madras.

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Vantage point

A person watches a cloud and lava erupting over the Mount Etna volcano in Sicily on Monday. Sicily's Catania airport began gradually reopening for flights on July 5, after they were temporarily suspended following an eruption from Europe's largest active volcano. AFP

Mount Etna,

- Mount Etna, active volcano on the east coast of Sicily.
- Like other active volcanoes, it varies in height, increasing from deposition during eruptions and decreasing from the periodic collapse of the crater's rim.
- Mount Etna is the highest active volcano in Europe, its topmost elevation being about 10,900 feet


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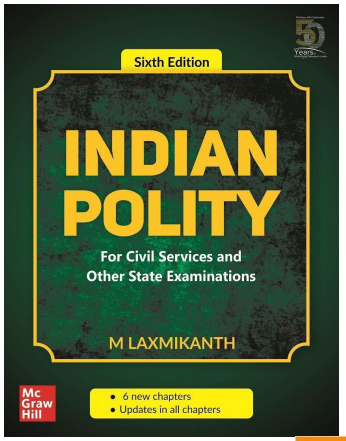

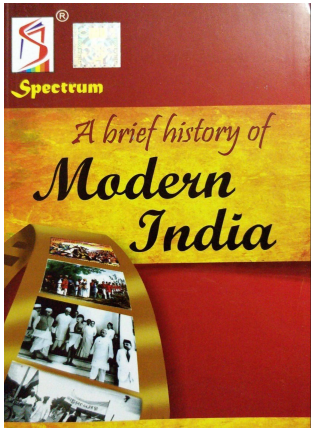

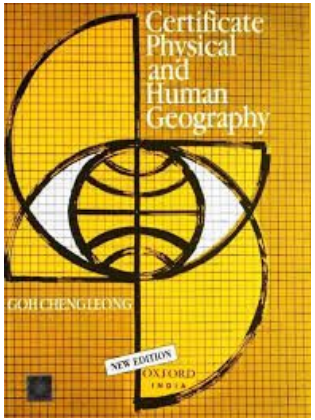

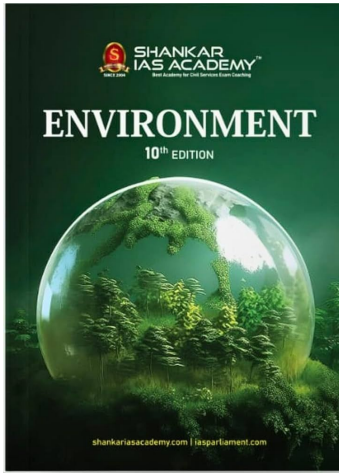

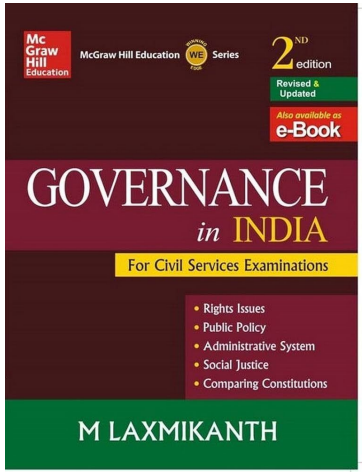

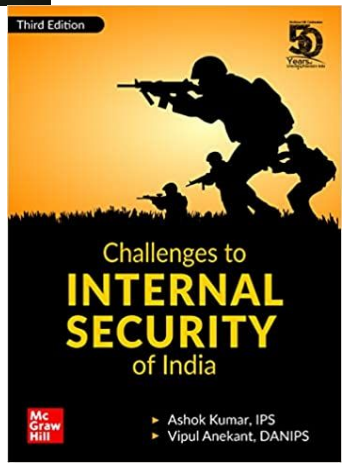

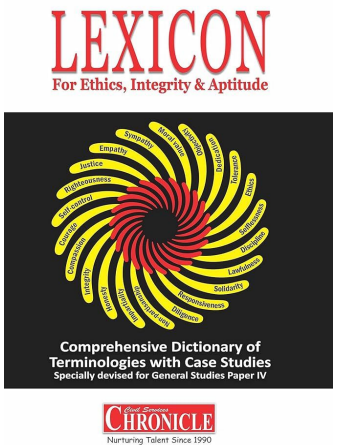

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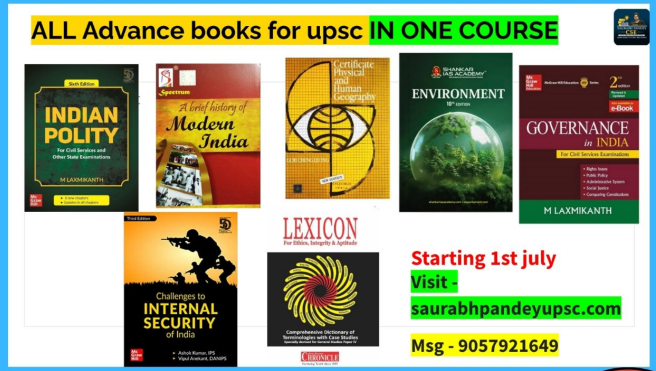

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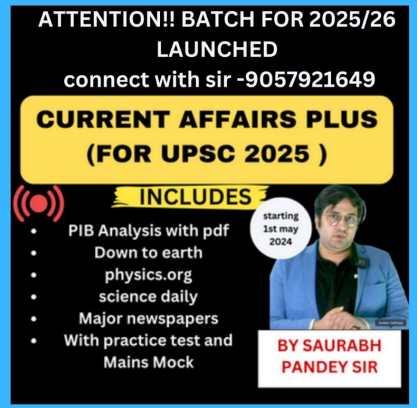

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