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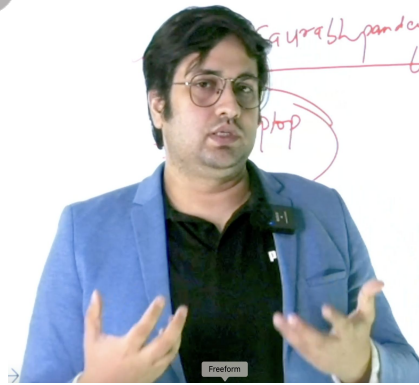


By saurabh Pandey

THE HINDU

Pamban bridge an engineering marvel: PM

Modi inaugurates India's first vertical lift sea bridge built over the Palk Strait at a cost of ₹531 crore, and flags off new train services; he says the bridge will have positive effects on the lives of lakhs of people; mega infrastructure projects are being implemented at a faster pace, the PM says, adding that a dedicated freight corridor is also being readied

S. Sundar
RAMESWARAM

Prime Minister Narendra Modi on Sunday inaugurated the new Pamban railway bridge, which connects the Rameswaram island off the Tamil Nadu coast with Ramanathapuram on the mainland.

Constructed by Rail Vikas Nigam Ltd. at a cost of ₹531 crore, the 2.07-km bridge over the Palk Strait features a 72.5-metre vertical lift span that can be raised to a height of 17 metres, facilitating smooth ship movement underneath while improving rail connectivity.

The Prime Minister also flagged off new train services between Rameswaram and Tambaram, Chennai, laid the foundation stone for the four-lane work on the section of National Highway no. 40 from Walajahpet, near Chennai, in Tamil Nadu to the Andhra Pradesh boundary, and dedicated three other four-lane highway projects in Tamil Nadu.

The Prime Minister described the new bridge, India's first vertical lift sea bridge, as an "engineering wonder" that "brought together technology and tradition". With the completion of the bridge, a long-pending demand of the people had been fulfilled, he said. "The Pamban rail bridge will support both ease of business and ease of travel. It will have positive effects on the lives of lakhs of people," he said.

Trade and tourism

The structure, which has replaced the now-defunct British-era old Pamban railway bridge, is expected to enhance connectivity, while benefiting trade and tourism in Tamil Nadu.

With the Palk Strait being a highly corrosive environment, the bridge has been constructed with stainless steel reinforcement and features high-grade protective paint, the government said. The new bridge is three metres higher than the existing one. Stating that the economy of the country had doubled in the past 10 years, the Prime Minister credited the faster growth to the availability of modern infrastructure. "We have increased investment in development of rail connectivity, roads, ports, airports, electricity and piped water supply, and gas supply by around six times," Mr. Modi said.

He further said that mega infrastructure projects are being implemented at a faster pace across the country. He said the Chenab rail bridge, one of the highest rail bridges in the world, has been constructed in Jammu and Kashmir in the north; the Atal Sethu in Mumbai, the longest sea bridge, has come up in the Western part of the country; the Bogibeel bridge, the longest rail-cum-road bridge, has been built over the Brahmaputra in Assam in the east; and the Pamban bridge with the vertical lift span has been commissioned in the south.

The Prime Minister added that a dedicated freight corridor was also being readied while work on the bullet train project was under way at fast pace. Modern trains like Vande Bharat, Amrit Bharat and Namo Bharat were making the rail network more advanced.

Connectivity in States

The path to a developed nation had become stronger with better regional connectivity, he said, adding every State in the country was getting better connectivity. Earlier, the Prime Minister also offered prayers at Sri Ramanathaswamy temple on the auspicious day of Rama Navami.

Railway Minister Ashwini Vaishnav and Minister of State for Information and Broadcasting, L. Murugan, also spoke.

Tamil Nadu Governor R.N. Ravi; State Ministers Thangam Thennarasu and R.S. Rajakannappan; MPs K. Navas Kani and R. Dharmar; and senior railway officials were present.

'HABIT OF CRYING'
» PAGE 4

Milestone structure: Prime Minister Narendra Modi waves as an Indian Coast Guard ship passes under the new Pamban bridge at Rameswaram in Ramanathapuram, Tamil Nadu on Sunday. ANI

'Teething trouble' in bridge lift span causes concern

RAMESWARAM

The vertical lift span of the new Pamban Rail Bridge, inaugurated by Prime Minister Narendra Modi on Sunday, caused concern when the centre span became stuck for some time as it was being lowered. A railway official dismissed the issue as a minor teething problem. "Seven trains, including the inaugural run of the Rameswaram-Tambaram train, have run over the new bridge today," the official stated. The incident with the lift span on the inaugural day proved embarrassing for officials. » PAGE 4

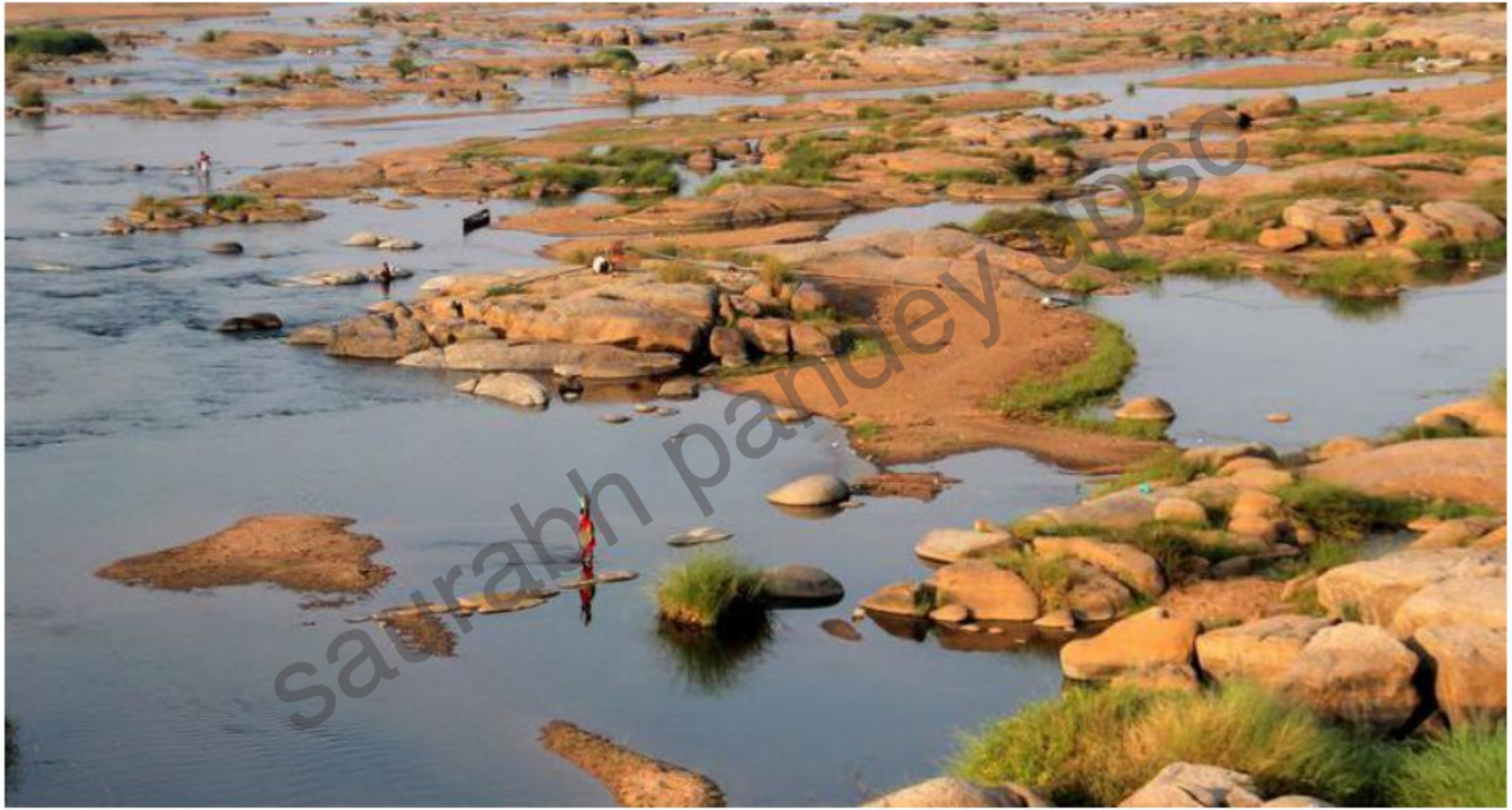
The New Pamban Bridge

- **The New Pamban Bridge is over 2 kilometres long and spans across the Palk Strait in Tamil Nadu, connecting Rameswaram island with Mandapam on the mainland.**
- **the New Pamban Bridge - the country's first vertical-lift sea bridge - in Tamil Nadu .**
- **The New Pamban Bridge is 2.07 kilometres long and spans across the Palk Strait in Tamil Nadu.**
- **It features a 72.5-metre navigational span that can be vertically lifted to 17 metres, allowing ships to pass below safely.**
-

- **The substructure can support two railway tracks, though it currently operates a single line. It connects Pamban (Rameswaram) Island with Mandapam on the mainland.**
- **The bridge is cleared for train speeds up to 80 kmph and is built to handle increased rail traffic and heavier loads.**
- **Constructed by Rail Vikas Nigam Limited (RVNL), a Navratna PSU under the Ministry of Railways.**
- **The original Pamban Bridge, built in 1914 by British engineers, used a manually operated Scherzer's span (a type of rolling lift bridge).**


saurabh pandey upsc

Daily battle



A long trek for water: A woman collects water from the Tel river bed near Sonpur in west Odisha. Every summer, people are faced with a familiar situation in this part of the State, with most water sources going dry. BISWARANJAN ROUT

Tel River

The Tel river flows in Nabarangpur, Kalahandi, Balangir, Boudh Sonepur District of Odisha, India. Tel is an important tributary of the Mahanadi.

Kaliyattam festival

The Kaliyattam festival is an annual Theyyam festival held in the temples in Kerala's Malabar region.

West Africa chimps are losing their culture, in another human legacy

In new research, scientists reported four dialects that male wild chimpanzees use in the Taï National Park to find mates. But after documenting the chimpanzees' lives for more than a generation, the scientists also reported these apes are 'forgetting' parts of the dialect thanks to human influences

Madhurima Pattanayak

Culture is what we learn from others and pass on to successive generations by practising it over and over. Scientists have found cultural traditions among humans as well as animals, the latter in the way they forage, socialise, use tools, care for themselves, and mate.

Among these traditions, the characteristic patterns of behaviour that involve communication are called dialects.

In new research published in the journal *Cell*, scientists with the Taï Chimpanzee Project in West Africa reported four dialects that male wild chimpanzees (*Pan troglodytes verus*) use in the Taï National Park to find mates to copulate with.

Unfortunately, after documenting the chimpanzees' lives for more than a generation, the scientists also reported these apes are 'forgetting' parts of the dialect thanks to human influences.

"Cultural behaviours are crucial for survival," Catherine Crockford, a scientist leading the project and researcher at the Max Planck Institute for Evolutionary Anthropology, Germany, and ISC Marc Jeannerod, France, said.

"Illegal hunting or logging may not only be killing individual chimpanzees but also destroying their cultures, which could threaten the survival of the remaining chimpanzees." Chimpanzees are also poached for use as pets or for bushmeat.

A female chimpanzee grooms an adult male in Loango National Park, Gabon. West African chimpanzees are a subspecies found in western Africa, including Côte d'Ivoire, Liberia, Guinea-Bissau, and Ghana. AFP

'Secretly ask females for sex'

Researchers once believed culture separated humans from other animals. But in the last seven decades, research has revealed cultural practices in many animals. Even so, community-specific dialects in non-human primates such as chimpanzees, orangutans, and bonobos have been rare.

The scientists with the Taï Chimpanzee Project reported four distinct types of dialects that male West Africa chimpanzees used to find mates: heel-kick, knuckle-knock, leaf-clip, and branch-shake.

In a heel-kick, the chimpanzees lifted their feet and kicked against a hard surface to make noise. The knuckle-knock involved repeatedly, but somewhat quietly, knocking their knuckles against hard surfaces.

Likewise, in the leaf-clip, chimpanzees bite a leaf and strip it into pieces without eating it, creating a ripping sound. The branch-shake is self-explanatory.

"It is amusing to watch how young subordinate males try to secretly ask females for sex without the dominant males knowing," Ms. Crockford said. "This is the main function of these more subtle gestures".

The team documented heel-kicks among the North, South, Northeast, and East chimpanzee communities; knuckle-knocking in the Northeast community; and leaf-clip and branch-shake among the North, South, and Northeast communities.

A dangerous demographic shift

The knuckle-knock gesture is restricted to the Northeast community. It was previously among adult males of the North community as well, but since 1999, it has suffered significant population loss.

The problem became so bad that between 2004 and 2011, the North group didn't have two adult males existing at the same time. Put another way, any adult male didn't have to compete with other adult males and thus had no use for the knuckle-knock dialect.

Researchers understand that demography plays a crucial role in shaping culture and keeping it alive across generations. A systematic data collection effort concluded in 2019 that no members of the North group had used knuckle-knocking in 20 years.

Significant changes in a population, in this case the near-complete loss of an entire demographic (adult males), can thus have a long-lasting impact on the preservation or loss of cultural traditions. Restoring them isn't easy. For example, with the help of ecologists and the Côte d'Ivoire government, the North group has had four adult males since 2016 but the knuckle-knock gesture hasn't reemerged among them.

> Cultures emerge over generations. Cultural behaviours – such as the use of specialised toolkits, nut-cracking with stone hammers or digging out underground bee nests with different-sized sticks – are crucial for survival

"While establishing absence is challenging, our observations demonstrate a shift-away from knuckle-knock gesture usage," the researchers wrote in their paper.

Their own language

To further understand the origins of the chimpanzees' culture, the team compared mating solicitation gestures involving the use of tools between Taï chimpanzees and Sonso chimpanzees at the Budongo Forest Reserve in Uganda.

Whereas theTaï chimpanzees preferred the knuckle-knock, the Sonso chimpanzees used the object-slap: moving the arm from the shoulder to slap an object with an open palm.

Likewise, the Sonso chimpanzees frequently used leaf-clipping to express their interest in mating but the Taï chimpanzees didn't.

Chimpanzees have genetically inherited certain gestures across subspecies but individuals have been known to express only a subset. But within a closed group, multiple individuals use the same set of gestures over time and can even differ from the gestures used in a neighbouring group.

The Budongo Forest Reserve is about 4,160 km from the habitat of the Taï chimpanzees of Côte d'Ivoire. "We can rule out that the different signals used in each community have a genetic origin. Given they live in a similar forest environment, we can also rule out environmental influences on culture," Ms. Crockford said.

"This leaves us with the most likely option: that different signals in neighbouring communities arise through social learning."

Bringing conservation to culture

"Cultures emerge over generations. Cultural behaviours – such as the use of specialised toolkits, nut-cracking with stone hammers or digging out underground bee nests with different-sized sticks – are crucial for survival," Ms. Crockford said.

According to her, the preservation of animal culture is a relatively new concept. The International Union for the Conservation of Nature (IUCN) recently included it among the metrics it uses to prepare its 'Red List of Endangered Species.' The message seems to be that chimpanzees should be protected as well as their cultures.

But the IUCN's job isn't done. In a November 2024 paper in *Science*, researchers reported that the deaths of a species' elders are disproportionately more harmful than the deaths of other members.

This is because the elders possess important cultural knowledge: where to find the best watering holes in particular weather, the ways to respond to different predators, caring for the young when the parents can't, and so on.

One of the authors of this study wrote then that the "loss of old individuals is not yet recognised by the IUCN as a means of listing threatened species."

(Madhurima Pattanayak is a freelance science writer and journalist based in Kolkata. madhurima.pattanayak@gmail.com)

THE GIST

- Cultural behaviours are crucial for survival. Illegal hunting or logging may not only be killing chimpanzees but also destroying their cultures, which could threaten the survival of the remaining chimpanzees
- Researchers once believed culture separated humans from other animals. But research has revealed cultural practices in many animals. Even so, community-specific dialects in non-human primates such as chimpanzees, orangutans, and bonobos have been rare
- A study concluded in 2019 that no members of a chimpanzee group being studied had used knuckle-knocking — a typical mating behaviour in 20 years. This was due to the near-complete loss of adult males in the community

Culture Behaviour in Animals

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- **The problem became so bad that between 2004 and 2011, the North group didn't have two adult males existing at the same time**

Facts

- **Taï National Park is a national park in Ivory Coast that contains one of the last areas of primary rainforest in West Africa. It was inscribed as a World Heritage Site in 1982 due to the diversity of its flora and fauna.**
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WHAT IS IT?

Hadean protocrust: hot and hellish

The Hindu Bureau

The Hadean protocrust is the name for the earth's crust — its outermost layer — when it first formed. The 'Hadean' prefix refers to the planet's first geologic aeon. At this time, within 200 million years of its genesis, the earth's surface was partially molten and almost constantly bombarded by rocks from space. As many volcanoes also raged, the surface was very hot and hellish.

As parts of the magma ocean cooled, the first pieces of the crust began to take shape. It was still somewhat flaky, with some parts sloughing off and new parts solidifying. The thicker parts of the crust slowly formed the first continents, which moved like plates on the asthenospheric mantle, a layer of hot, gooey rock going 400 km down.

The plates soon began drifting into each other, sometimes sliding over, sometimes diving under. Such plate tectonics have left unique chemical signatures in the crust over millennia. In fact, scientists have understood the history of plate tectonics by studying these signatures.

A representative illustration of the earth's Hadean protocrust as it took shape. IMAGE CREATED WITH CHATGPT

A new study by an international team of researchers led by Macquarie University in Australia has now called this assumption into question. The researchers have reported that the signatures scientists have associated with plate tectonics actually existed in the Hadean protocrust, before the plates began to subduct, calling an important tenet of geology into question.

The study, which used a combination of models and lab studies, will have to be validated by independent research.

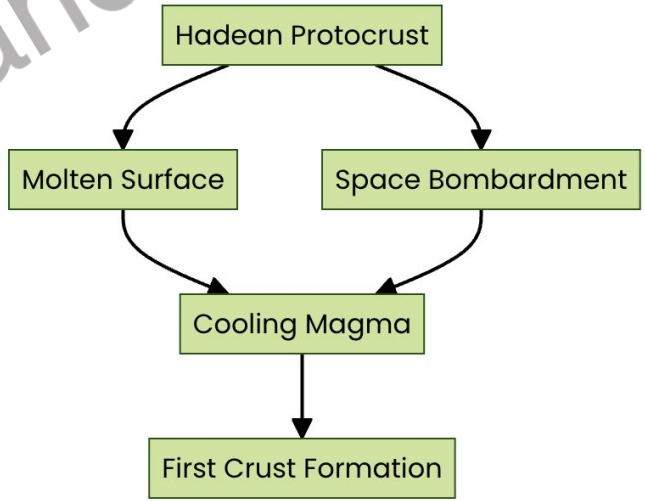
For feedback and suggestions for 'Science', please write to **science@thehindu.co.in** with the subject 'Daily page'

What is the Hadean Protocrust?

Definition: The Hadean protocrust is the Earth's outermost layer during its first 200 million years.

Origin of Term: Named after Hades, reflecting the era's hellish conditions.

Conceptual Diagram:



Understanding the Hadean Eon

Geological Start: Marks the beginning of Earth's geological history.
Environment: Characterized by a molten surface and frequent volcanic activity.

The Hellish Environment of Early Earth

Molten Surface: Rivers of lava and glowing hot ground.
Space Bombardment: Frequent impacts from space debris shaped the early crust.

The Birth of the First Crust

Cooling Process: Uneven cooling of the magma ocean led to crust formation.
Continental Formation: Thicker crust parts coalesced into the first continents.

The Dynamics of Plate Tectonics

Crustal Movement: Tectonic plates drifted, slid, and interacted.
Asthenospheric Mantle: Acted as a conveyor belt for plate movement.

Chemical Signatures in the Crust

Plate Tectonics Chemistry: Chemical signatures reveal Earth's geological history.

New Research Challenging Old Assumptions

Macquarie University Findings: Suggests chemical signatures existed in the Hadean protocrust, challenging previous geological assumptions.

Conclusion

The Hadean protocrust represents a chaotic yet transformative period in Earth's history, offering insights into the planet's origins and geological processes.

BIG SHOT

Scientists perform a necropsy on a baby mammoth at the North-Eastern Federal University in Yakutsk, Russia, on March 27. The carcass was dug up in 2024 in icy Yakutia. It weighs 180 kg, is 120 cm tall and 200 cm long. They found it lived and died more than 130,000 years ago after analysing the permafrost where she was found. AFP

Yakutsk

- Yakutsk is a Russian port city on the Lena River, in east Siberia. It's home to the Mammoth Museum, with millennia-old fossils of woolly mammoths.
- The Melnikov Permafrost Institute Underground Laboratory has a tunnel showcasing fossils, including a mammoth calf, in below-freezing temperatures.

Can the U.S. President serve a third term?

What does 22nd Amendment to the U.S. Constitution state? How is U.S. President Donald Trump trying to circumvent the 22nd Amendment and serve one more term as President? Are there circumstances through which the U.S. Speaker could become U.S. President? What are the rules in other nations?

EXPLAINER

Kartikey Singh

The story so far:

On March 30, the 78-year-old U.S. President Donald Trump said he's "not joking" about serving a third term in the White House. He further claimed that a legal loophole could make it possible.

Does the U.S. Constitution allow it?

The 22nd Amendment to the U.S. Constitution, ratified on February 27, 1951, limits U.S. Presidents to two elected terms. It was brought in response to Franklin D. Roosevelt's unprecedented 'four-term' Presidency (1933-1945), which broke the 'two-term' unwritten precedent set by the nation's first President, George Washington, who voluntarily declined a third term in 1796.

The Amendment prohibits anyone from being elected President more than twice, and if someone has served as President for more than two years of another's term (for example, a Vice President who became President due to the President's death or resignation), they can only be elected once. Thus, effectively, the maximum U.S. Presidential tenure can be 10 years (two years as a successor plus two full terms). For Mr. Trump, elected in 2016 and 2024, the 22nd Amendment unequivocally bars a third term, due to his two elected tenures (2017-2021 and 2025-2029), regardless of their 'non-consecutive' nature.

What is the 'VP loophole'?

Despite the 22nd Amendment's clarity, Mr. Trump has suggested ways to circumvent it. One idea he proposed involves J.D. Vance running for President in 2028 with Mr. Trump as Vice President (VP). If elected, Mr. Vance would resign, allowing Trump to assume the Presidency. However, the 12th Amendment blocks this strategy, stating: "No person constitutionally ineligible to the office of President shall be eligible to that of Vice-President of the United States." Since the 22nd Amendment bars Mr. Trump from another term, he cannot serve as VP either.

New rules: A protest against the policies of U.S. President Donald Trump in California, on April 5. AFP

While the VP route is blocked, another theoretical path exists through 'succession', as explained by Professor Bruce G. Peabody in his paper. The 22nd Amendment prohibits a person from being "elected" to the Presidency more than twice but does not bar "serving" beyond two terms. In other words, a twice-elected President could ascend to the Oval Office via the line of succession, such as by becoming Speaker of the House, who is elected by members of the House and need not himself be a member of Congress, if the President and VP become unavailable.

A third pathway – repealing the 22nd Amendment – is highly unlikely. Under Article V, this requires either a two-thirds vote in both the House and the Senate or a 'constitutional convention'– a process never used – called for by two-thirds (34) of State legislatures, followed by ratification by three-fourths (38) of the 50 States. Given the current U.S. political landscape, the likelihood of Mr. Trump securing a constitutional amendment, which has not been done in the past 33 years, is virtually non-existent.

Which world leaders have extended their tenure?

Leaders all over the world have skilfully extended their rule by reshaping constitutional limits. For instance, Vladimir Putin, after two terms as Russia's President (2000-2008), hit the 'consecutive' two-term limit under Article 81(3) of the 1993 Constitution. To circumvent this limit, he then became Prime Minister (2008-2012) as his ally Dmitry Medvedev took the Presidency and extended the Presidential term from four to six years. Returning as President in 2012 and 2018, Mr. Putin, with a 2020 amendment backed by a loyal Duma and judiciary, reset his term count, potentially holding power until 2036.

Türkiye's Recep Tayyip Erdogan, Prime Minister (2003-2014), turned President, axed term limits via a 2017 referendum, and reshaped Türkiye's system into a Presidential one. Similarly, China's Xi Jinping eliminated the two-term cap in 2018. This change allowed Mr. Xi to rule indefinitely, cementing his hold over the party and the State.

Yet, some leaders thrive without rewriting the rules. In Germany, where chancellors face no 'term limits' but need 'Parliamentary support', Angela Merkel ruled for 16 years. Similarly, Prime Ministers in Canada and Britain, unbound by fixed terms, can lead indefinitely, sustained by 'party confidence'.

Why doesn't India have term limits?

Unlike the U.S. Presidential framework, India's Parliamentary system imposes no term limits on its Prime Minister, as tenure depends on retaining the Lok Sabha's confidence (Article 75(3)). This design ensures 'voter sovereignty', 'democratic flexibility', and 'parliamentary accountability', allowing leaders who sustain public trust to serve extended periods. For instance, current Prime Minister Narendra Modi could serve 15 years by 2029. However, the system also includes checks like the "no-confidence" motion, which has historically ended tenures – such as those of V.P. Singh (1990), H.D. Deve Gowda (1997) and Atal Bihari Vajpayee (1999). Moreover, regular elections, coalition dynamics, floor debates, judicial oversight, and a free press ensure a robust democratic balance.

Kartikey Singh is a final year student at RGNUL, Patiala, Punjab.

THE GIST

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Topic → Can Donald Trump Serve a Third Term?

Introduction

- The possibility of Donald Trump serving a third term has sparked debate and curiosity.
- The 22nd Amendment is a significant barrier to this idea.
- Let's explore the legal framework and its implications

The 22nd Amendment: A Constitutional Barrier

- Ratified on February 27, 1951, it limits U.S. Presidents to two elected terms.
- A response to Franklin D. Roosevelt's four-term presidency.
- Ensures a rotation of leadership and upholds democratic principles.

The VP Loophole: A Misguided Strategy?

- Trump suggested a strategy involving J.D. Vance running for President with him as VP.
- The 12th Amendment states that anyone ineligible for the presidency cannot serve as VP.
- This makes Trump's proposal unfeasible

Alternative Paths to the Presidency

- Other theoretical paths include ascending through the line of succession.
- A former president could become President again if they assume a role like Speaker of the House.
- Repealing the 22nd Amendment is highly improbable due to political complexities

Global Perspectives: Leaders Who Extended Their Tenure

- Some leaders have extended their rule by reshaping constitutional limits.
- Vladimir Putin, Recep Tayyip Erdogan, and Xi Jinping have manipulated frameworks to extend power.

The Case of Leaders Without Term Limits

Leaders like Angela Merkel and Prime Ministers in Canada and Britain serve without formal term limits.
Their tenure depends on parliamentary support and confidence.

Why India Lacks Term Limits for Prime Ministers

- India's parliamentary system imposes no term limits on its Prime Minister.
- Tenure depends on retaining the confidence of the Lok Sabha.
- Checks like the “no-confidence” motion ensure accountability

Conclusion

- Trump's aspirations for a third term face significant legal barriers.
- The U.S. Constitution is designed to prevent prolonged power, ensuring a healthy democratic process.

Why change track to hydrogen?

Lalith Trivedi

Indian Railways, one of the world's largest rail networks, is on the verge of a historic milestone: near 100% electrification of its vast track system. This ambitious transition underscores a strategic commitment to modernisation and decarbonisation. However, in this electrified landscape, does investing in hydrogen-powered locomotives align with rational decision-making?

A closer examination suggests otherwise.

Practical option: Electrification will stay the most efficient, economically viable and sustainable path forward.

Pros of electrification

The electrification of Indian Railways is a multi-year, multi-billion-dollar endeavour, aimed at reducing carbon emissions and fossil-fuel dependence. Today, electric trains dominate the network, supported by a grid that is increasingly powered by renewable sources like solar and wind. The government cites this as a cornerstone of its climate strategy, projecting substantial cuts in greenhouse gas emissions.

More importantly, the electrification has delivered tangible economic benefits. It has significantly lowered traction costs, compared with diesel-powered operations, improving efficiency while reducing operational expenses. Given this progress, the shift to hydrogen – a technology still in its infancy – raises serious economic and technical concerns.

Unviable alternative

While some European nations, including Germany and France, have piloted hydrogen-powered trains, the experiments have yielded mixed results, particularly in terms of commercial viability. These trains have primarily been deployed on low-traffic branch lines where electrification is not feasible. In contrast, Indian Railways has prioritised full electrification, leaving little room for hydrogen traction to add value.

Significant challenges

Storage and transportation complexity – Hydrogen must be stored at extremely high pressure (above 350 bar) or in liquid form at ultra-low temperature (-253 degree C). Both need costly and complex infrastructure, raising operational risks and expenses.

Inefficiency in energy conversion – "Green hydrogen" production requires substantial electricity. Given that nearly 70% of India's power generation still comes from coal-fired plants, using this energy to produce hydrogen, rather than feeding it into the grid for electric trains, results in avoidable energy losses.

High cost of distribution – Establishing a hydrogen ecosystem for railways would necessitate a vast investment in production, compression, transportation, and refuelling infrastructure; this money would be better spent on expanding electrification and renewable energy capacity.

Safety concerns – H drogen's high flammabili demands rigorous safe measures, adding anoth layer of complexity a cost. Transporting a handling hydrogen at sca would require extensi regulatory framewor and risk mitigati strategies.

Railways must choo between reinforcing su cess in electrification or verting resources to an u tested hydrogen futu Given the existing infra tructure, proven cost a vantages and ongoing newable ener integration, the logi choice is clear: electrifi tion stay the most efficie economically viable, a sustainable path forward

(The writer is with T Hindu businessline)

Indian Railways: The Electrification Journey

Introduction to Indian Railways

- Indian Railways is a crucial part of India's economy and social fabric, connecting the entire nation.
- The network is moving towards greener alternatives with a focus on near-total electrification.

The Milestone of Near 100% Electrification

- A multi-year, multi-billion-dollar project aimed at reducing carbon emissions.
- Electric trains are now dominant, supported by renewable energy sources

Strategic Commitment to Modernisation

- Focus on modernising railway infrastructure through technology and innovation.
- Aims for a more efficient and sustainable future.

Decarbonisation Goals

- Aligns with global efforts to reduce reliance on fossil fuels.
- Contributes to a cleaner environment and economic benefits

Pros of Electrification

Reducing Carbon Emissions: Electric trains produce fewer emissions than diesel.
Economic Benefits: Lower traction costs and improved efficiency

The Case Against Hydrogen-Powered Locomotives

European experiments with hydrogen trains show mixed results.
Indian Railways prioritises full electrification over hydrogen.

Unviable Alternative: Lessons from Europe

Hydrogen technology is not yet commercially viable for widespread use.

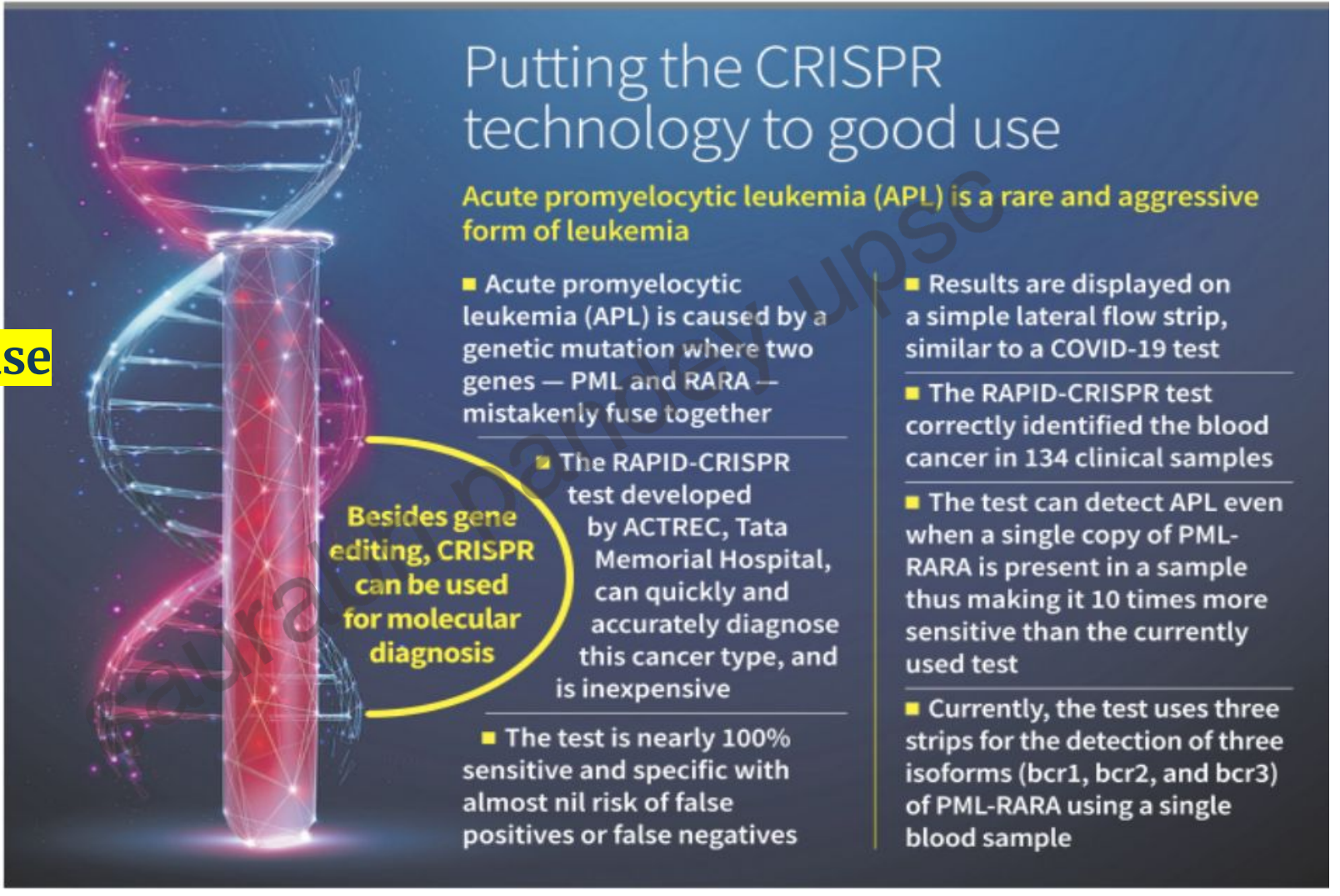
Significant Challenges of Hydrogen Technology

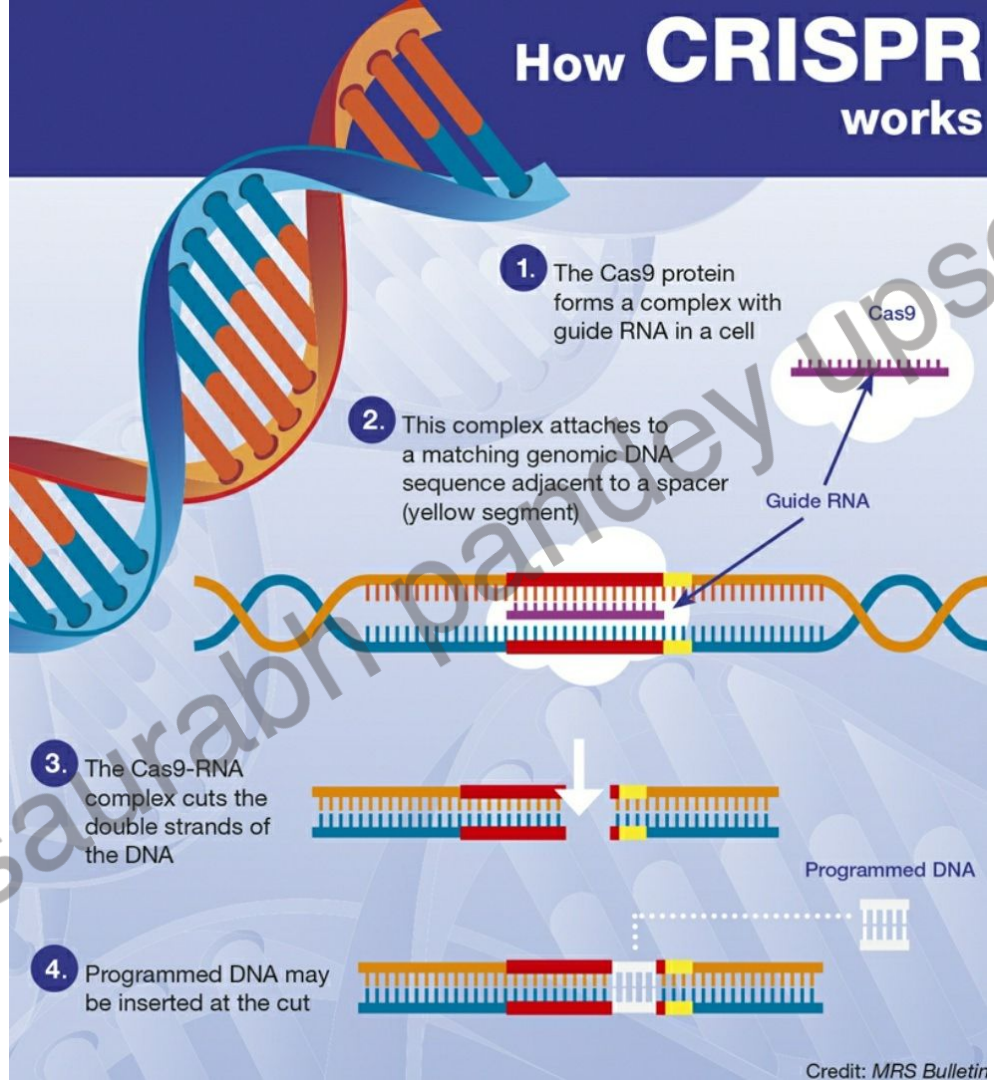
- Storage and Transportation Complexity: High pressure and low temperature requirements.
- Inefficiency in Energy Conversion: High energy losses in hydrogen production.
- High Cost of Distribution: Requires significant investment in infrastructure.
- Safety Concerns: High flammability demands rigorous safety measures.

Conclusion: The Path Forward for Indian Railways

Reinforcing electrification is the most efficient and sustainable path.
Proven cost advantages and renewable energy integration support this choice

ACTREC's CRISPR-based test





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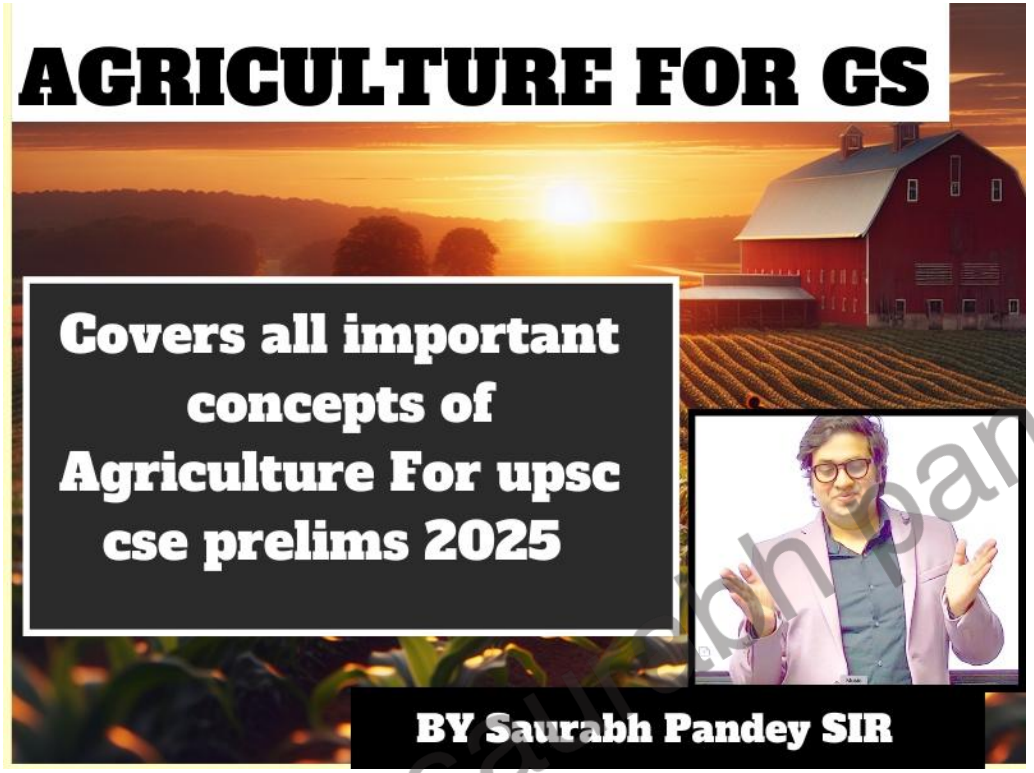

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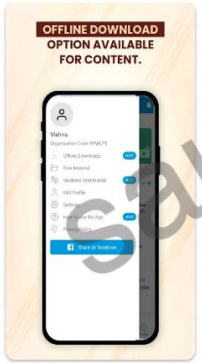

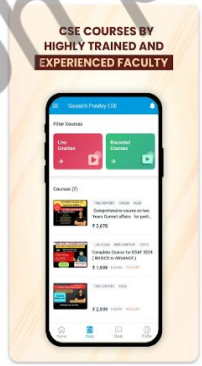

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