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Mpemba Effect — Indian Researchers Crack a 57-Year Scientific Puzzle

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SCIENCE & TECH

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Mpemba Effect — Indian Researchers Crack a 57-Year Scientific Puzzle

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WHY IN NEWS

Researchers from the Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR), Bengaluru, created the world's first computational simulation conclusively demonstrating the Mpemba Effect — the counterintuitive phenomenon where hot water can freeze faster than cold water under certain conditions.

WHAT IS THE MPEMBA EFFECT?

The **Mpemba Effect** refers to the observation that, under certain conditions, a sample of hot water can freeze faster than an equal sample of cold water — even though the hot water starts at a higher temperature and must therefore "travel farther" to reach freezing point.

This appears to violate common intuition: a warmer object should take longer to cool than a cooler one, all else being equal. Yet experimental observations have repeatedly suggested otherwise.

Historical origin: The effect is named after **Erasto Mpemba**, a Tanzanian student who first noticed it in 1969 while making ice cream. He observed that the hot ice cream mixture froze faster than the cold one when placed in the freezer. His physics teacher and later a university professor, Dr. Denis Osborne, took his observation seriously and published the finding in a scientific journal. The phenomenon has been debated in physics ever since.

WHY WAS IT SO DIFFICULT TO PROVE?

The core challenge was that the Mpemba Effect is **not universal** — it does not occur every single time hot water is cooled. It appears only under specific conditions involving:

- The composition of the water (dissolved gases, mineral content)
- Container shape and material
- Freezer temperature and air circulation
- Whether the water is covered or uncovered

Because conditions must align precisely, reproducing the effect in a controlled lab setting was notoriously difficult. Critics argued the effect was either an artifact of measurement error or an inconsistency in experimental setup.

THE JNCASR BREAKTHROUGH

Researchers at **JNCASR (Jawaharlal Nehru Centre for Advanced Scientific Research), Bengaluru** developed the first **computational simulation** of the Mpemba Effect — essentially creating a theoretical model that shows *why and how* hot water can freeze faster under specific thermodynamic conditions.

The key insight from the simulation involves **entropy** — the measure of disorder in a system. Hot water has higher entropy (more disordered molecular motion). Under the right conditions, hot water loses entropy faster than cold water — a non-equilibrium thermodynamic process that gives it a "head start" toward the ordered, low-energy state of ice.

This does **not** mean hot water always freezes faster. The simulation identifies the conditions under which this anomalous behaviour occurs — bridging the gap between anecdotal observation and theoretical physics.

JNCASR — ABOUT THE INSTITUTION

JNCASR (Jawaharlal Nehru Centre for Advanced Scientific Research) is an autonomous institution located in Jakkur, Bengaluru, Karnataka. It was established in 1989 and functions under the **Department of Science and Technology (DST)**, Government of India.

JNCASR is a deemed university and research centre focusing on cutting-edge research in:

- Condensed matter physics and materials science
- Chemistry and molecular biology
- Neuroscience
- Evolutionary biology and ecological sciences
- Theoretical sciences

It has produced notable alumni and faculty who have made significant contributions to Indian and global science, and is regularly ranked among India's top research institutions.

SCIENTIFIC SIGNIFICANCE AND APPLICATIONS

The Mpemba Effect, once properly characterised, has implications beyond a physics curiosity:

Industrial cooling systems: Understanding when hot liquids cool faster than cold ones can optimise industrial freezing and cooling processes — relevant in food production, chemical manufacturing, and cryogenics.

Non-equilibrium thermodynamics: The simulation advances understanding of systems that are far from thermodynamic equilibrium — a frontier area of physics with applications in quantum computing and energy storage.

Science education: The Mpemba Effect is a reminder that intuition can be wrong in physics, and that empirical observation by non-experts (a schoolboy in Tanzania) can seed important scientific inquiry.

UPSC RELEVANCE

Prelims: JNCASR Bengaluru; DST; Mpemba Effect — definition, history; Erasto Mpemba (1969); entropy; computational simulation; non-equilibrium thermodynamics.

Mains GS-3: Role of research institutions in advancing Indian science; significance of the Mpemba Effect breakthrough; DST-funded institutions; science and technology developments in India.

📌 FACTS CORNER — KNOWLEDGEPEDIA

MPEMBA EFFECT — KEY FACTS:

Definition: Phenomenon where hot water can freeze faster than cold water under certain conditions

Named after: Erasto Mpemba, Tanzanian student, 1969 (ice cream observation)

Co-published with: Dr. Denis Osborne (university professor)

Breakthrough (Jan 2026): JNCASR, Bengaluru — first computational simulation

Core mechanism: Hot water loses entropy faster under specific thermodynamic conditions

Not universal: Occurs only under specific conditions (container, water composition, freezer setup)

JNCASR:

Full form: Jawaharlal Nehru Centre for Advanced Scientific Research

Location: Jakkur, Bengaluru, Karnataka

Established: 1989

Type: Autonomous institution + deemed university

Parent body: Department of Science and Technology (DST), Government of India

Research areas: Condensed matter physics, materials science, neuroscience, ecology

RELATED CONCEPTS:

Entropy: Measure of disorder/randomness in a thermodynamic system (Second Law of Thermodynamics)

Non-equilibrium thermodynamics: Study of systems that are not at equilibrium — includes phase transitions, chemical reactions, biological processes

Run-of-river hydropower: Power generated from river flow without large-scale water storage (relevant to Wangchhu project news same day)

OTHER DST AUTONOMOUS INSTITUTIONS:

JNCASR, Bengaluru — interdisciplinary research

IUCAA, Pune — astrophysics

S.N. Bose National Centre, Kolkata — physical sciences

NIAS, Bengaluru — interdisciplinary advanced studies

Sources: GKToday, JNCASR

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