6. Discovery Of a New Genetic Code – S & T

A study published in the journal *Science* reports a major breakthrough in molecular biology by demonstrating the existence of a previously unrecognised genetic code operating in certain archaea.

Archaea

Definition - Archaea are single-celled, prokaryotic microorganisms that resemble bacteria in size and shape but are fundamentally distinct in their genetics, biochemistry, and evolutionary lineage. They constitute one of the three domains of life

1. Bacteria
2. Archaea
3. Eukarya

Habitat and Ecological Distribution - Archaea were initially discovered in extreme environments, leading to their classification as extremophiles. However, modern research shows that archaea are ecologically widespread.

Examples of Habitats

Extreme environments

1. Antarctic sub-zero lakes
2. Hot springs
3. Deep-sea hydrothermal vents
4. Highly saline or acidic environments

Moderate environments

1. Soil
2. Oceans
3. Human gut microbiome

Significance - Their ability to survive under extreme physical and chemical stress makes archaea ideal models for

1. Studying molecular evolution
2. Understanding early life on Earth
3. Exploring limits of biological adaptation

Core Characteristics of Archaea

Cellular Structure

1. Unicellular and prokaryotic
2. No nucleus and no membrane-bound organelles
3. Similar in size to bacteria

Biochemical and Genetic Distinctiveness

1. Cell membrane contains ether-linked lipids (not ester-linked as in bacteria and eukaryotes)
2. Cell walls do not contain peptidoglycan
3. Gene transcription and translation machinery is closer to eukaryotes than bacteria

Growth and Cultivation

1. Generally slow-growing
2. Extremely difficult to culture in laboratories due to Requirement of precise temperature, pressure, salinity, or chemical conditions
3. Many archaea remain unculturable, known only through genomic sequencing

Genetic Code- Conceptual Background

Genetic Code - The genetic code is the set of rules by which information in DNA is translated into proteins. DNA consists of four nitrogenous bases

1. Adenine (A)
2. Guanine (G)
3. Cytosine (C)
4. Thymine (T)

Triplet Codons - Each amino acid is encoded by a triplet codon (three bases). Example-

1. TTT → Phenylalanine
2. TTA → Leucine

Standard Genetic Code - Total codons- 64

1. 61 sense codons → encode 20 amino acids
2. 3 stop codons → signal termination of protein synthesis

Known Exceptions to the Standard Genetic Code

Despite being considered nearly universal, the genetic code has rare but important exceptions

Examples - Mycoplasma (bacterium) - TGA (normally a stop codon) → codes for tryptophan

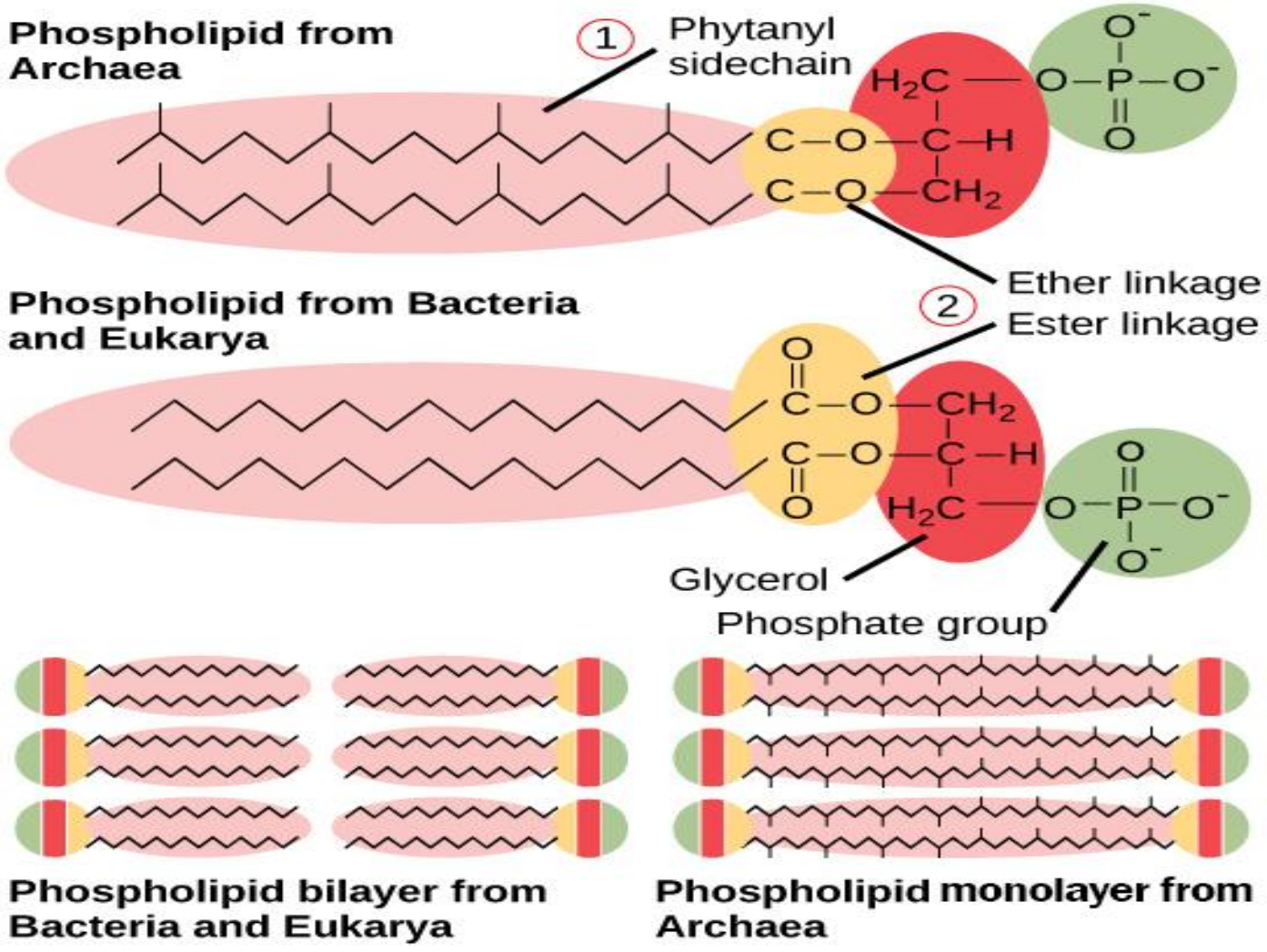
Humans - TGA can encode selenocysteine, a rare amino acid

Some archaea - TAG can encode pyrrolysine (Pyl) instead of acting as a stop codon

Key Discovery of the Study- The 'Pyl Code'

Major Finding - In certain archaea, the TAG codon has been completely reassigned. TAG-

1. Always codes for pyrrolysine



2. Never functions as a stop codon

Implication - This is not a partial or occasional reassignment. It represents a fully alternative genetic code system.

Features of the 'Pyl Code'

Feature	Standard Genetic Code	Pyl Code
Sense codons	61	**62**
Amino acids encoded	20	**21**
Stop codons	3	**2**
TAG codon	Stop codon	Codes for pyrrolysine

Revolutionary - Challenges the long-held assumption that the genetic code is fixed and universal.

Demonstrates evolutionary plasticity at the molecular level

Archaea Identified in the Study

Computational Identification -Researchers identified **nine archaeal species** with a fully reassigned TAG codon.

Species Studied Experimentally

Methanococcoides burtonii - Found in extremely cold Antarctic lakes

Methanomethylophilus alvi - Found in the human gut

Key Insight - Presence of the same non-standard genetic code in

1. Extreme environments
2. Normal biological environments

Indicates that the Pyl code is

1. Stable
2. Functional
3. Evolutionarily advantageous

Experimental Validation

Method Used

Mass spectrometry - Identifies precise amino acid composition of proteins

Findings - 54 previously unknown proteins containing pyrrolysine were identified

These proteins play roles in

1. DNA replication
2. Energy metabolism
3. Core cellular processes

Scientific Importance - Combines

1. Computational genomics
2. Experimental biochemistry

Demonstrates how **data science and laboratory biology converge** in modern research

Evolutionary Significance

Flexibility of the Genetic Code - Shows that genetic codes can evolve and diversify. Suggests early life may have

1. Experimented with multiple coding systems
2. Selected codes based on metabolic efficiency

Molecular Evolution - Evolution operates not only on Species and populations

But also, on

1. Information systems
2. Protein synthesis rules

Implications for Astrobiology - Expands the criteria for identifying extraterrestrial life. Life elsewhere may

1. Use alternative genetic codes
2. Operate under extreme environmental conditions

Strengthens the possibility of life on-

1. Icy moons (Europa, Enceladus)
2. Extreme exoplanets

Implications for Biotechnology and Synthetic Biology - Enables design of organisms with

1. Expanded amino acid repertoire
2. Novel proteins with enhanced functions

Potential applications

3. Industrial enzymes
4. Drug development
5. Protein engineering

Opens the door to **custom genetic codes** for specialised tasks

Conclusion

The discovery of the Pyl genetic code in archaea fundamentally reshapes our understanding of life's molecular foundations. It demonstrates that the genetic code is not an immutable universal rule, but a dynamic, evolvable system shaped by ecological and metabolic needs.

This finding not only deepens insights into early evolution on Earth but also broadens the scientific imagination regarding life beyond Earth and future biotechnological innovation.

Source- https-//www.thehindu.com/sci-tech/science/pyrrolysine-unusual-genetic-code-in-antarctic-microbes-yields-rare-amino-acid/article70470028.ece