Impact of mtDNA Mutations on Age-Related Muscle Loss

Source: TH

Why in News?

A recent study published in ***Genome Research*** reveals that **deletion mutations in mitochondrial Deoxyribonucleic Acid (mtDNA)** contribute significantly to **muscle loss with age.**

- Researchers found that these **mutations impair mitochondrial function**, leading to **muscle degradation.** This discovery offers potential pathways for delaying age-related muscle decline.

What is Mitochondria?

- **About: Mitochondria** are membrane-bound organelles found in the cytoplasm of most **eukaryotic cells.**
  - Often referred to as the **"powerhouses" of the cell,** mitochondria are essential for **producing energy** needed for various cellular processes.
  - Mitochondria are **inherited exclusively from the mother through the egg cell**.
- **Key Functions**:
  - **ATP Production:** Mitochondria generate **adenosine triphosphate (ATP),** the primary energy carrier in cells.
    - ATP is crucial for almost all cellular functions, including muscle contraction, protein synthesis (process by which cells create proteins from DNA), and cell division.
  - **Cellular Respiration:** Mitochondria are central to **cellular respiration** (break down food and release energy in the form of ATP).
  - **Regulating Cell Death**: Mitochondria are involved in controlling **apoptosis** (type of cell death), which is important for maintaining healthy tissues and organs.
- **Mitochondrial DNA (mtDNA):** Unlike most other organelles, mitochondria have their own DNA, known as **mtDNA.**
  - mtDNA is **prone to deletion mutations,** where parts of the **DNA are lost.** These mutations can have significant consequences on cellular function.
    - A deletion mutation in mtDNA makes the molecule smaller and less functional. Mutated mtDNA can **outcompete healthy mtDNA** during replication, causing a **gradual decline in mitochondrial function.**

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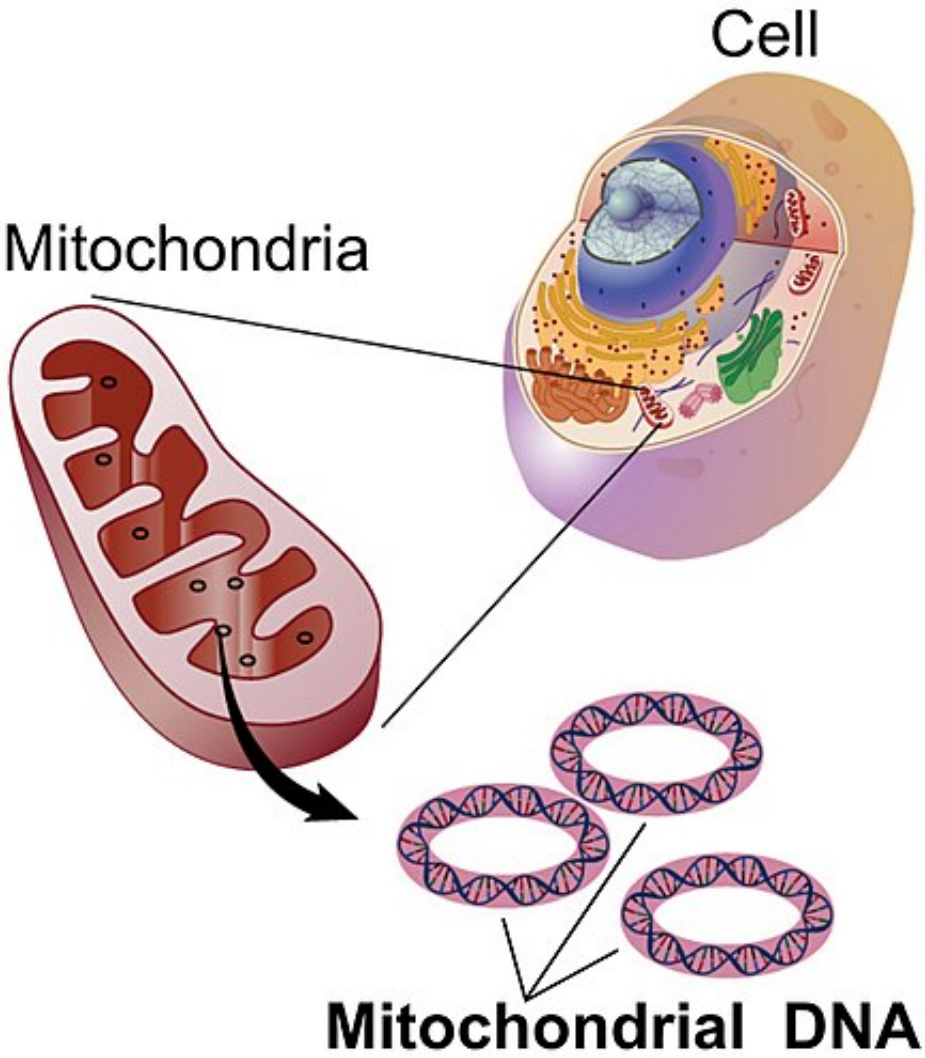

Feature	Nuclear Genome (DNA)	Mitochondrial DNA (mtDNA)
Size	3.2 billion base pairs	16,569 base pairs
Shape	Linear, organized into 23 chromosomes	Circular
Genes	~20,000 protein-coding genes and ~15,000–20,000 non-coding genes	13 protein-coding genes, 24 non-coding genes
Inheritance	Inherited from both parents	Inherited only from the mother
Location	Found in the nucleus	Found in the mitochondria
Function	Encodes instructions for making most proteins	Encodes proteins crucial for mitochondrial function

Note: A gene is a segment of DNA that is transcribed into **messenger RNA (mRNA).** The mRNA then moves from the nucleus to the **cytoplasm,** where the cell uses it to make proteins.

What are the Key Findings of the Study?

- **mtDNA Mutations:** The study identifies that deletion mutations in mitochondrial DNA (mtDNA) play a significant role in the loss of muscle mass with age.
- **Dysfunction and Muscle Loss:** Mutations **impair mitochondrial function,** causing muscle cells to struggle in generating enough **ATP,** leading to **muscle cell death and atrophy.**
    - The study found that mtDNA deletions lead to the **creation of chimeric genes** (where two different mitochondrial genes fuse and form abnormal sequences).
        - These chimeric genes disrupt the normal expression of mtDNA, further accelerating mitochondrial dysfunction.
- **Age-Related Changes:** Researchers found that older individuals showed a **two-fold increase in chimeric mitochondrial mRNA** due to mtDNA deletions, which, along with **abnormal gene expression**, accelerated **mitochondrial dysfunction and aging in muscle and brain tissues.**
- **Biological Age Indicators:** mtDNA deletion mutations and chimeric mRNA are valuable biomarkers for biological aging.
    - Understanding their role could lead to **therapies that prevent or repair these mutations,** potentially **delaying age-related muscle loss** and other aging symptoms.

UPSC Civil Services Examination, Previous Year Questions (PYQs)

Q1. In the context of hereditary diseases, consider the following statements: (2021)

1. Passing on mitochondrial diseases from parent to child can be prevented by mitochondria replacement therapy either before or after in vitro fertilization of the egg.
2. A child inherits mitochondrial diseases entirely from mother and not from father.

Which of the statements given above is/are correct?

(a) 1 only
(b) 2 only
(c) Both 1 and 2
(d) Neither 1 nor 2

Ans: (c)