

Molecular and Cellular Mechanisms of Cardiac Aging

Genetic, Cellular, and Therapeutic Perspectives

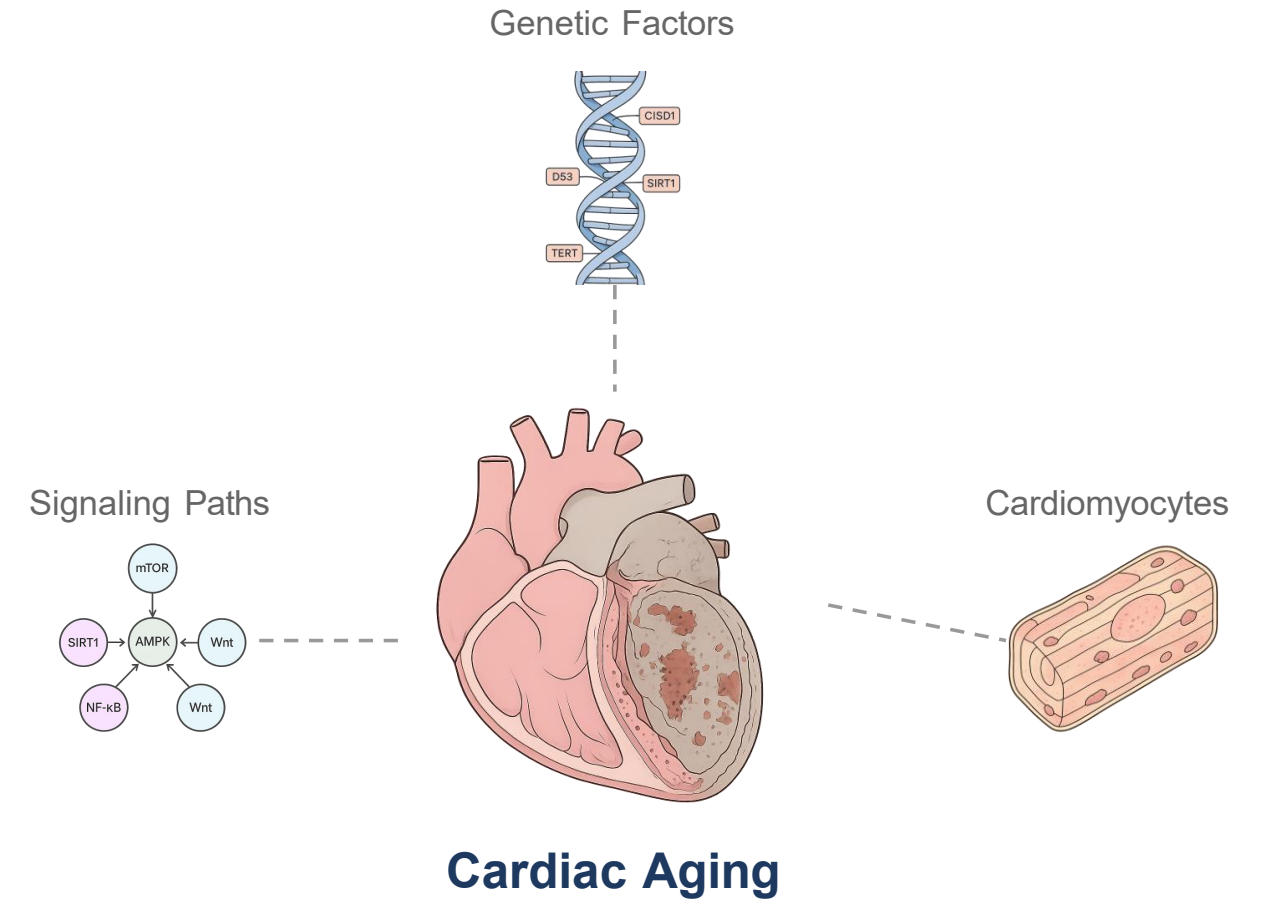
Introduction: Cardiac Aging

Background

- Heart disease prevalence increases with age due to cardiac aging processes
- Normal aging shows gradual cellular changes vs. pathological rapid dysfunction and fibrosis
- Understanding genetic, cellular, and molecular mechanisms is critical for prevention

Research Focus

- Genetic factors: C1SD1/2/3, SIRT1/3, TERT, p53
- Cellular mechanisms and signaling pathways
- Therapeutic interventions and prevention



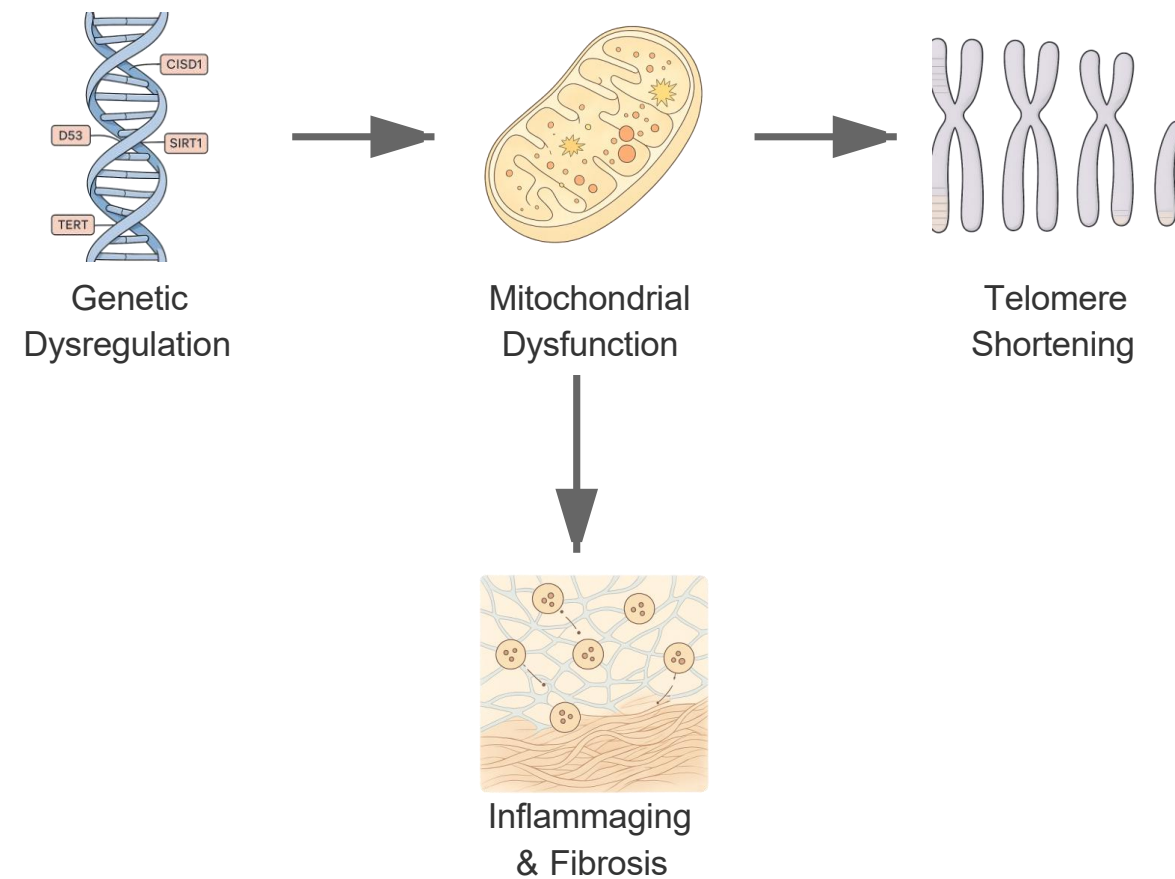
Molecular Mechanisms of Cardiac Aging

Cascade of Aging Processes

- Genetic dysregulation initiates aging cascade
- Mitochondrial dysfunction and oxidative stress
- Telomere shortening impairs regeneration
- Inflammaging accelerates fibrosis

Key Signaling Pathways

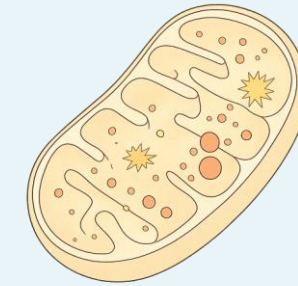
- mTOR, AMPK, FOXO pathways
- SIRT1 / PGC / Wnt – Catenin
- TGF and NF – B regulation



Key Cellular Mechanisms in Cardiac Aging

Mitochondrial Dysfunction

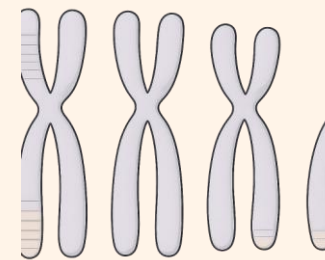
- Degradation of mitochondrial function central to cardiac aging
- Increased oxidative stress damages cardiomyocytes
- Impaired energy metabolism affects contractility



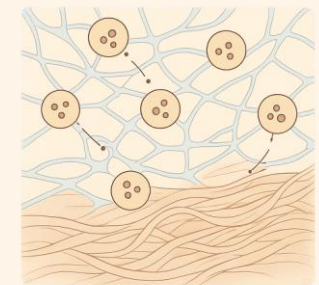
Mitochondrial Dysfunction

Telomere & Inflammaging

- Telomere shortening impairs cardiomyocyte regeneration capacity
- Chronic low-grade inflammation accelerates cardiac aging
- ECM remodeling and fibrosis reduce function



Telomere Shortening



Inflammaging

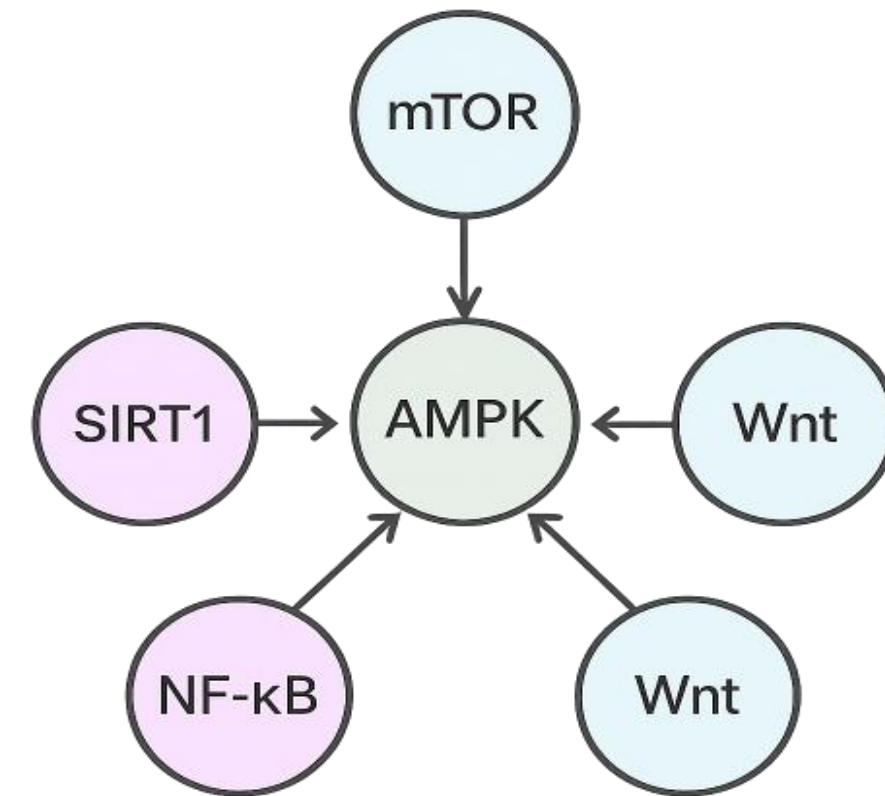
Signaling Pathways Regulating Cardiac Aging

Critical Regulatory Networks

- mTOR: Nutrient sensing and cellular growth
- AMPK: Energy homeostasis and metabolism
- FOXO: Oxidative stress resistance
 - SIRT1 / PGC : Mitochondrial biogenesis
 - Wnt / catenin : Cellular differentiation
 - TGF: Fibrotic remodelling
 - NF-B: Inflammatory responses

Impact

- Dysregulation leads to cardiovascular disease



Interconnected Signaling Network

7 major pathways regulate aging

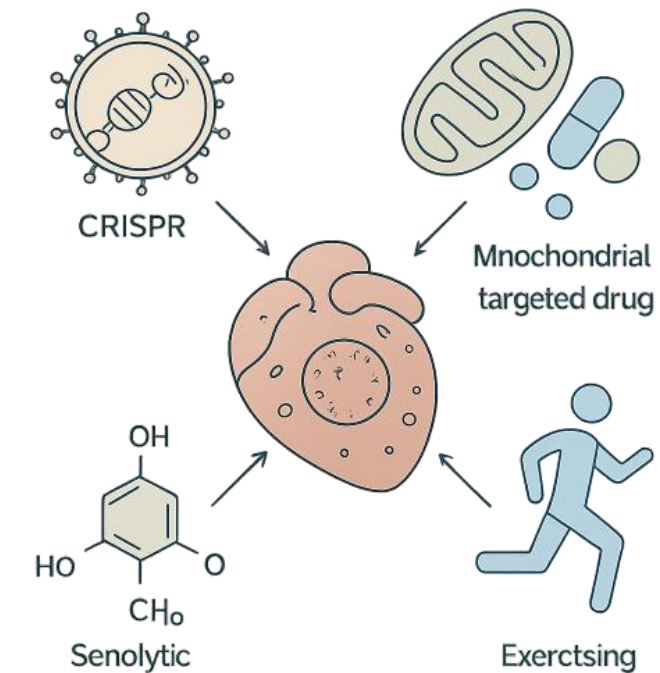
Therapeutic Interventions and Future Directions

Therapeutic Strategies

- CRISPR-based gene therapy targeting age-related genes (CISD, SIRT, TERT, p53)
- Senolytics and flavonoids remove senescent cells
- Mitochondrial-targeted medicines enhance bioenergetics
- Exercise and lifestyle interventions reduce inflammation

Future Directions

- Develop personalized therapy protocols
- Clinical trials for cardiovascular wellness in elderly



Multi-Modal Therapeutic Approach

Promising strategies to delay cardiac aging