Urinary Bladder Mechanics:
Potential Role of Hydrostatic Skeleton Design Principle

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Introduction

Large strains & maintaining shape : a biomechanical contradiction!

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Nature's solution: structural design

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Hydrostatic skeleton:
Contracting fibers vs. cavity fluid transmit pressure for coordinated movement and shape support.

… comparative anatomy, embryology, and especially molecular biology, demonstrate a striking unity among organisms, and show that the sometimes quite bewildering diversity is the result of variations over a series of basic themes, some of which are even common to all living beings.

C. Nielsen Animal evolution: Interrelationships of the living phyla. 2012



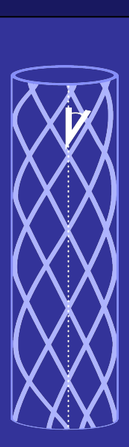
Methodology

40-year timeframe literature review: Anatomy, Comparative Biology, Embryology, Mechanics (Bio-, Fluid, Structural).

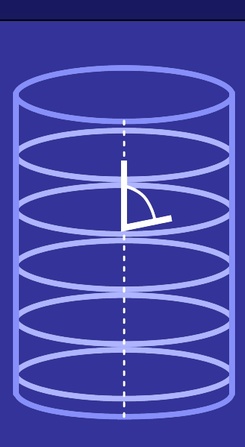
Findings

1.Geodesic Fiber Arrangement

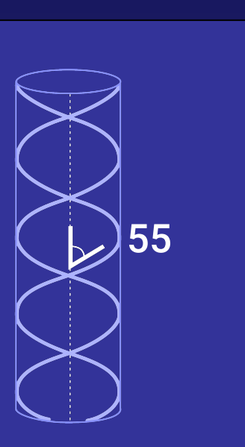
The bladder's fibers are arranged in a geodesic pattern (circular, longitudinal, and helical).
This unique arrangement, combined with connective tissue reinforcement, allows the bladder to efficiently expand and contract while controlling shape changes.



a)Contracting fibers at angles less than 55 degrees prevent excessive elongation



b)Contracting fibers at angles greater than 55 resist circumferential expansion

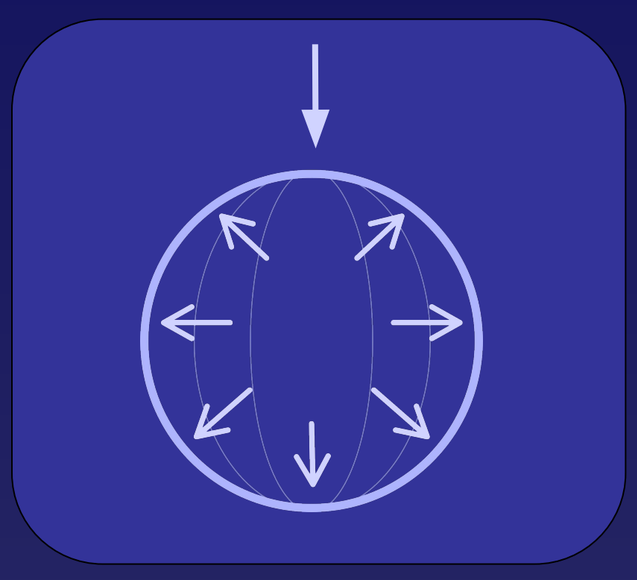


c) Balanced state

d)Helical design of connective tissue fibers offers reinforcement advantage

2.Pressure Transmission

The bladder's incompressible fluid content (urine) transmits pressure and thus should be considered an inherent mechanical component of the organ



Pressure applied on one point of liquid, transmits equally in all direction
-Paskal`s law

3.Opposing balance of the tension and compression forces creates prestress- an emergent property of the whole organ.

Mutual interaction of the geodesically arranged fibers and incompressible fluid content (urine) suggest a strong parallel with the hydrostatic skeleton (HS) design principle. This alignment potentially explains the bladder's remarkable ability to adapt to significant volume changes without compromising its functionality and shape

Conclusion

This research:

- provides preliminary evidence supporting the applicability of the HS design principle to understanding urinary bladder mechanics.
- offers a framework for a holistic perspective on bladder function, particularly in its ability to adapt to volume changes while maintaining structural integrity.
- suggests a basis for further experimental research. Future studies should focus on validating these findings and exploring their clinical implications.

Takeaway message

Nature's ancient hydrostatic design, refined by evolution, may hold the key to unlocking new perspectives on bladder function and innovative therapeutic approaches.