The unicellular origins of complex physiology

Prof. John S. Torday – Harbor-UCLA Medical Center, USA

The Unicellular Origins of Complex Physiology

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Sterols and Membrane Fluidity in Prokaryotes and Eukaryotes

- Sterols play a fundamental role in membrane fluidity in determining interactions between the external and internal environments of the cell
- Bacteria express hopanoids, which determine the structure of the cell membrane
- Eukaryotes express cholesterol, which plays the same role that hopanoids do in the cell membrane

Role of Cholesterol in Eukaryotic Cell Membranes

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Role of Cholesterol in Eukaryotic Cell Membranes

Epstatic Balance Between Lipids and Calcium: Driver of Eukaryotic Evolution

Vertical Integration of Cholesterol in Vertebrate Evolution

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How Surfactant Phospholipid Lowers Surface Tension

- Alveolar type II cell
- Phosphatidylcholine = zwitterion
- Air-liquid interface
- Apposing negative charges reduce surface tension

Homologies Interrelating Skin and Lung Cell Physiology

Macrosopic | Skin | Lung
---|---|---
Epiidermis | | |
Dermis | | |
Fat tissue | | |
Microscopic | Skin | Lung

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Measuring Surface-Tension Lowering Effect of Surfactant

The Physical Chemistry of the Phosphatidylycholine Surface Film

Effect of Temperature on Surface Activity

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Skin-Brain Homology
Homologies Relating Skin and Lung Cell Physiology

Evolution of Whole Animal Physiology

The Cell as a Fractal
- Mandelbrot described physiology as fractal. It is self-similar, due to the underlying, integrative mechanisms of cellular ontogeny, phylogeny and homeostasis
- This process is self-referential, all the way back in vertebrate phylogeny to their unicellular origins
- What are the integrating mechanisms that would account for the evolution of multicellular organisms from unicellular life? If they were known, they would provide fundamental insights to the mechanisms of evolution

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The Cell as a Fractal

- The First Principles of Physiology are knowable since they are the mechanistic basis for ontogeny and phylogeny, which are one and the same process when seen from the cellular perspective, occurring on different time-scales, i.e. they are diachronic.
- Given that, I maintain that the innate organizing principle of physiology – cellular homeostasis - is fractal.
- I propose that the epistatic balancing selection between calcium and lipid homeostasis was essential to the initial conditions for eukaryotic evolution, starting the process of vertebrate evolution, continuously perpetuating and embellishing it from unicellular organisms to metazoans in all phyla.

Fractal - repetition of a self-similar form at all levels

The Cell as the First Fractal of Vertebrate Evolution

- Liposome → Chemiosmosis → Cell
- Entropy
- Homeostasis
- Metazoan Evolution
- Endomesoderm
- Endoderm

This then is the basis for ‘fractal physiology’
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Levels of Structural Organization

The Effects of Cholesterol

A. Possible timeline in evolution

Endocrine Hormones
Metakron

Lipid raft
Metakron
Paracrine Autocrine Juxtacrine

Cholesterol
Eukaryote

Prokaryote

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Emergent and Contingent
The water-land transition - how fractal physiology facilitated vertebrate adaptation to land

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