Power, sex, suicide: mitochondria and the meaning of life

By Nick Lane, 2005

Introduction (page 1-18)

Mitochondria: clandestine rulers of the world

In every eukaryotic cells
Evolutionarily originated from free living bacteria
Independent genome
Involved in energy, sex, fertility, suicide, ageing, and death

Knowledge about mitochondria in general

Molecular Eve: maternal inheritance

Genetic fingerprinting: partly due to abundance
- 5-10 copies of genes/mitochondria
- maternal relatives

Mitochondrial theory of ageing
- free radicals from respiratory chain
- attack cells every second
- irreversible mutation & buildup over a lifetime
- cell death: ageing & degenerative diseases
- affect metabolically active tissues: muscle & brain

Mitochondrial transfer to oocyte: ooplasmic transfer

Mitochondria as symbionts: described in Star Wars

Recent advances in mitochondria

Apoptosis: programmed cell death

what is cancer? Escape from apoptosis

Implications

why would potentially free-living cells accept a death penalty
for the privilege of living in a larger community of cells?

Origin of eukaryotic cells

primitive eukaryotic cell engulfed a bacterium, which finally became
totally dependent and evolved into the mito
the origin of complex cells is inseparable from the origin of the mito

Origin of sexes: why two

because one sex must specialize to pass on mito in the egg cell,

while the other must not (Chap 6).

Mitochondria make a comeback:

a series of review paper in Science, March 5, 1999

Chemiosmosis

Why the principle of energy generation became so central to so many different forms of life?

Mitochondrial genes

transfer of mito genes to nucleus and the remaining genes

it will explain why bacteria never attained the complexity of the eukaryotes

The whole trajectory of evolution

Origin of life itself

Through the genesis of complex cells and multicellular organisms

To the attainment of larger size, sexes, warm-bloodedness, and into the decline of old age and death

The meaning of life

New insights into

why we are here at all

Whether we are alone in the universe

Why we have our sense of individuality

Why we should make love

Where we trace our ancestral roots

Why we must age and die

Cell biology background (pp 8-11)

General properties of mitochondria

- bacterial appearance and size
- cellular contents: the more active, the more mito
- two membranes
- intracellular movement
- division & branching networks
- single circular naked DNA
- bacterial transcription and translation
- own ribosomes of bacterial appearance
- antibiotics block protein synthesis in the mito

History of mitochondrial studies

1886, Richard Altman: bioblast, a living component surrounded by a reservoir of nutrients

the bioblast was disputed because of staining problem

Acidic staining to observe chromosome dissolved mito

other staining colored mito transiently (due to the oxidation of stains)

1897, Carl Benda demonstrated the presence and named mitochondria

(mitos, meaning thread, and chondrin, meaning small grain

1912, BF Kingbury proposed that mito is the respiratory centres of the cells

1949, Eugene Kennedy & Albert Lehninger showed respiratory enzymes in mito

1918, Paul Portier claimed symbiosis of mito (even claimed mito culture)

1925, Ivan Wallin suggested bacterial nature of mito

1967, Lynn Margulis presented strong evidence of symbiotic nature of mito

1981, Fred Sanger sequenced human mito genome, revealing faster mutation rate and

supporting bacterial origin

The bacterial nature of mito

slower evolution rate than nucleus, retaining atavistic properties?

bacterial origin?

Margulis also argued that mito culture may be possible

Why is it not possible?

mito gene only encoding 13 genes

mito proteins (~800) encoded by nuclear genes

Margulis suggested ‘serial endosymbiosis theory’

enkaryotic cells by a succession of mergers between cells (ex. centrioles)

emphasizing collaboration of bacteria

however, mito was not a choice but essential of the eukaryotic condition

all eukaryotic cells either have or once had

A single origin of eukaryotic cells having mito

if a result of collaboration between bacteria, all sorts of distinct euk cells

they are contingent on the existence of mito

Pico-eukaryotes discovered from extreme environments

possible intermediates between bacteria and eukaryotes

however, all grouped into known groups of eukaryotes

Ostreococcus tauri, a smallest known eukaryotic cell (1 μm diameter)

a nucleus with 14 linear chromosomes

one chloroplast

several tiny mito

Part 1 (pp19-64)

Hopeful Monster

The origin of the eukaryotic cell

The appearance of a chimeric cell containing mito
Only once, in spite of engulfing another is commonplace
What was so special?

The origin of life on earth

4 billion years ago by the estimates of molecular clock

Late 1970s

finding of archaebacteria

living in excessively hostile conditions, like thermal vents

Evolution by the chance of contingency vs the necessity of convergence

Stephen Jay Gould

Conway Morris

life will keep converging on the best solutions

flight evolved independently no less than four times

convergence outweighs contingency (necessity overcomes chance)

What brake on evolution?

evolutionary flamboyance evolved in the last 600 million years
primitive eukaryotic cells dates back to 3000 million years

Evolution of large multicellular creatures
multicellular colony & multicellular organism
cellular differentiation
however, multicellular cooperation may not have been an obstacle

The evolution of eukaryotic cell
evolved only once
far more improbable than the evolution of multicelluar organism
all eukaryotes either have, or once had, mito,
meaning the importance of mito in the evolution

***The birth of the nucleus: Science Aug 6, 2004

Evolution of eukaryotes (general concept)

http://en.wikipedia.org/wiki/Eukaryote

Eukaryotes are closely related to archaea, at least in terms of nuclear DNA and genetic machinery. In other respects, such as membrane composition, they are similar to eubacteria. Three main explanations for this have been proposed:

- Eukaryotes resulted from the complete fusion of two or more cells, the cytoplasm forming from a eubacterium and the nucleus from an archaeon (alternatively a virus).

- Eukaryotes developed from Archaea, and acquired their eubacterial characteristics from the proto-mitochondrion.

- Eukaryotes and Archaea developed separately from a modified eubacterium.

Lecture will focus on

- Presenting summaries
- Providing references
- Provoking questions

You need to

- Read, Ask, and Discuss

Grading will depend on your participation

Schedule

1-26	27-64	65-84	85-104	105-129
130-147	148-177	178-199	200-226	227-241
242-265	266-288	289-301	302-311	312-321