Phylogenetics of Archaeal Lipids

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Outline

- Phlogenetics of Archaea
- Phlogenetics of archaeal lipids
- Papers

Phyla

- Two? main phyla
  - Euryarchaeota
    - Methanogens
    - Extreme halophiles
    - Extreme thermophiles
    - Sulfate-reducing
  - Crenarchaeota
    - Extreme thermophiles
  - Korarchaeota?
    - Hyperthermophiles
    - indicated only by environmental DNA sequences
  - Nanoarchaeum*?*
    - *N. equitans* a fast evolving euryarchaeal lineage, not novel, early diverging archaeal phylum
  - Ancient archael group?
    - In deepest brances of Crenarchaea? Euryarchaea?

Archaeal Lipids

- Methanogens
  - Di- and tetra-ethers of glycerol and isoprenoid alcohols
  - Core mostly archaeol or caldarchaeol
  - Core sometimes sn-2- or sn-3-hydroxyarchaeol or macrocyclic archaeol
  - PMI
- Halophiles
  - Similar to methanogens
  - Exclusively synthesize bacterioruberin
- Marine Crenarchaea

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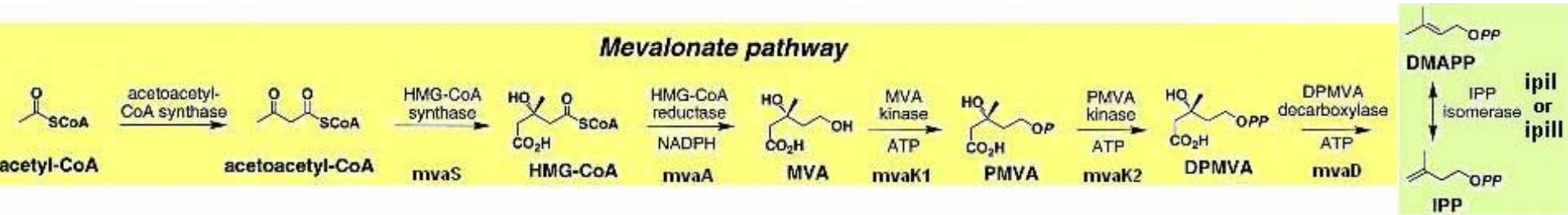
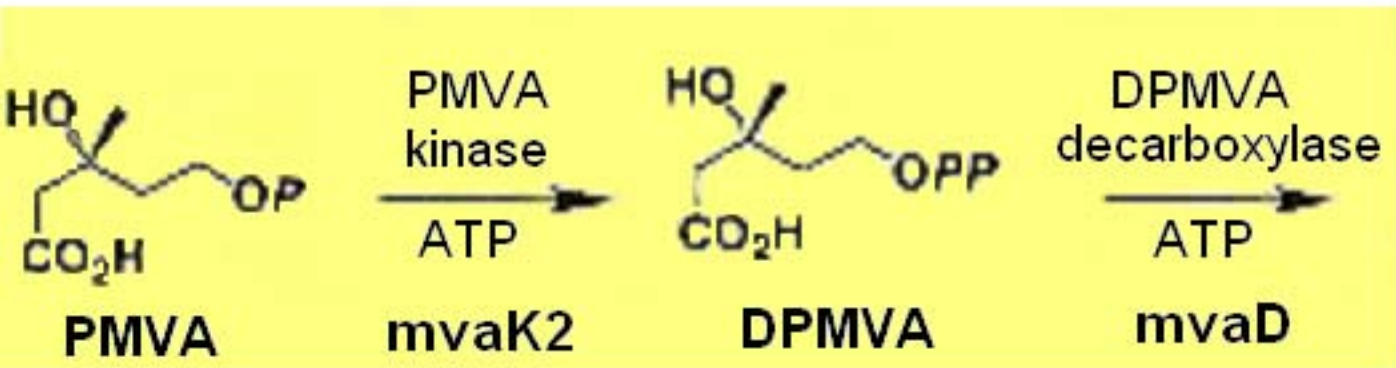
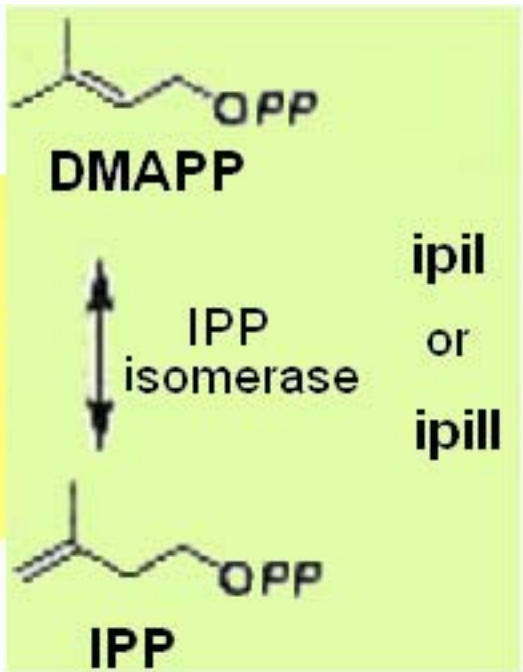
Archaeal Lipids	Biological Origin	Depositional Environment
Crocetane	methanotrophs?	methane seeps?
PMI (2,6,10,15,19-pentamethylicosane)	methanogens, methanotrophs	hypersaline, anoxic
Squalane		hypersaline?
C_{31}-C_{40} head-to-head isoprenoids		

Smit & Mushegian

- “Lost” enzymes of MVA pathway must exist
  - Phosphomevalonate kinase (PMK)
  - Diphosphomevalonate decarboxylase
  - Isopentenyl diphosphate isomerase (IPPI)







Kaneda et al. 2001 Rohdich et al. 2001

Boucher et al.

- Isoprenoid biosynthesis of archaea evolved through a combination of processes
  - Co-option of ancestral enzymes
  - Modification of enzymatic specificity
  - Orthologous and non-orthologous gene displacement
  - Integration of components from eukaryotes and bacteria
  - Lateral gene transfer within and between archaeal orders

Blumenberg et al.

- Anaerobic oxidation of methane
  - Sulphate reducing bacteria
  - Anaerobic archaea
    - ANME-1
    - ANME-2

Archaea involved in AOM

- ANME-1 (***Methanomicrobiales*** and *Methanosarcinales* of Euryarchaeota)
  - ^{13}C depleted
  - Internally cyclized tetraether lipids
  - Nonisoprenoidal glycerol diethers
- ANME-2 (*Methanosarcinales* of Euryarchaeota)
  - ^{13}C depleted
  - *sn*-2-hydroxyarchaeol
  - Crocetane and crocetenes
  - Ester-linked diglycerides

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Blumenburg et al. 2004

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Brocks & Summons 2003

Schouten et al.

- New glycerol dialkyl glycerol tetraethers
- HPLC/MS anaylysis of intact lipids
- Not just from hyperthermophiles
- Structures are diverse
- Organisms that make GDGTs can be a significant component of microbial communities

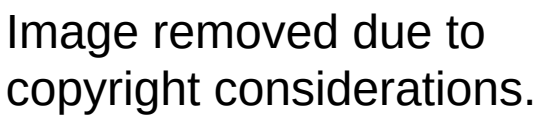
a a methanogens

a b
a c
c c
c d
d d

Hyper-thermophilic cultures

Low-temperature marine sediments

d e psychophilic marine



Extreme thermophilic Crenarchaeota can increase the number of pentacyclic rings with increasing T.

Psychrophilic marine Crenarchaeota add a hexyl ring for low T

I-VII identified as core ether lipids in hyperthermophilic archaea

I is caldarchaeol

II-VII present in hyperthermophilic and nonthermophilic archaea

VIII predominantly synthesized by marine nonthermophilic Crenarchaeota

X-XIV terrestrial

Schouten et al. 2000

Koga & Morii

- Archaeal lipids
  - Core
    - Archaeol
    - Caldarchaeol
    - New
  - Phosphodiester bonded polar head group or glycoside

Classes

- Cultivated Euryarchaeota fall into eight classes
  - Archaeoglobi
  - Halobacteria
  - Thermococci
  - Thermoplasmata
  - Methanopyri
  - Methanococci
  - Methanobacteria
  - Methanomicrobia
- Cultivated Crens fall into 1 class with four orders
  - Thermoprotei
    - Thermoproteales
    - Caldisphaerales
    - Desulfurococcales
    - Sulfolobales

Key Genera
Phylum Euryarchaeota

- Halobacterium
- Haloferax
- Natronobacterium
- Methanobacterium
- Methanocaldococcus
- Methanosarcina
- Thermoplasma
- Ferroplasma
- Picrophilus
- Thermococcus
- Pyrococcus
- Methanopyrus
- Archaeoglobus
- Ferroglobus

Extreme halophiles

Methanogens

Thermophilic and extremely acidophilic

Hypothermophiles

Key Genera
Phylum Crenarchaeota

- Sulfolobus
- Acidianus
- Thermoproteus
- Pyrodictium
- Pyrolobus
- Ignicoccus
- Staphlothermus

Hyperthermophiles from terrestrial volcanic habitats

Hyperthermophiles from submarine volcanic habitats