Structures on the Edge of Stability

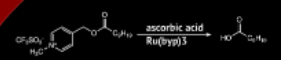
Sarah E. Maurer, smaurer@ifk.sdu.dk
Center for Fundamental Living Technology, University of Southern Denmark, Odense, DK

Low pH, High salt, High temperature

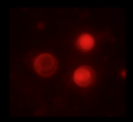
Namani & Deamer, OLEB 2008

- Salt normally detrimental
- Necessary for certain reactions
- Likely component of prebiotic oceans

Synthesis and self-assembly



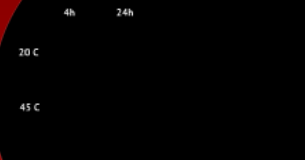
Goal: light driven reaction causes formation of vesicular structures.
Growth and Division!



Lack of stability as a selection mechanism?

Experimental work

Temperature and Stability



- Permeability and rate of fusion are both increased at higher temp
- Adding second amphiphile (GM headgroup) decreases these effects.

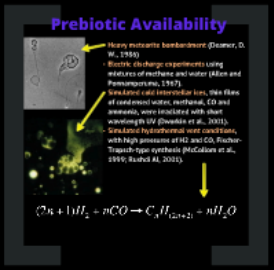
Maurer, et al. Astrobiology 2009, 9, 979-987.

Single chain amphiphile library

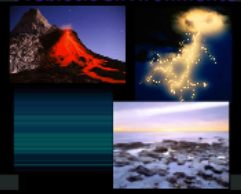
- Concentrations
- Salt stability
- pH
- Temperature

Background

Prebiotic Availability



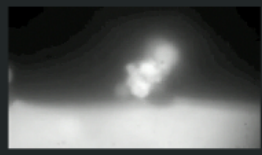
Prebiotic environments



Conclusion

The emergenceness of these systems are dependent on the instabilities inherently present in lipid structures, which need to be harnessed to create protocellular systems

Outlook



Movement caused by instablity trapped between glass

- Competition between stable and unstable systems (including cannabalism)
- Temperature induced reactions from fusion or leakage
- Discovery of new environments for protocellular reactions

Acknowledgements

Steen Rasmussen
Pierre-Alain Monnard
Marty Hanczyc
Gabriel Piedrafita
Maik Hadorn
Eva Bonzli
Lone Laursen
Mark Dorr
Michael Wamberg
Pernille Pedersen
Phillipp Loffler
Rafal Weiczorek

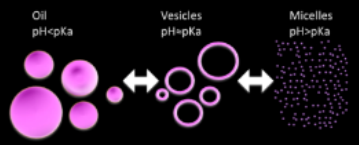
Lack of stability as a selection mechanism?

What is stability?

pH sensitivity

Critical vesicle concentration

Salt concentrations



Structures on the Edge of Stability

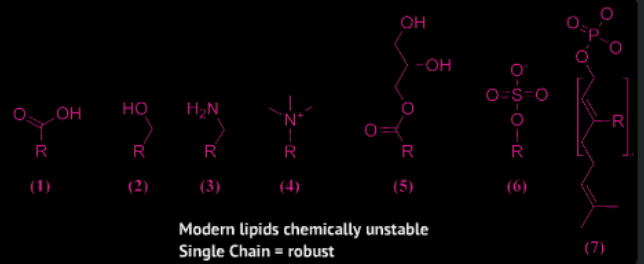
Sarah E. Maurer, smaurer@ifk.sdu.dk
Center for Fundamental Living Technology, University of Southern Denmark, Odense, DK

Acknowledgements

Steen Rasmussen
Lone Laursen
Pierre-Alain Monnard
Mark Dorr

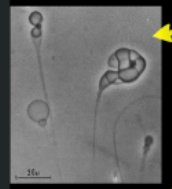
Single chain amphiphile library

- Concentrations
- Salt stability
- pH
- Temperature



Modern lipids chemically unstable
Single Chain = robust

Prebiotic Availability



- Heavy meteorite bombardment (Deamer, D. W., 1986)
- Electric discharge experiments using mixtures of methane and water (Allen and Ponnamperuma, 1967).
- Simulated cold interstellar ices, thin films of condensed water, methanol, CO and ammonia, were irradiated with short wavelength UV (Dworkin et al., 2001).
- Simulated hydrothermal vent conditions, with high pressures of H2 and CO, Fischer-Tropsch-type synthesis (McCollom et al., 1999; Rushdi Al, 2001).

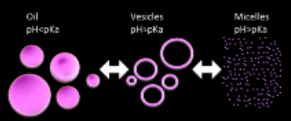
$$(2n+1)H_2 + nCO \rightarrow C_nH_{(2n+2)} + nH_2O$$

Background

measure of the changes in a specific characteristic over time

What is stability?

Encapsulation ability
Temperature sensitivity
Permeability
pH sensitivity
Critical vesicle concentration
Salt concentrations

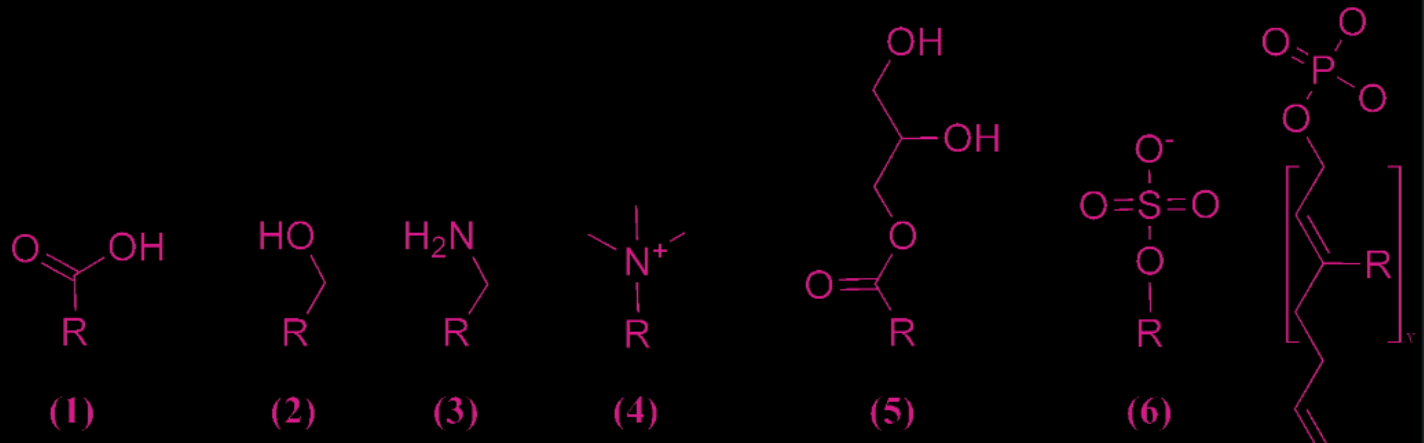


Prebiotic environments

tures on the

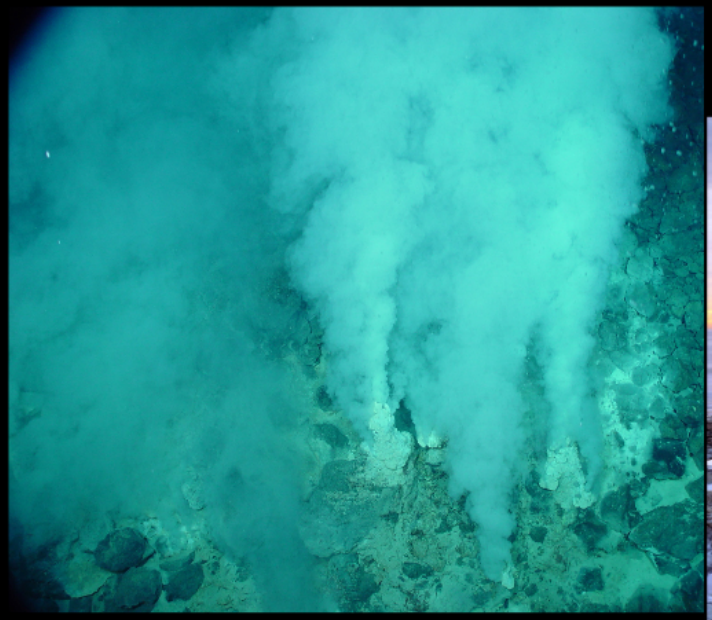
Single chain amphiphile library

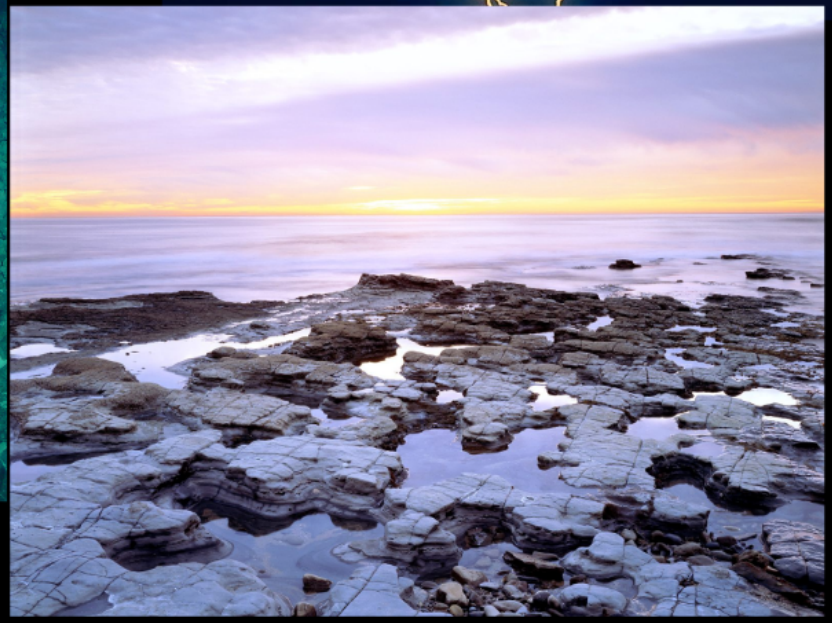
- Concentrations
- Salt stability
- pH
- Temperature



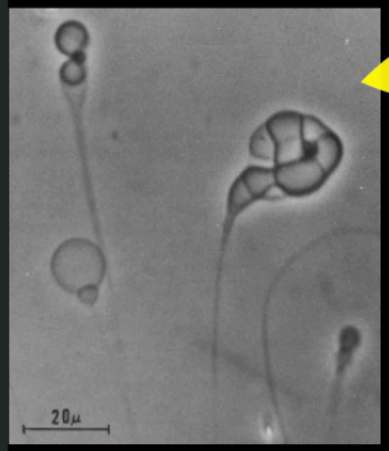
Modern lipids chemically unstable
Single Chain = robust

Prebiotic environments





Prebiotic Availability



- Heavy meteorite bombardment (Deamer, D. W., 1986)
- Electric discharge experiments using mixtures of methane and water (Allen and Ponnamperuma, 1967).
- Simulated cold interstellar ices, thin films of condensed water, methanol, CO and ammonia, were irradiated with short wavelength UV (Dworkin et al., 2001).
- Simulated hydrothermal vent conditions, with high pressures of H2 and CO, Fischer-Tropsch-type synthesis (McCollom et al., 1999; Rushdi AI, 2001).

$$(2n+1)H_2 + nCO \rightarrow C_nH_{(2n+2)} + nH_2O$$

What is stability?

measure of the changes in a specific characteristic over time

Encapsulation ability

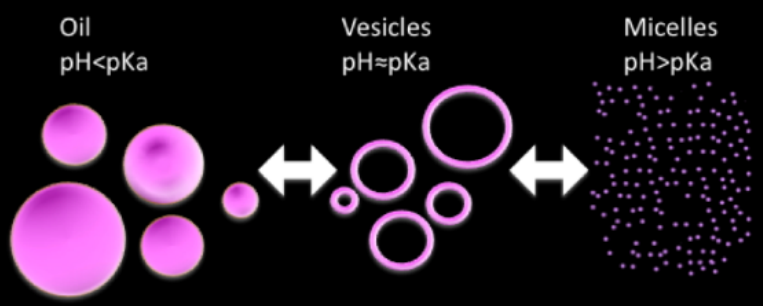
Temperature sensitivity

Permeability

pH sensitivity

Critical vesicle concentration

Salt concentrations

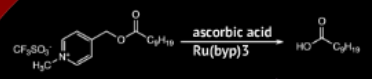


Low pH, High salt, High temperature

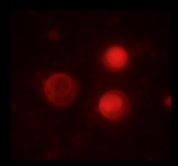
Namani & Deamer, OLEB 2008

- Salt normally detrimental
- Necessary for certain reactions
- Likely component of prebiotic oceans

Synthesis and self-assembly



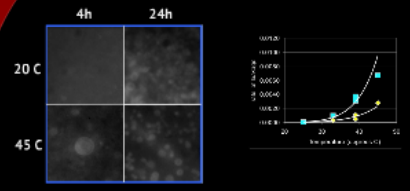
Goal: light driven reaction causes formation of vesicular structures.
Growth and Division!



Lack of stability as a selection mechanism?

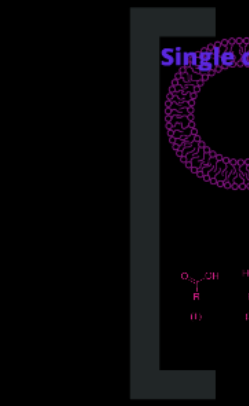
Experimental work

Temperature and Stability



- Permeability and rate of fusion are both increased at higher temp
- Adding second amphiphile (GM headgroup) decreases these effects.

Maurer, et al. Astrobiology 2009, 9, 979-987.



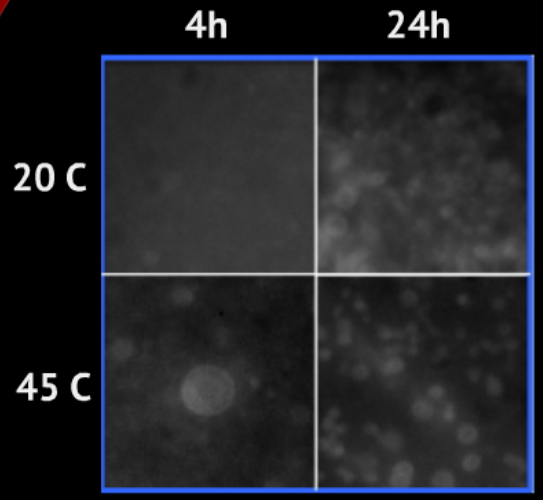
Structures on Edge of Stabil

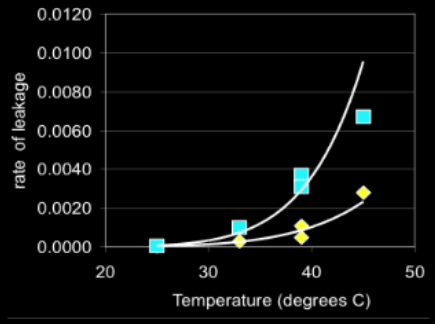
Sarah E. Maurer, smaurer@ifk.sdu.dk
Center for Fundamental Living Technology, University of Southern Denm

Acknowledgements

Steen Rasmussen
Pierre-Alain Monnard
Marty Hanczyc
Gabriel Piedrafita
Maik Hadorn
Lone Laursen
Mark Dorr
Michael Wamberg
Pernille Pedersen
Phillipp Loffler

Temperature and Stability

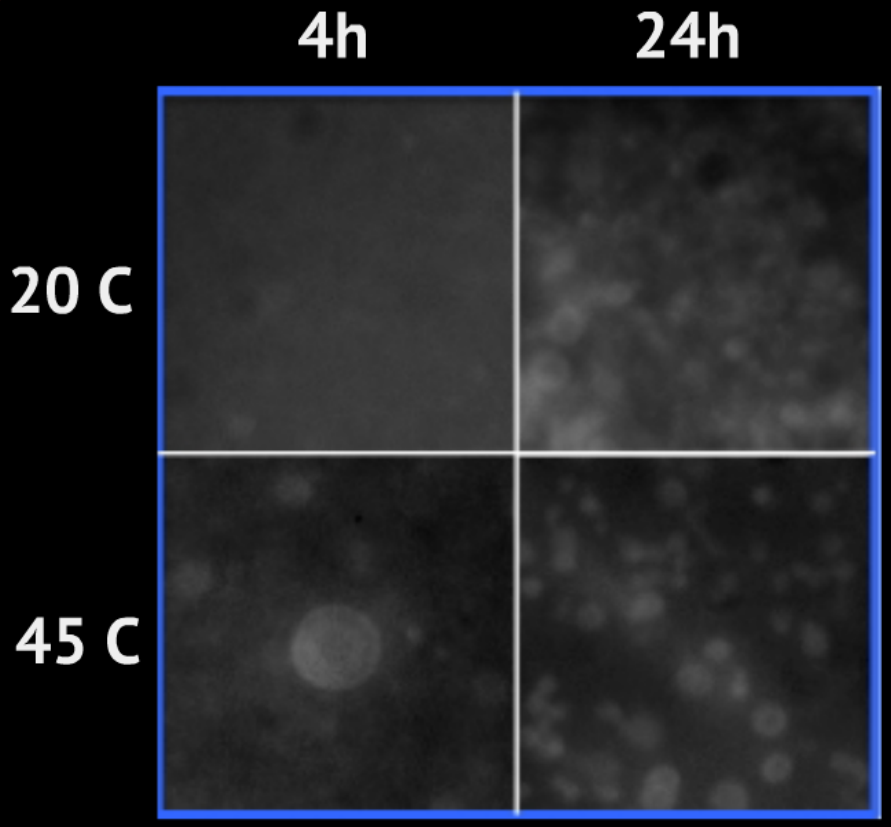


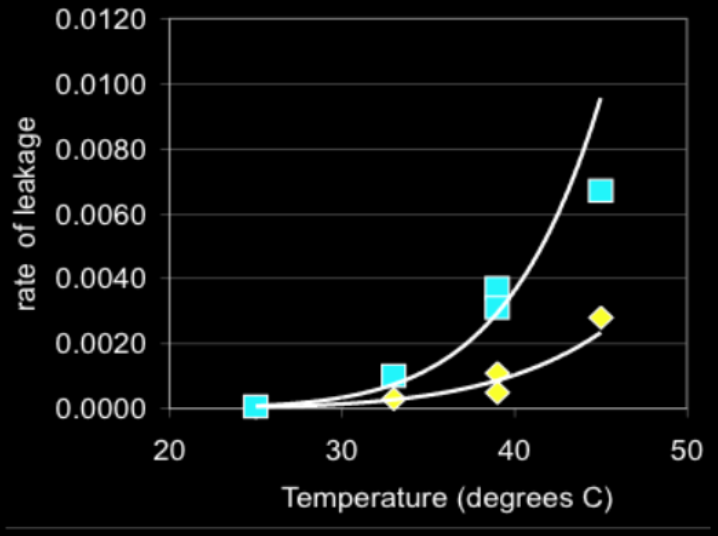


- **Permeability and rate of fusion are both increased at higher temp**
- **Adding second amphiphile (GM headgroup) decreases these effects.**

Maurer, et al. Astrobiology 2009, 9, 979-987.

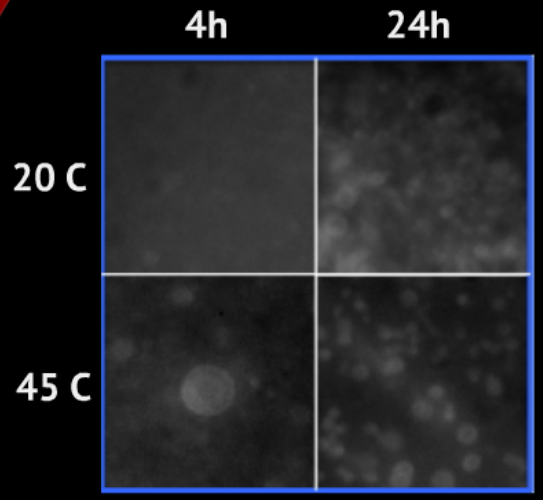
and Stability

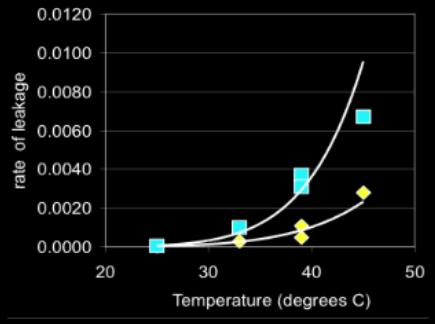




- **Permeability and rate of fusion are both increased at higher temp**

Temperature and Stability





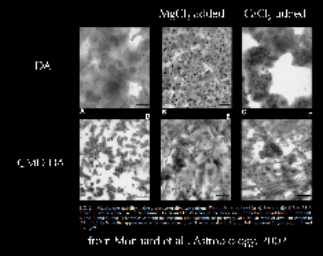
- **Permeability and rate of fusion are both increased at higher temp**
- **Adding second amphiphile (GM headgroup) decreases these effects.**

Maurer, et al. Astrobiology 2009, 9, 979-987.

Low pH,
High salt,
High temperature

Namani & Deamer, OLEB 2008

- Salt normally detrimental
- Necessary for certain reactions
- Likely component of prebiotic oceans



Goal: lig
causes f
structur
Growth

$MgCl_2$ added

$CaCl_2$ added

DA

GMD:DA

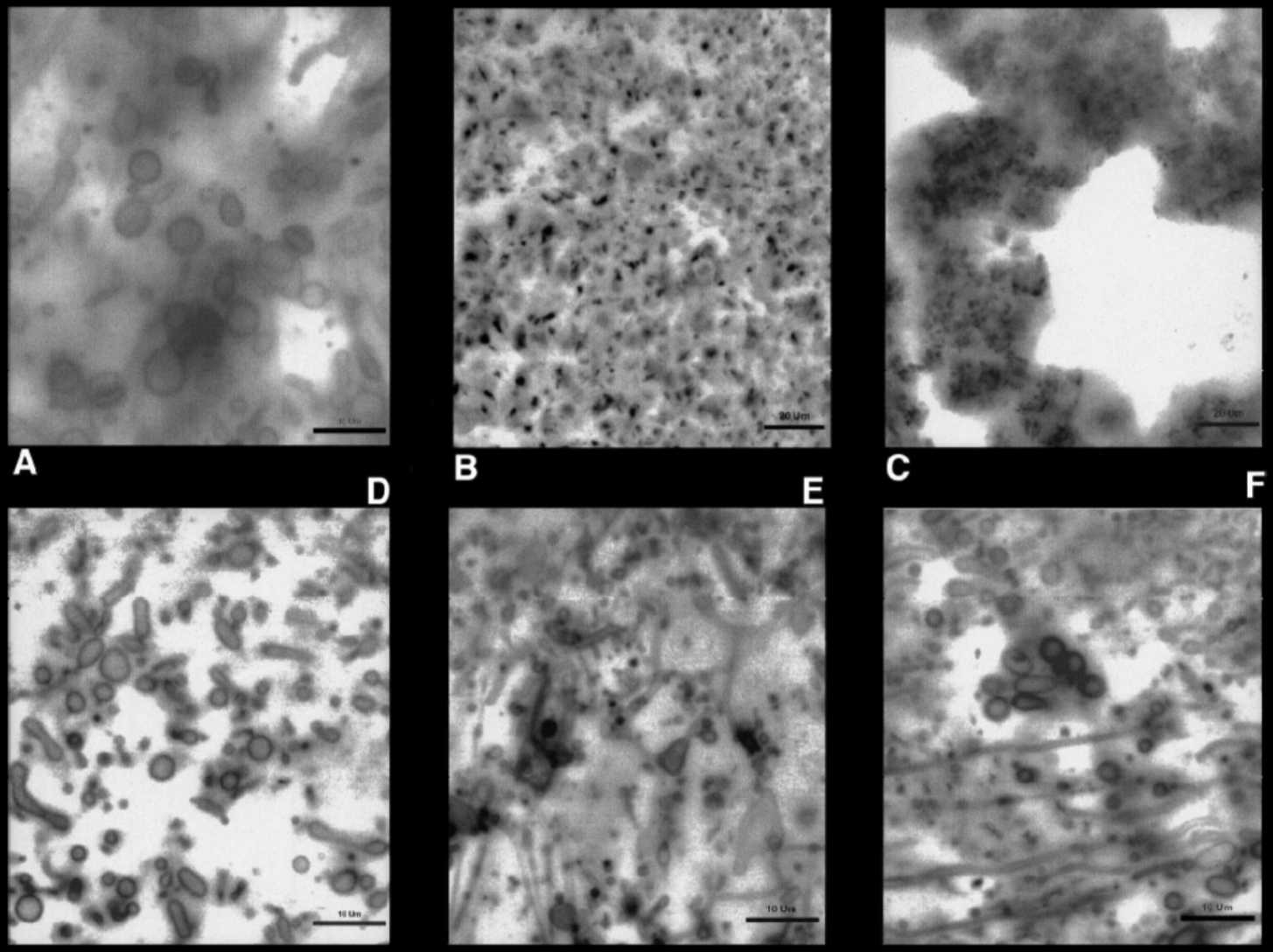
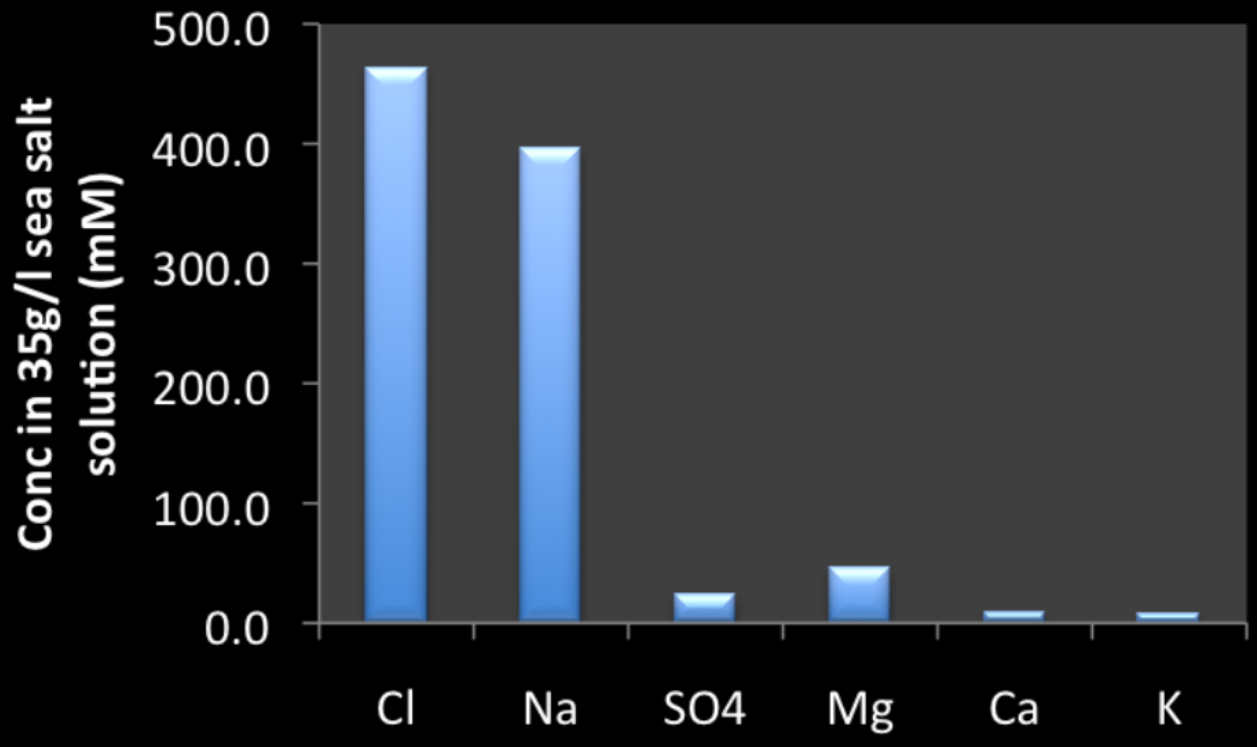


FIG. 2. Membrane stability in the presence of divalent cations. Photomicrographs of (A–C) DA and (D–F) GMD:DA mixed bilayers stained with rhodamine 6G. A and D: Vesicles in the stock solution before the addition of any salt. B and E and C and F: Samples contain magnesium and calcium, respectively, at a molar ratio of divalent cation to DA of 1:2. E: Note the appearance of flattened structures. The bar scales in A and D–F represent 10 μm and in B and C 20 μm.

from Monnard et al., Astrobiology, 2002

- Salt normally detrimental
- Necessary for certain reactions
- Likely component of prebiotic oceans



$MgCl_2$ added $CaCl_2$ added

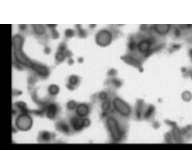
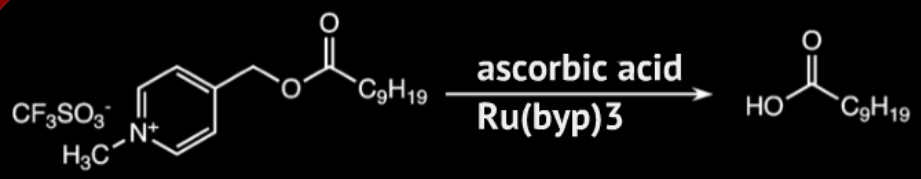


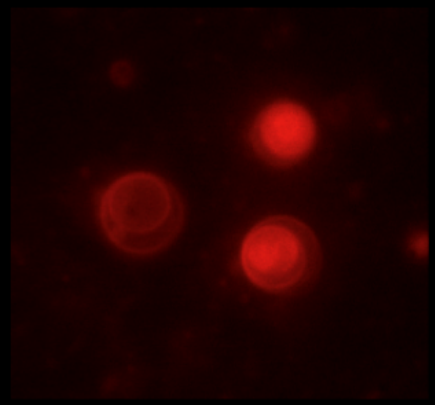
FIG. 2. Membrane stabilit
mixed bilayers stained with
B and E and C and F: Samp
DA of 1:2. E: Note the appea
C 20 μm.

from Mor

Synthesis and self-assembly



Goal: light driven reaction causes formation of vesicular structures.
Growth and Division!



Lack of stability as a selection mechanism?

al work

ty

ense, DK

Conclusion

The emergenceness of these systems are dependent on the instabilities inherently present in lipid structures, which need to be harnessed to create protocellular systems

Outlook

Movement caused by instablity trapped between glass

- Competition between stable and unstable systems (including cannabalism)
- Temperature induced reactions from fusion or leakage
- Discovery of new environments for protocellular reactions

Structures on the Edge of Stability

Sarah E. Maurer, smaurer@ifk.sdu.dk
Center for Fundamental Living Technology, University of Southern Denmark, Odense, DK

Acknowledgements

Steen Rasmussen
Pierre-Alain Monnard
Marty Hanczyc
Gabriel Piedrafita
Maik Hadorn
Eva Bonzli
Lone Laursen
Mark Dorr
Michael Wamberg
Pernille Pedersen
Phillipp Loffler
Rafal Weiczorek

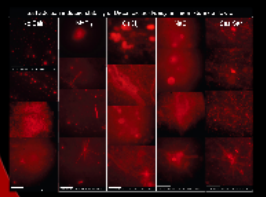
Structures on the Edge of Stability

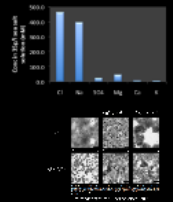
Sarah E. Maurer, smaurer@ifk.sdu.dk
Center for Fundamental Living Technology, University of Southern Denmark, Odense, DK

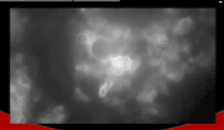
Low pH, High salt, High temperature

Namani & Deamer, OLEB 2008

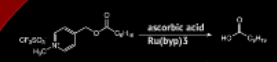
- Salt normally detrimental
- Necessary for certain reactions
- Likely component of prebiotic oceans



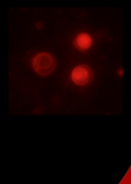




Synthesis and self-assembly



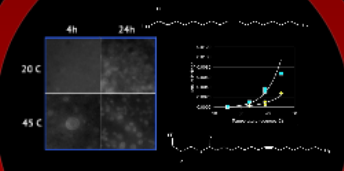
Goal: light driven reaction causes formation of vesicular structures.
Growth and Division!



Lack of stability as a selection mechanism?

Experimental work

Temperature and Stability



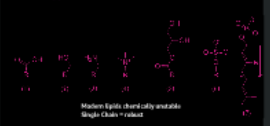
- Permeability and rate of fusion are both increased at higher temp
- Adding second amphiphile (GM headgroup) decreases these effects.

Maurer, et al. Astrobiology 2009, 9, 979-987.

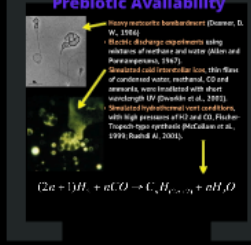
Background

Single chain amphiphile library

- Concentrations
- Salt stability
- pH
- Temperature

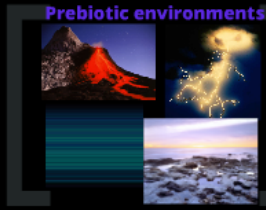


Prebiotic Availability



What is stability?

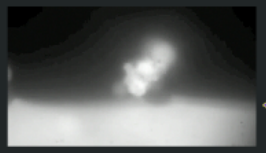
Prebiotic environments



Conclusion

The emergenceness of these systems are dependent on the instabilities inherently present in lipid structures, which need to be harnessed to create protocellular systems

Outlook



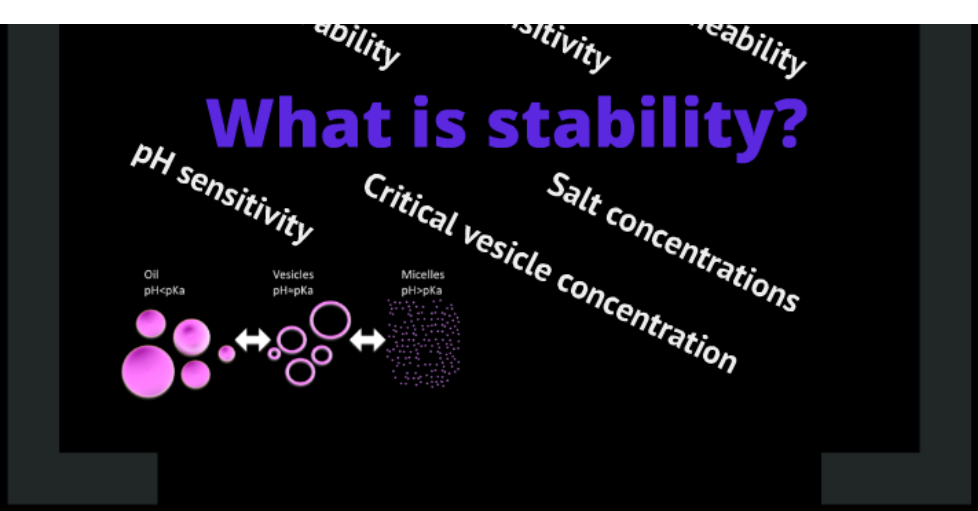
Movement caused by instablity trapped between glass

- Competition between stable and unstable systems (including cannabalism)
- Temperature induced reactions from fusion or leakage
- Discovery of new environments for protocellular reactions

Acknowledgements

Steen Rasmussen
Pierre-Alain Monnard
Marty Hanczyc
Gabriel Piedrafita
Maik Hadorn
Eva Bonzli
Lone Laursen
Mark Dorr
Michael Wamberg
Pernille Pedersen
Phillipp Loffler
Rafal Weiczorek

Lack of stability as a selection mechanism?



Structures on the Edge of Stability

Sarah E. Maurer, smaurer@ifk.sdu.dk
Center for Fundamental Living Technology, University of Southern Denmark, Odense, DK

Acknowledgements

Steen Rasmussen
Lone Laursen
Pierre-Alain Monnard
Mark Dorr