Microbial ocean metagenomics : the central dogma meets systems ecology.

Ed DeLong - October 4, 2006 - San Diego

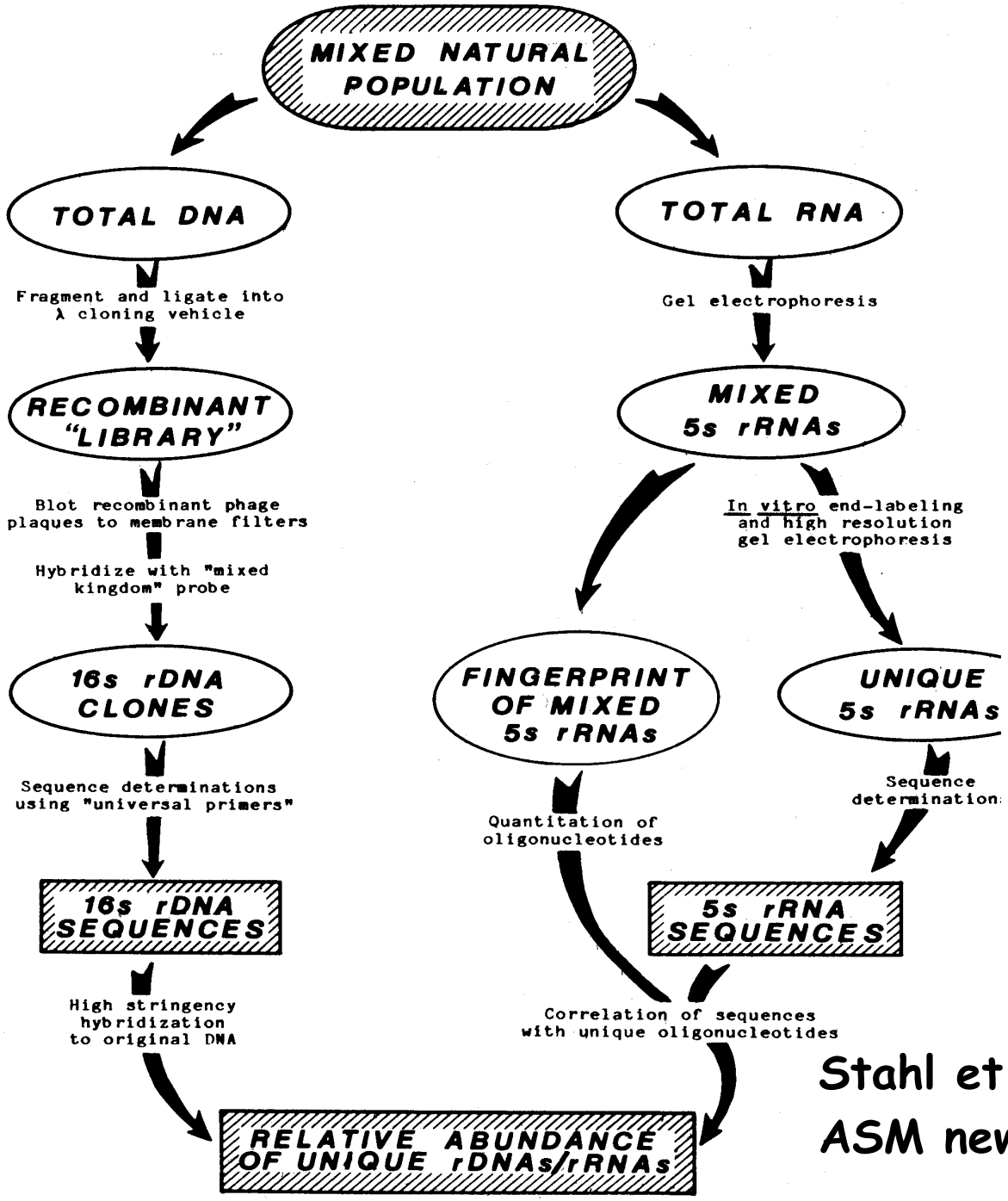
CULTIVATION INDEPENDENT SURVEYS

A la Pace et al., 1986

(Stahl, Olsen, Lane, et al.)

1986 ISME-4 in Ljubljana

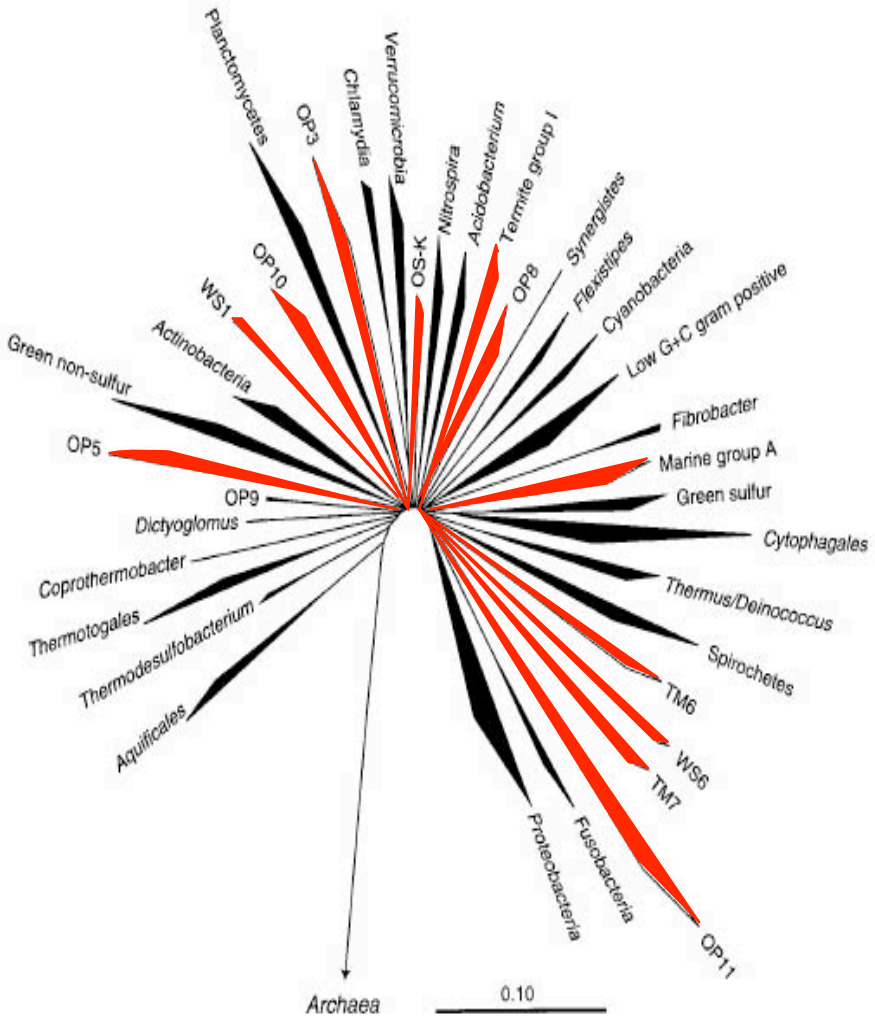
Perspectives in Microbial Ecology

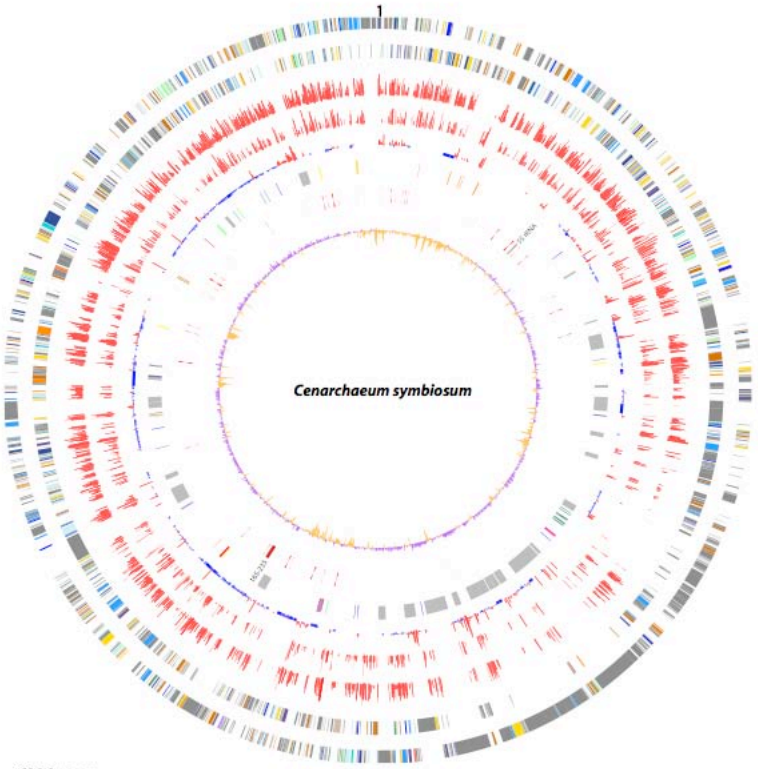


Stahl et al.
ASM news

UNCHARACTERIZED NATIVE TAXA

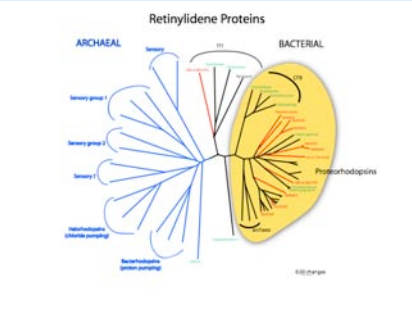
GENOMIC ANALYSES

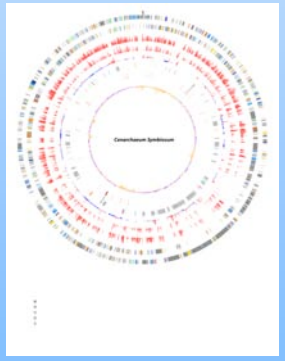


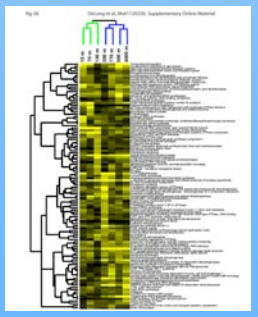


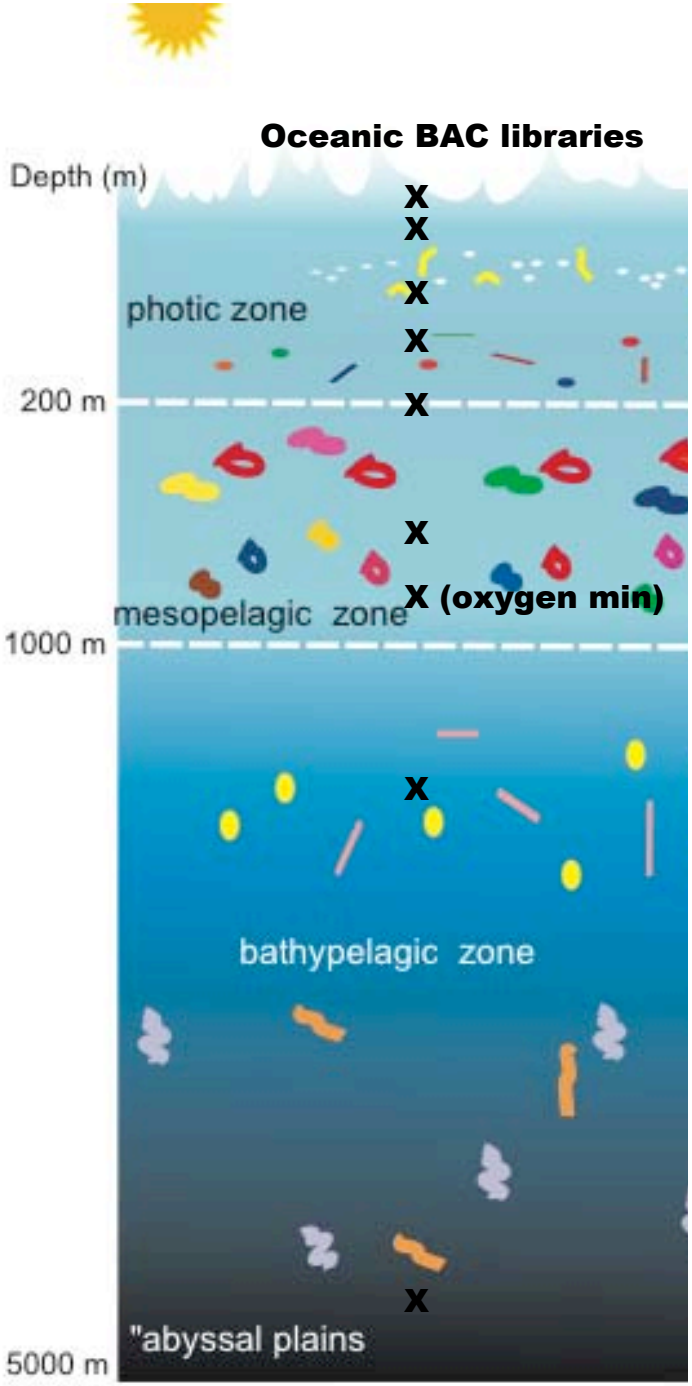
Microbial Community Genomics & Ecology

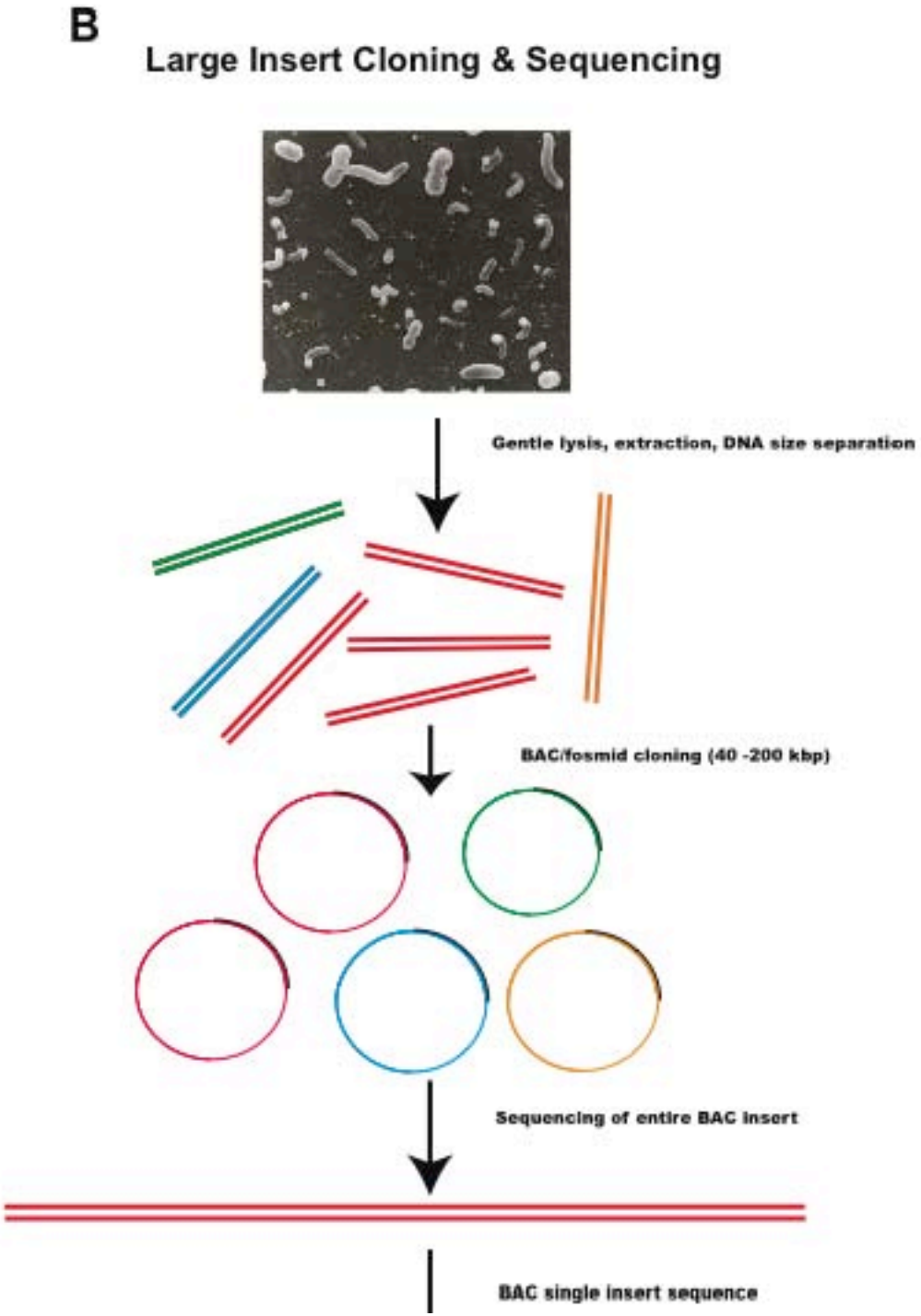
- Philosophical underpinnings
- Proteorhodopsin ecology
- Archaeal metagenomics
- Comparative community genomics



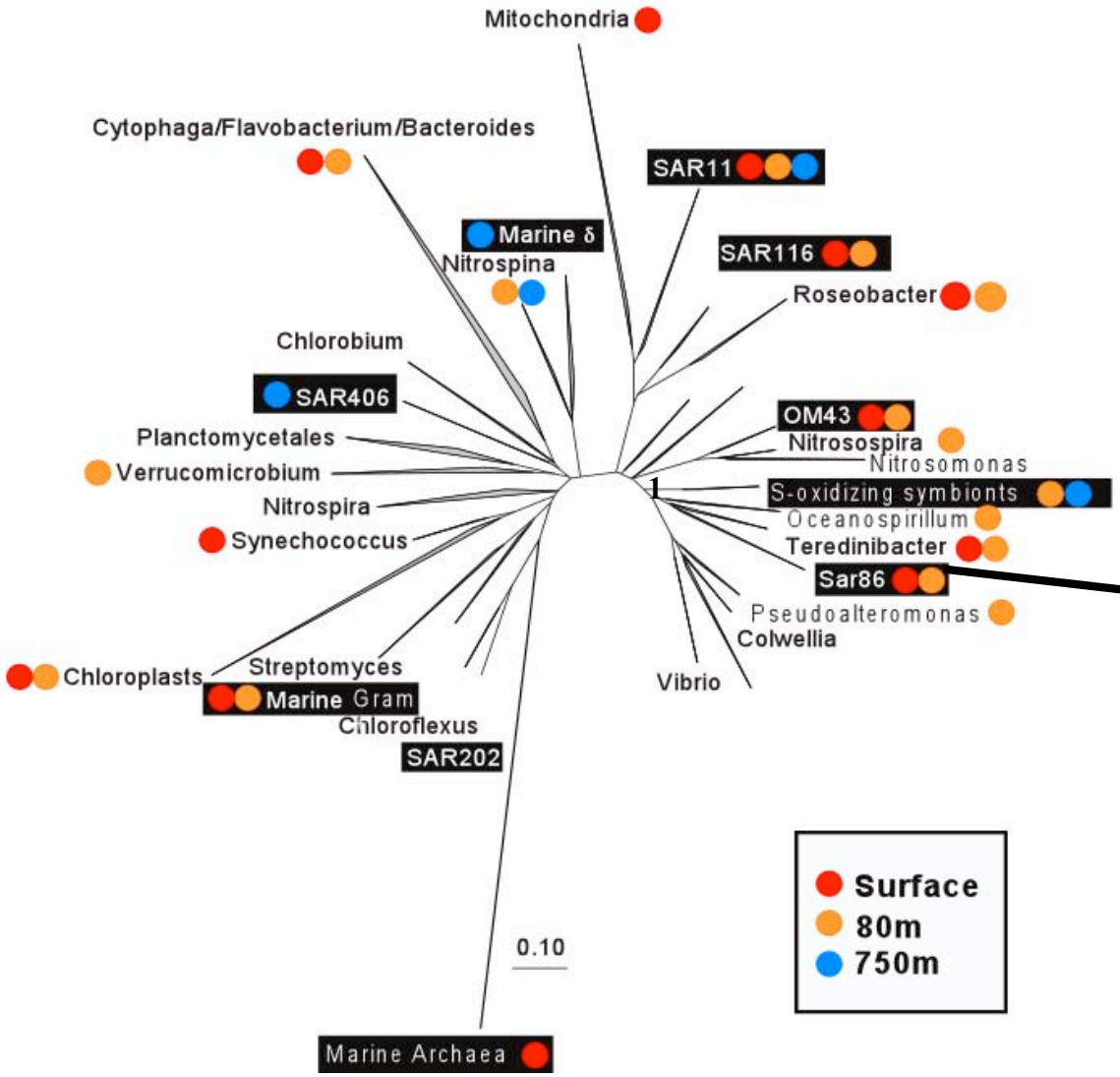




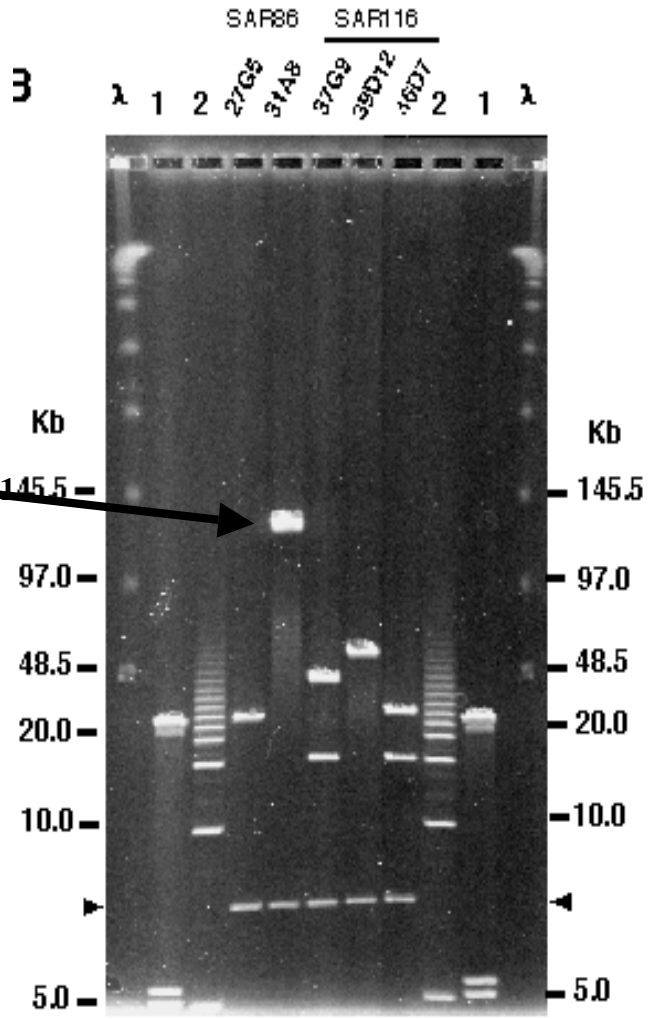

Oceanic BAC libraries
Depth (m)
photic zone
200 m
mesopelagic zone
1000 m
bathypelagic zone
"abyssal plains
5000 m
X
X
X
X
X
X
X (oxygen min)
X
X


B
Large Insert Cloning & Sequencing
Gentle lysis, extraction, DNA size separation
BAC/fosmid cloning (40 -200 kbp)
Sequencing of entire BAC insert
BAC single insert sequence

Monterey Bay BACs

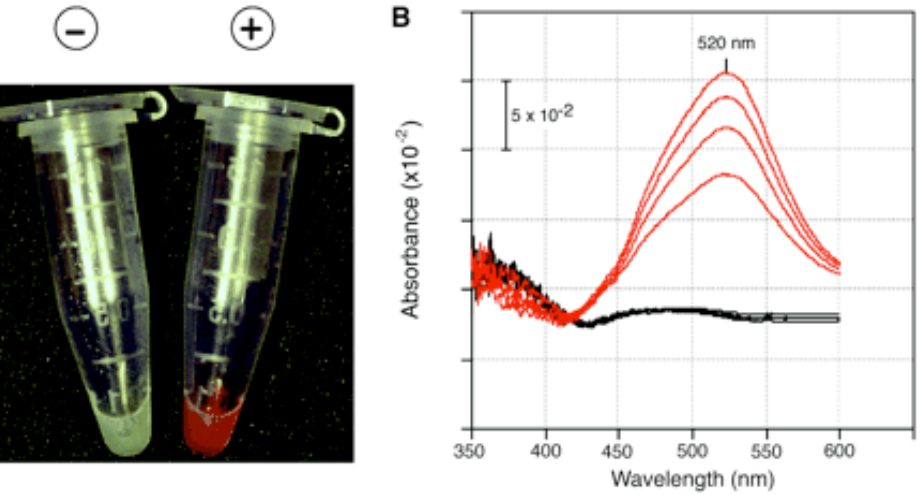


SAR86 130 kbp BAC

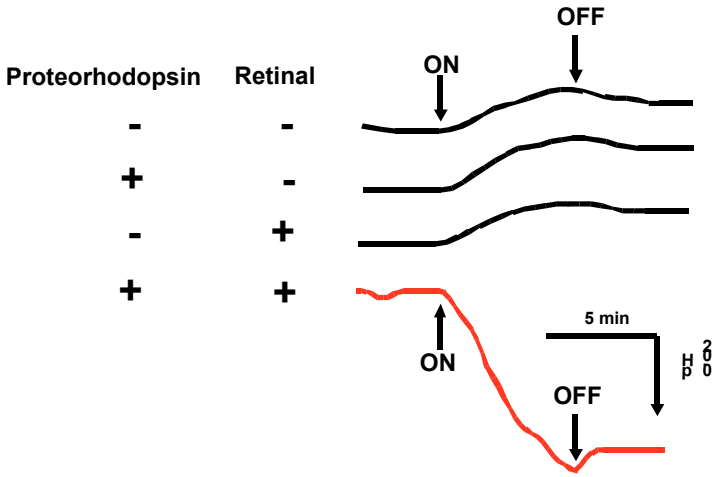


LIGHT-DRIVEN PROTON PUMPING IN E. COLI (via " SAR86" PROTEORHODOPSIN)

Oded Beja

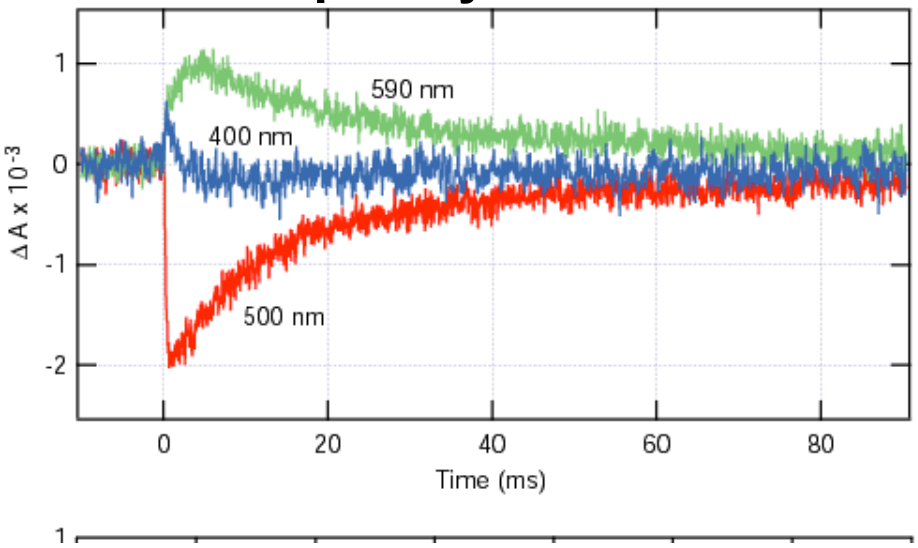


Expression of proteorhodopsin in *E. coli*

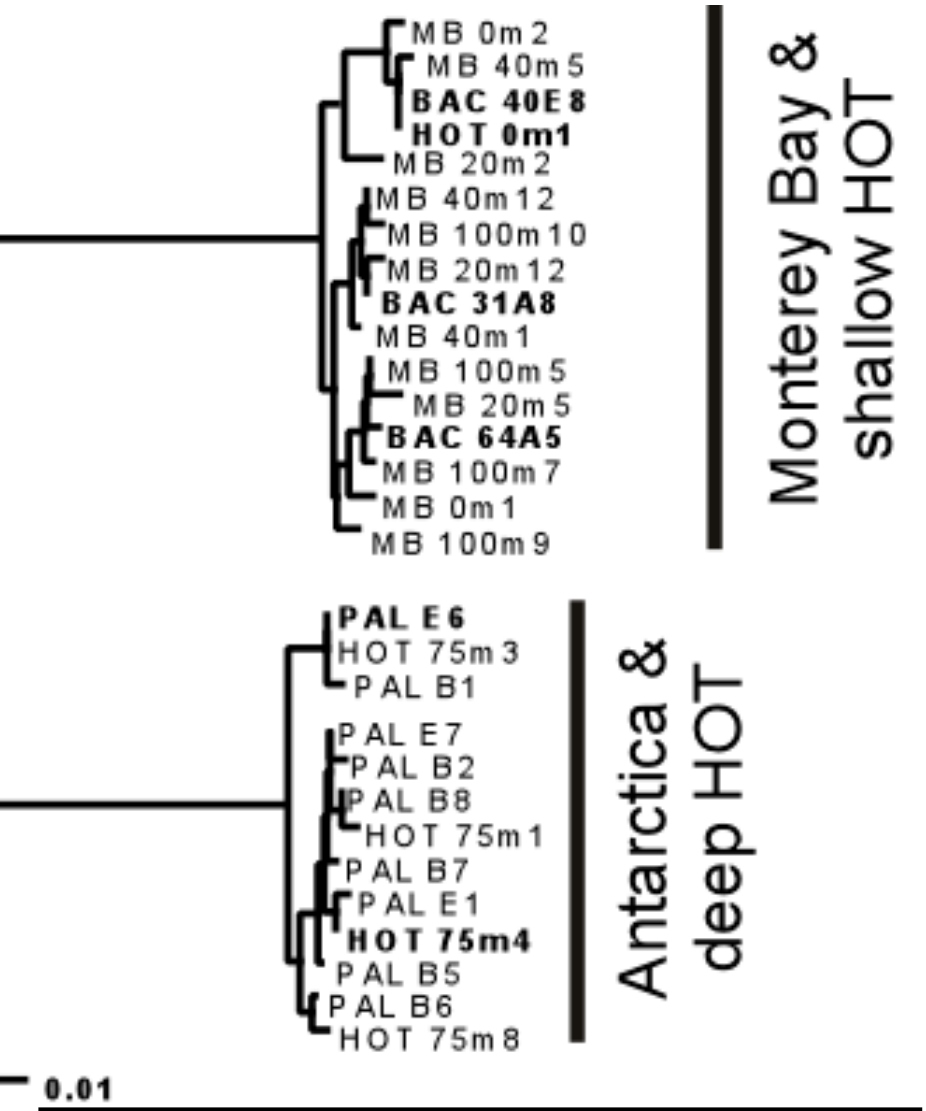


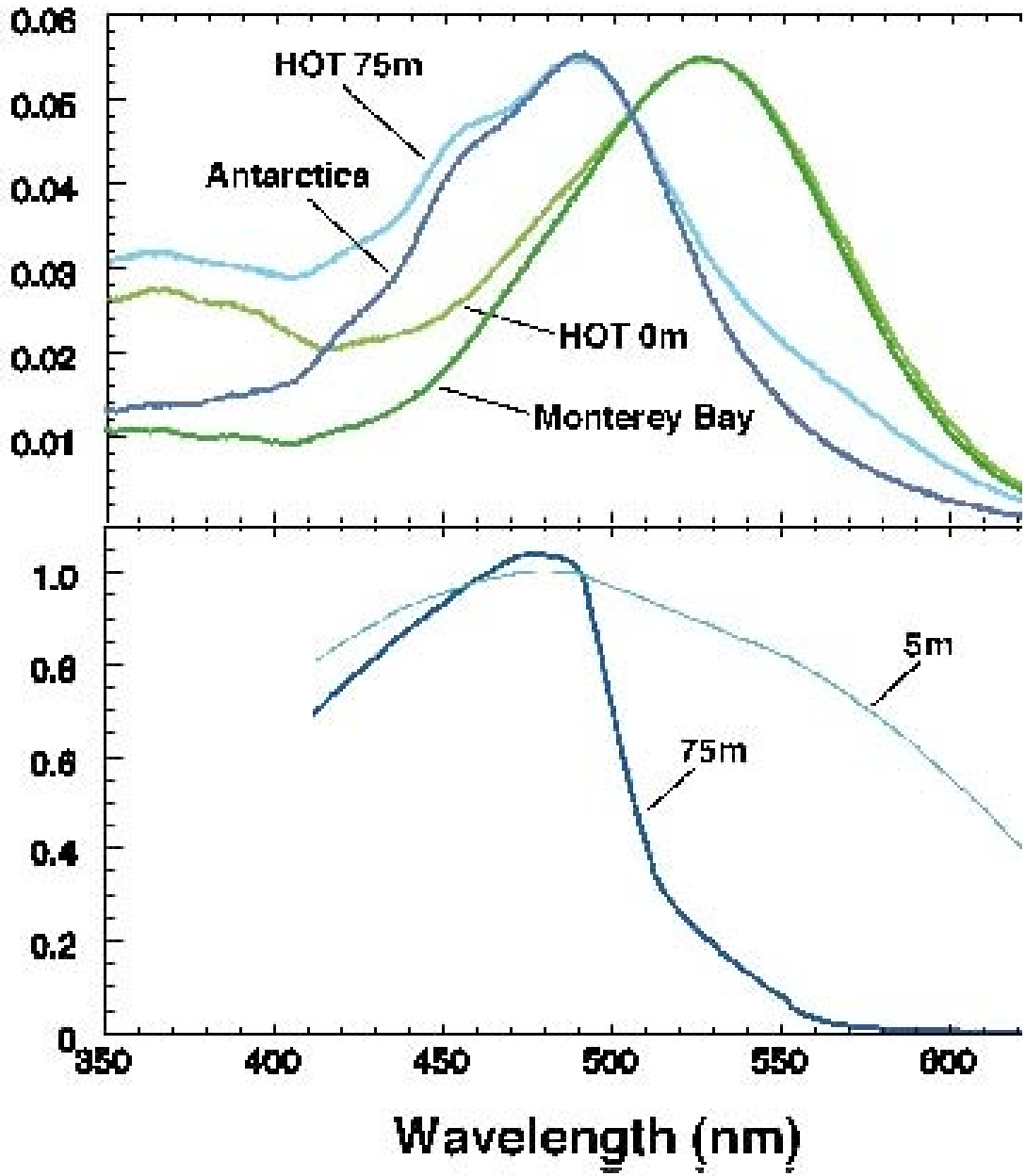
Béjà et al. Science 289: 1902-1906 (2000)

Fast photcycle kinetics

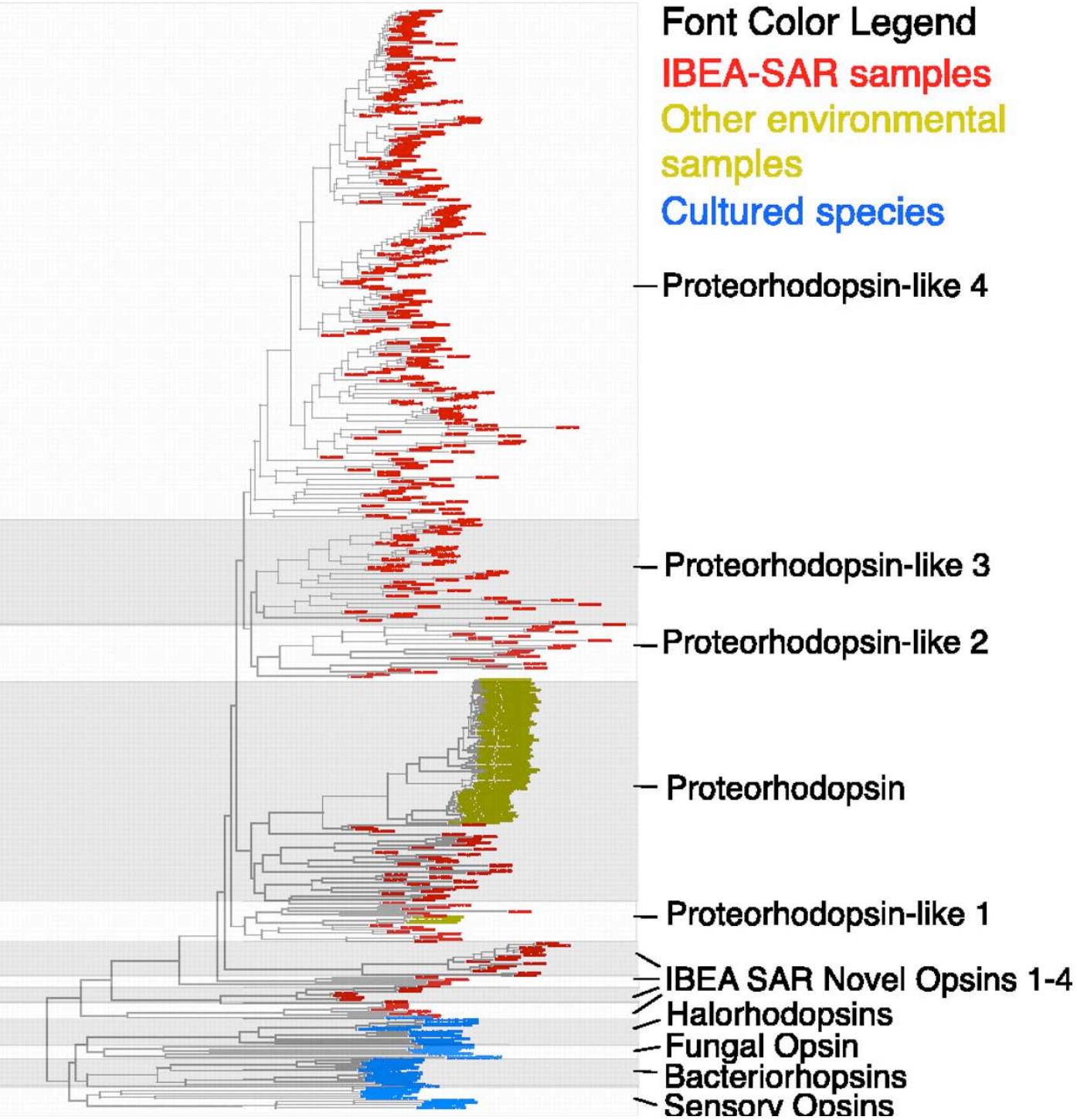


Depth-specific differences in proteorhodopsin variants





Béjà et al. Nature 411:786-789 (2001)



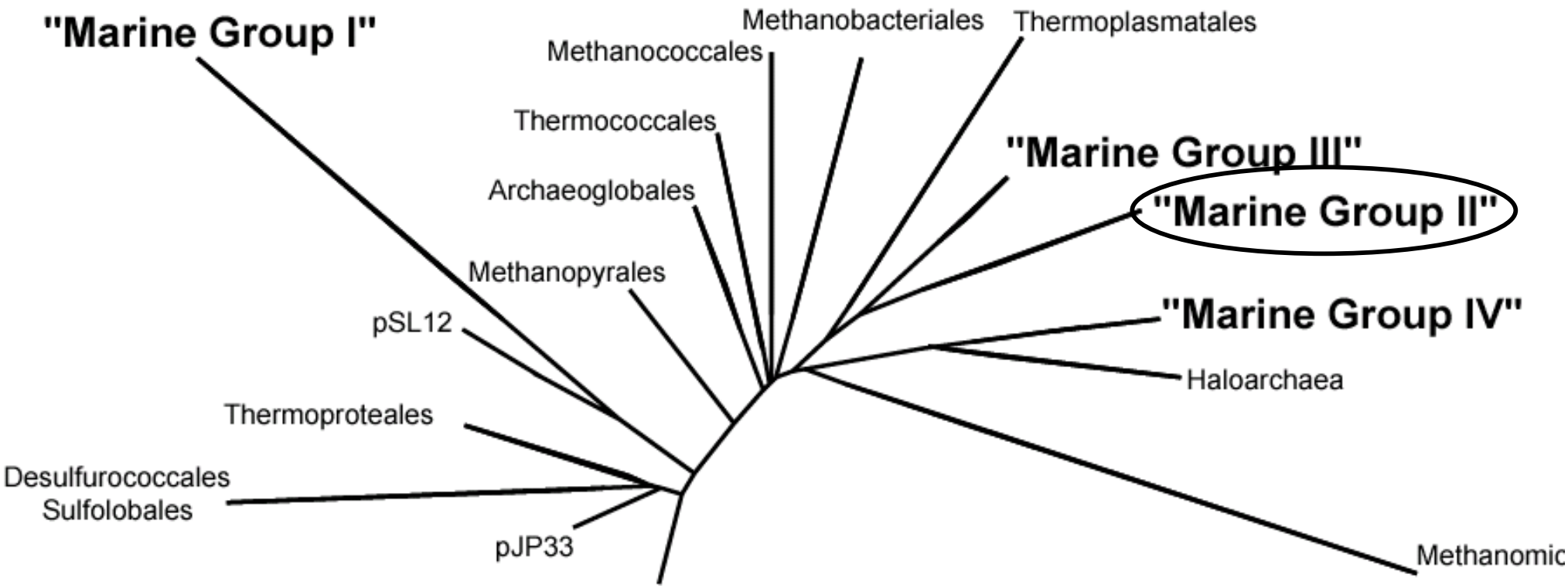
Venter et al., Environmental Genome Shotgun Sequencing of the Sargasso Sea,

Science 394:66-74 (2004)

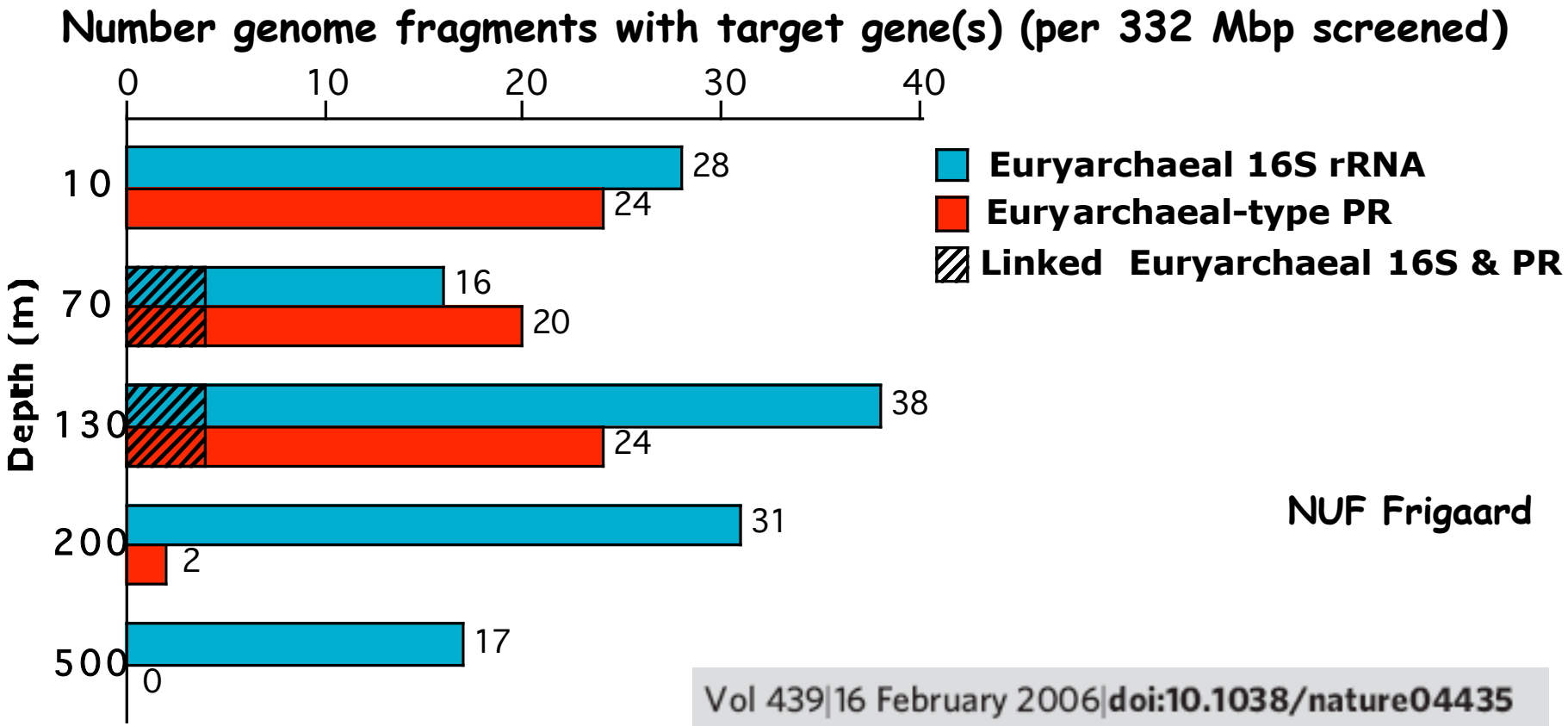
PLANKTONIC ARCHAEA

CRENARCHAEOTA

EURYARCHAEOTA



Archaeal PR gene distributions track the light gradient



NUF Frigaard

Vol 439|16 February 2006|doi:10.1038/nature04435

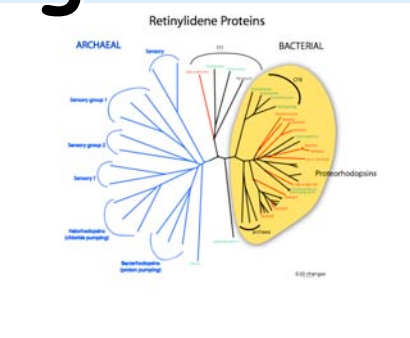
nature

Proteorhodopsin lateral gene transfer between marine planktonic Bacteria and Archaea

Niels-Ulrik Frigaard[1]†, Asuncion Martinez[1], Tracy J. Mincer[1] & Edward F. DeLong[1]

Microbial Community Genomics & Ecology

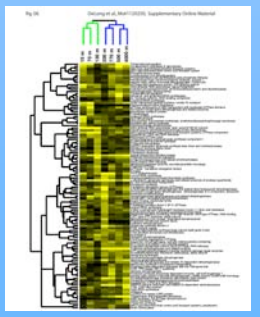
- Background/Philosophical underpinnings

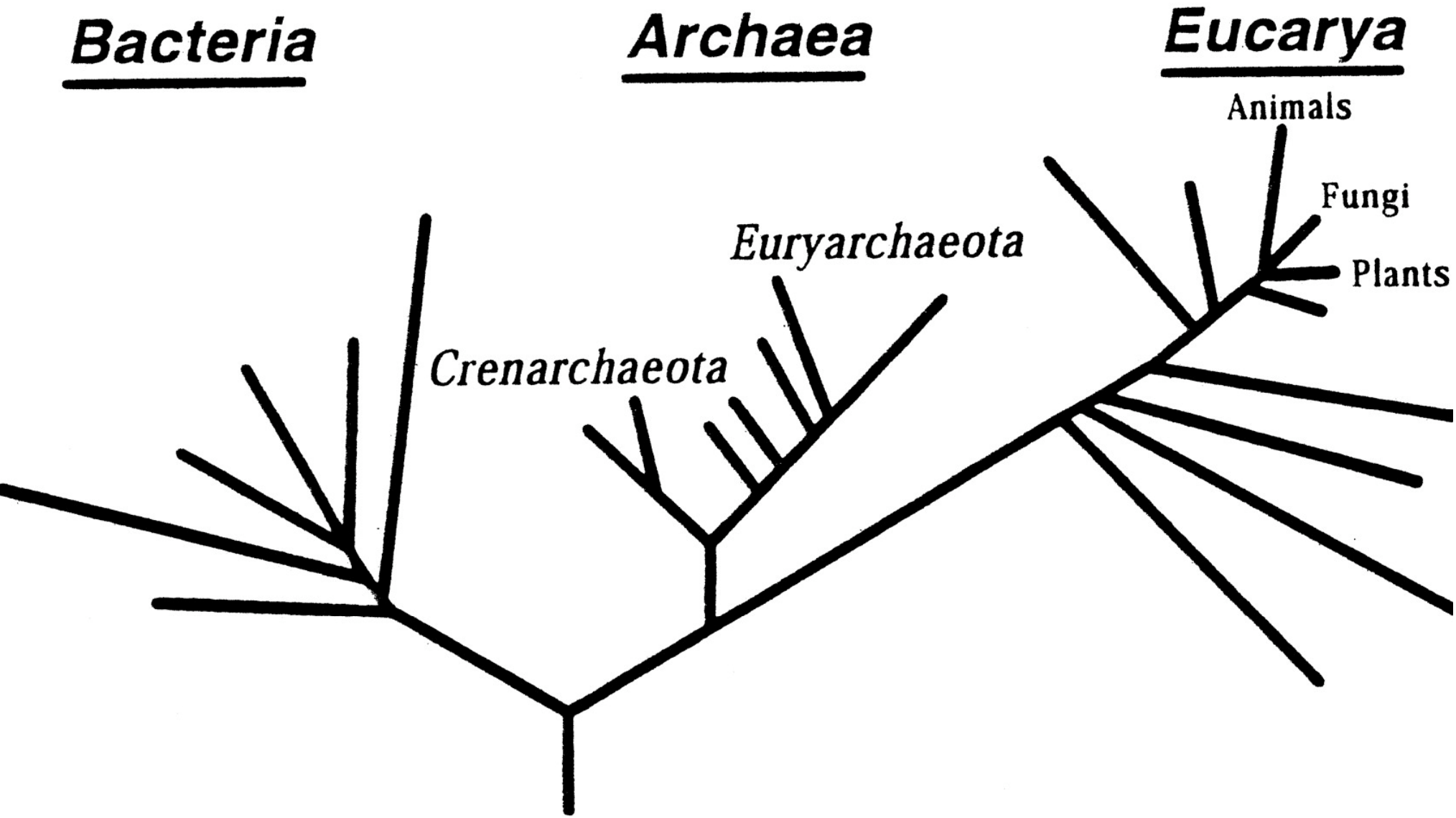


- Proteorhodopsin ecology

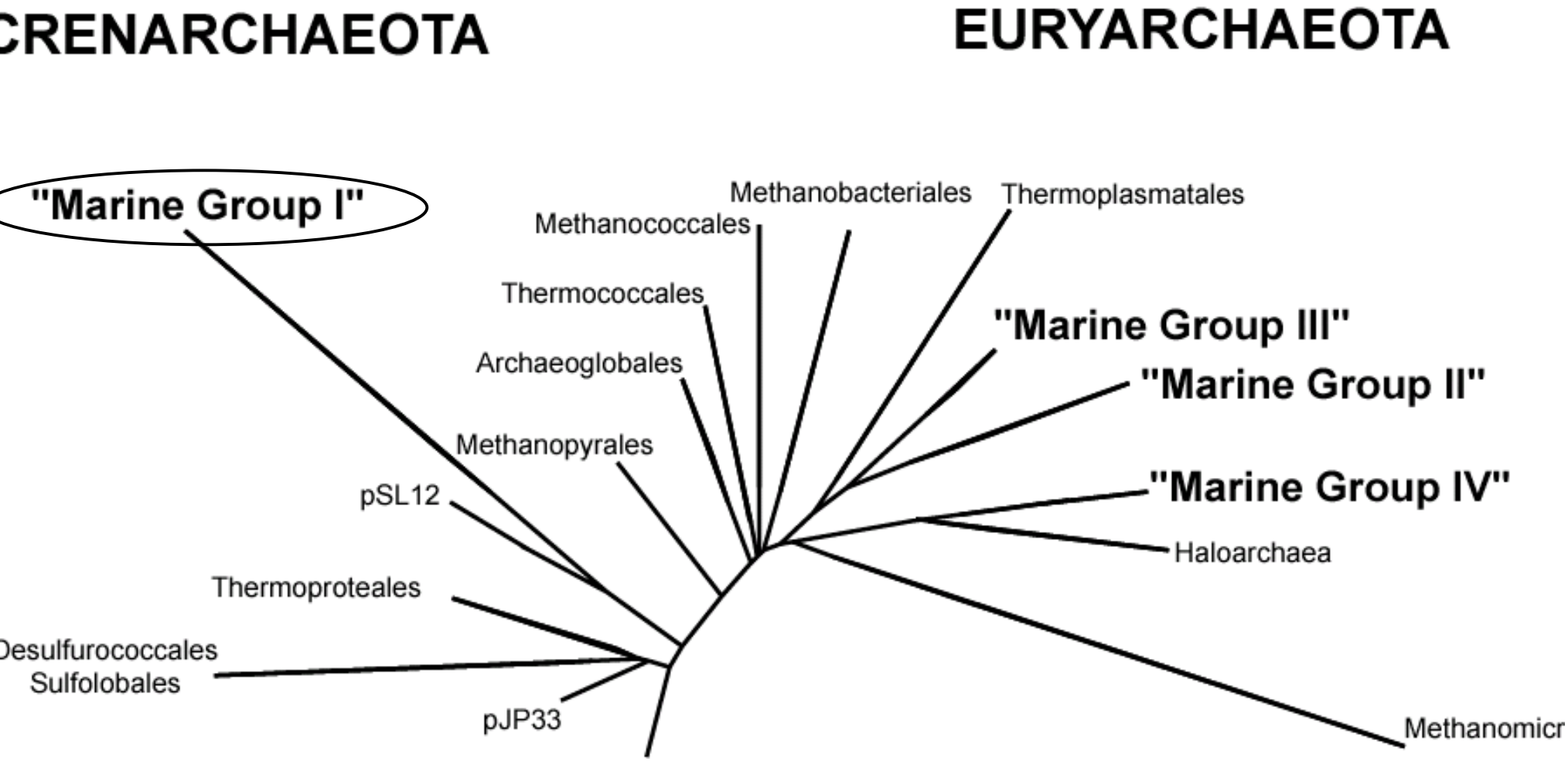
- Crenarchaeal metagenomics

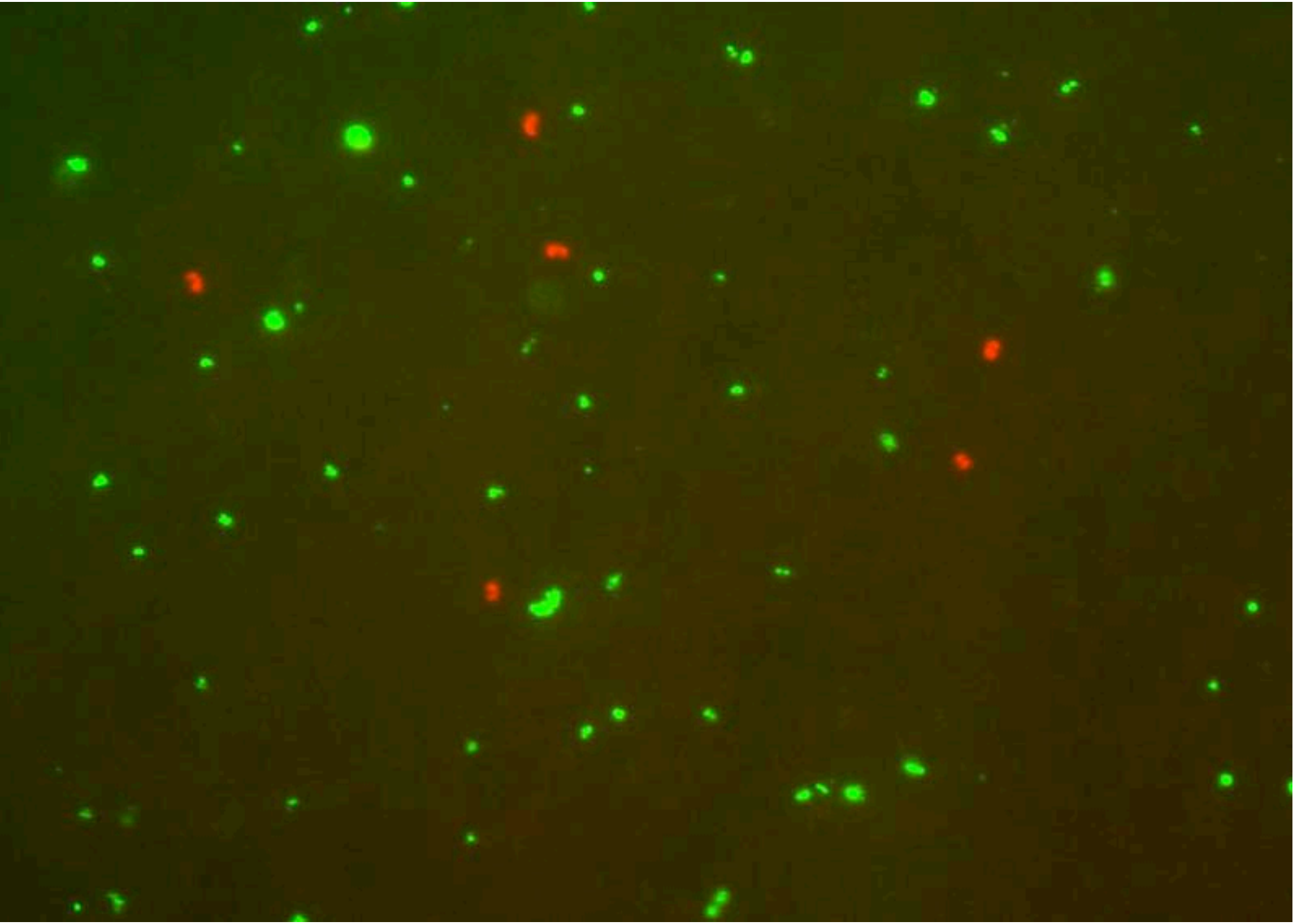
- Comparative community genomics




Bacteria
Archaea
Eucarya
Animals
Fungi
Plants
Euryarchaeota
Crenarchaeota

PLANKTONIC MARINE ARCHAEA

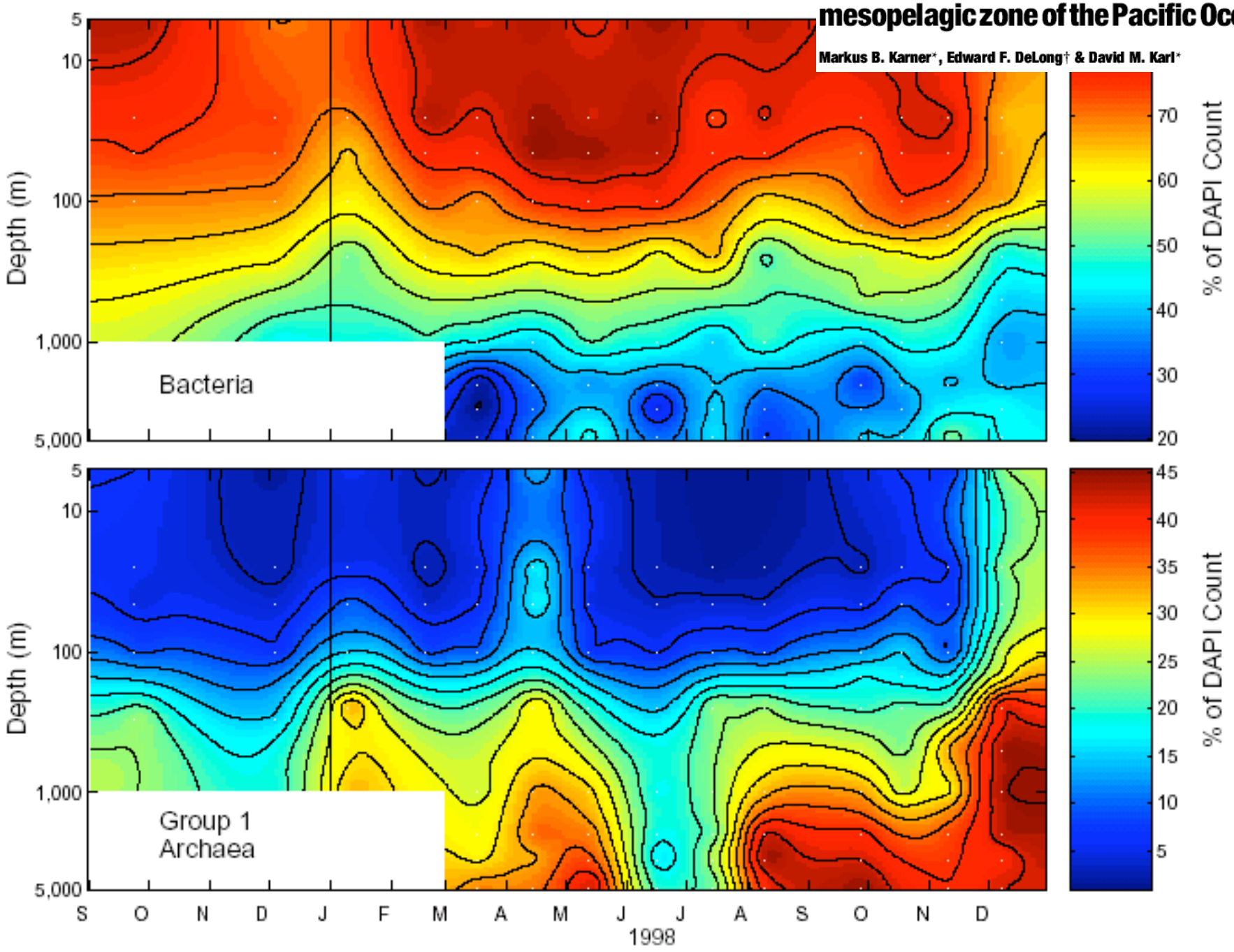




NATURE | VOL 409 | 25 JANUARY 2001 | www.nature.com

Archaeal dominance in the mesopelagic zone of the Pacific Ocean

Markus B. Karner*, Edward F. DeLong† & David M. Karl*



Crenarchaea fix CO_2 - what is the reductant ?

Reports of crenarchaeal-associated amoA-like gene fragments

Venter et al, Science 304: 66 (2004)
Schleper, Nat Rev Micro 3: 479 (2005)
Konneke et al., Nature 437: 543 (2005)
Truesch, Schleper et al., EM 7:1985 (2005)
Francis et al., PNAS 102:14683 (2005)
Hallam et al., PLoS 4: e95 (2006)
Wuchter et al., PNAS 103:12317 (2006)
Leininger, Schleper,et al. Nature 442: 806 (2006)

ARCHAEAL NITRIFICATION ????

Vol 437|22 September 2005|doi:10.1038/nature03911

Isolation of an autotrophic ammonia-oxidizing marine archaeon

Martin Könneke[1]*†, Anne E. Bernhard[1]*†, José R. de la Torre[1]*, Christopher B. Walker[1], John B. Waterbury[1] & David A. Stahl[1]

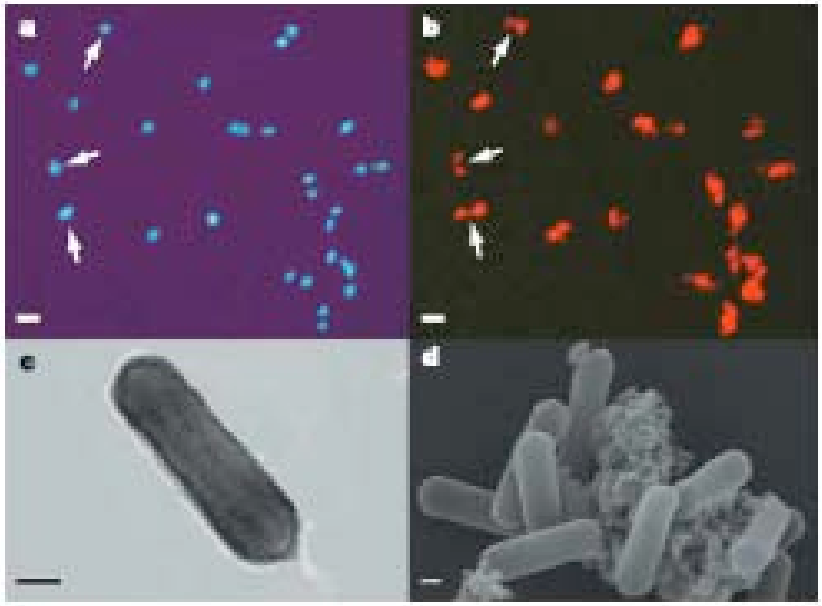


Figure 2 | Photomicrographs of SCM1. a, b, Fluorescence image of cells in identical fields of view stained with DAPI (a) and after hybridization with nucleotide polyprobes targeting SCM1 cells (b). Arrows indicate cells showing the characteristic peanut-like shape of marine Crenarchaeota[1,3,18]. Scale bars represent 1 μm. c, Transmission electron micrograph of negative-stained cells. Scale bar represents 0.1 μm. d, Scanning electron micrograph of Au/Pd-sputtered cells. Scale bar represents 0.1 μm.

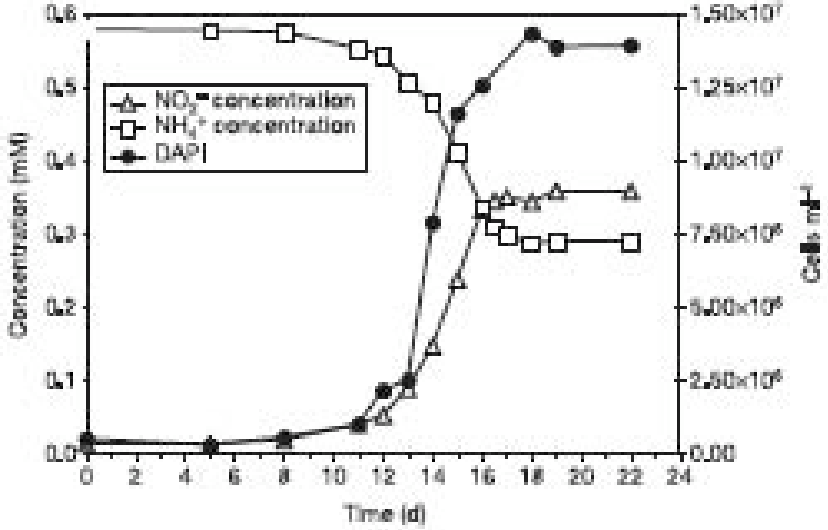
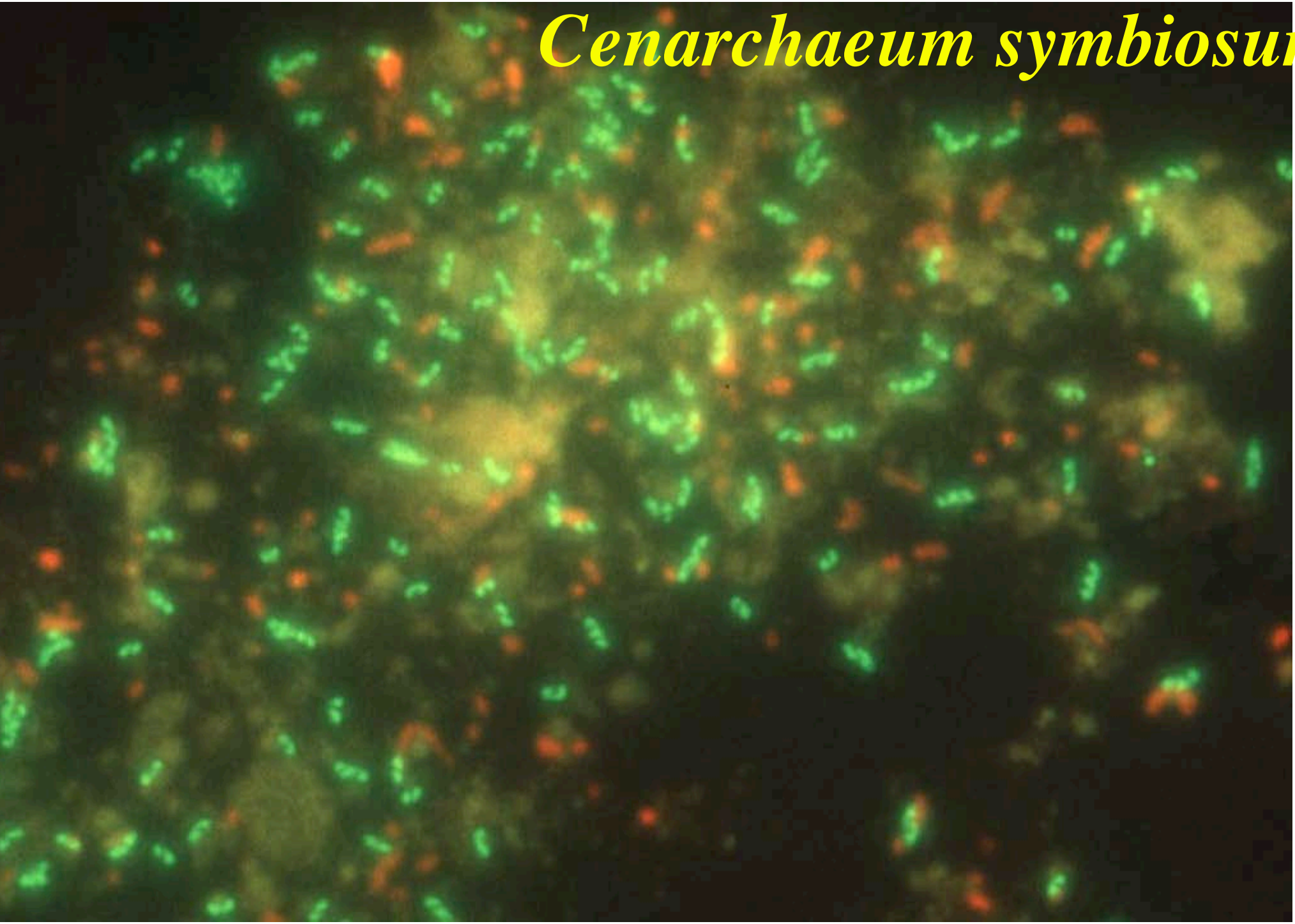
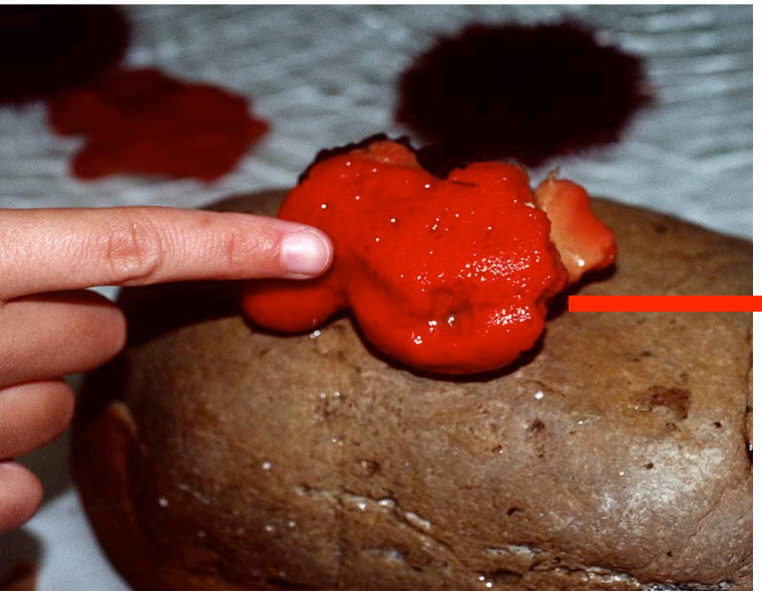
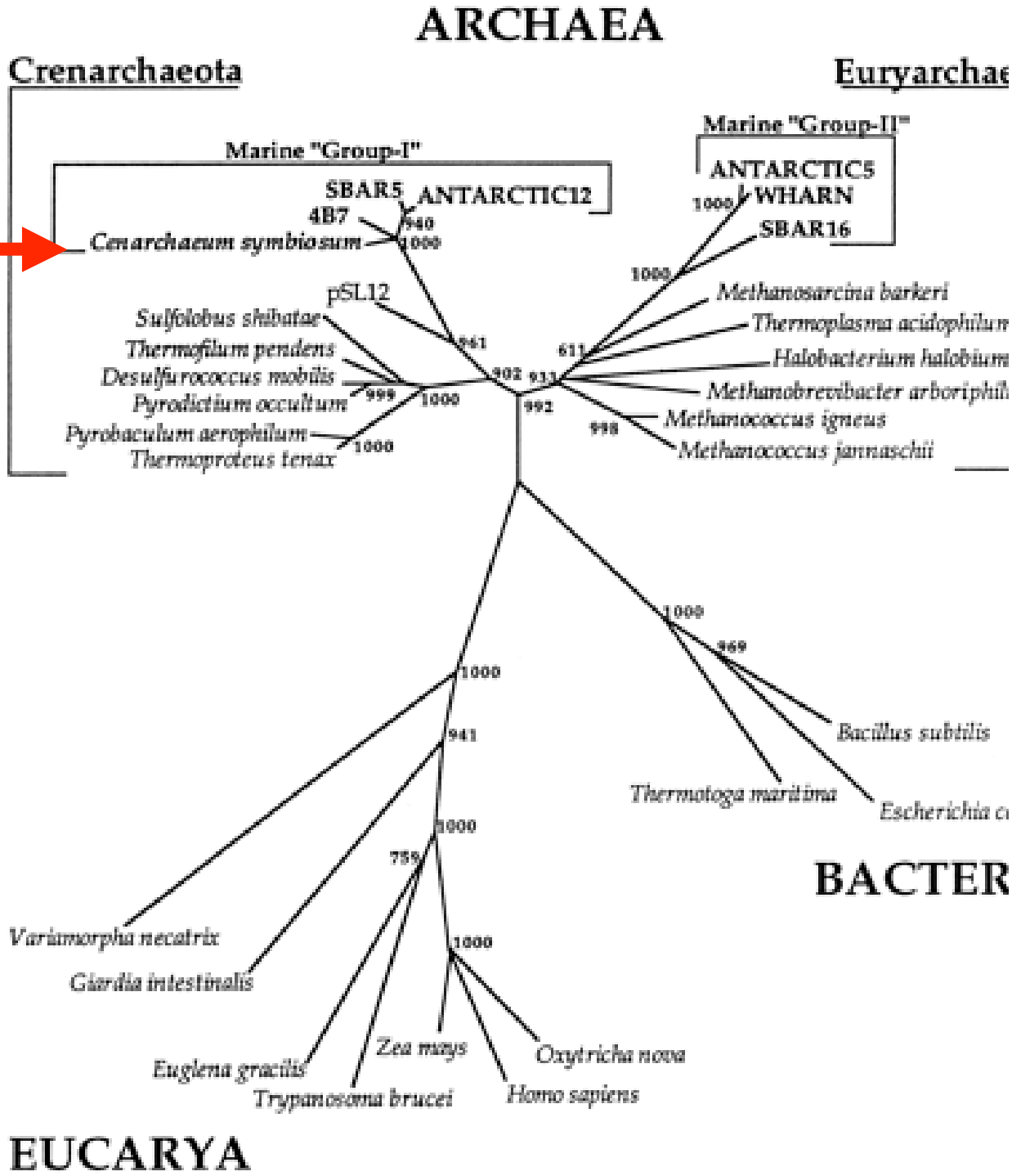


Figure 3 | Near-stoichiometric conversion of ammonia to nitrite by SCM1. Growth of SCM1 in Synthetic Crenarchaeota Media containing ammonium chloride and bicarbonate as sole energy and carbon sources, respectively. DAPI-stained cells were directly counted on filters by fluorescence microscopy. Ammonium consumption and nitrite production were determined in triplicate as described previously[27].

as '*N. maritimus*' to inhabit oligotrophic environments where they may function as important primary producers. In environments devoid of organic energy sources and sunlight, the oxidation of


Cenarchaeum symbiosum

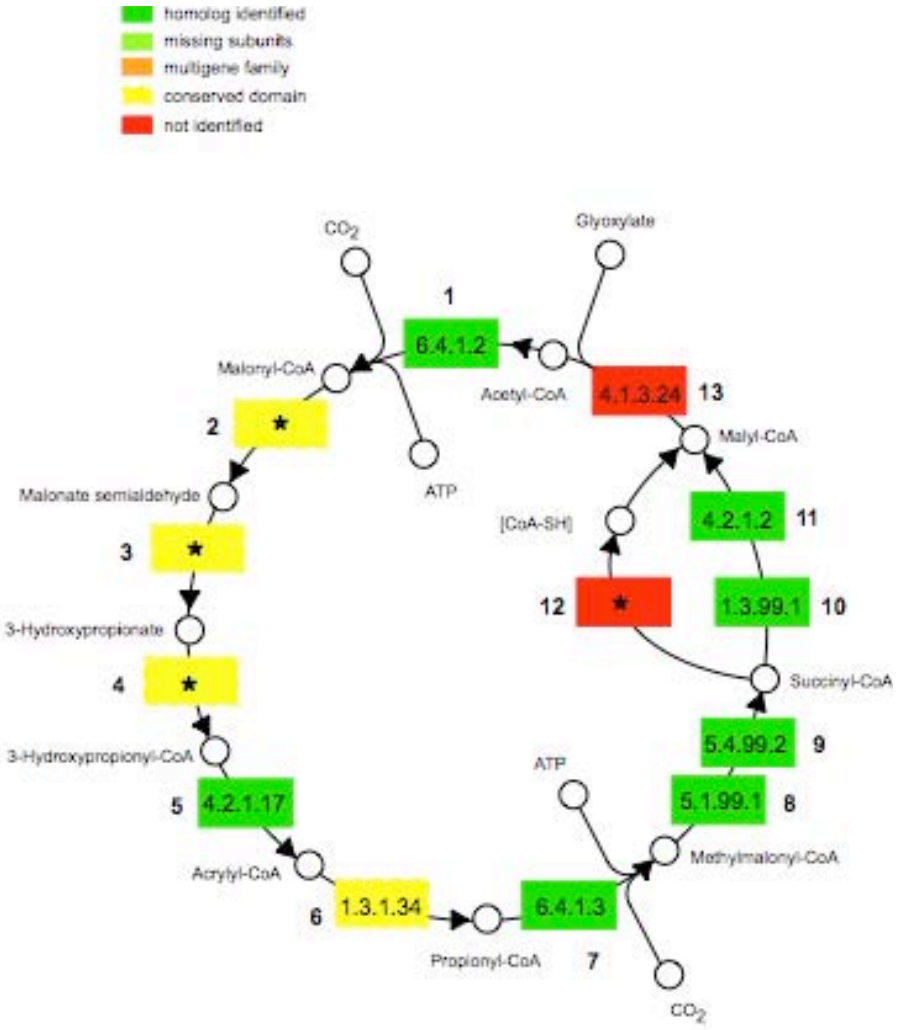



ARCHAEA
Crenarchaeota
Euryarchae
Marine "Group-I"
Marine "Group-II"
SBAR5
ANTARCTIC12
4B7
Cenarchaeum symbiosum
ANTARCTIC5
WHARN
SBAR16
pSL12
Sulfolobus shibatae
Thermofilum pendens
Desulfurococcus mobilis
Pyrodictium occultum
Pyrobaculum aerophilum
Thermoproteus tenax
Methanosarcina barkeri
Thermoplasma acidophilum
Halobacterium halobium
Methanobrevibacter arboriphil
Methanococcus igneus
Methanococcus jannaschii
Bacillus subtilis
Thermotoga maritima
Escherichia c
BACTER
Variamorpha necatrix
Giardia intestinalis
Euglena gracilis
Trypanosoma brucei
Zea mays
Homo sapiens
Oxytricha nova
EUCARYA

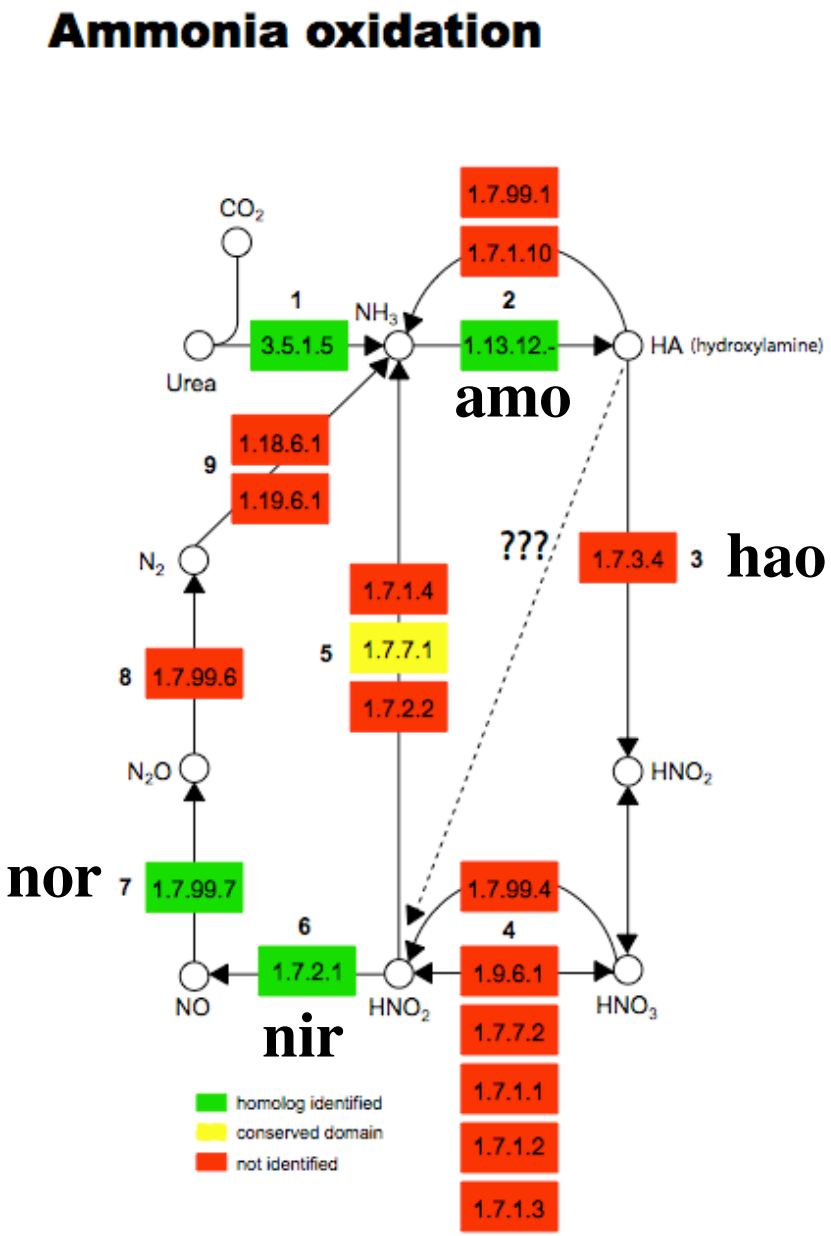
Marine archaeal autotrophy

Hallam et al., PLoS Biol. 4: e95. 2006

Hydroxypropionate cycle components in *C. symbiosum*



arine archaeal NH_4 oxidation

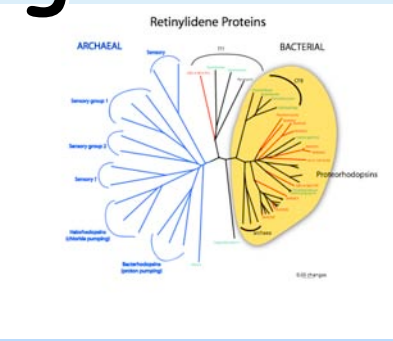


Hallam et al., PLoS Biol. 4: e95. 2006

Gene name		Locus	cenFOS
urea transporter		*dur3*	+
urease			
	α	*ureC*	+
	β	*ureB*	+
	γ	*ureA*	+
	E	*ureE*	+
	F	*ureF*	+
	G	*ureG*	+
	H	*ureH*	+
ammonia monooxygenase			
	A	*amoA*	+
	B	*amoB*	+
	C	*amoC*	+
hydroxylamine oxidoreductase		*hao*	-
nitrate reductase		*nar*	-
nitrite reductase		*nirK*	+
ferredoxin-nitrite reductase		*nirA*	+

Microbial Community Genomics & Ecology

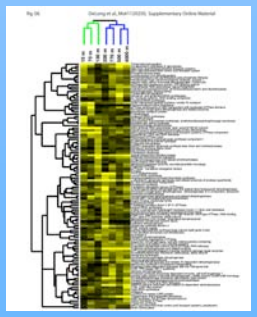
- Background/Philosophical underpinnings



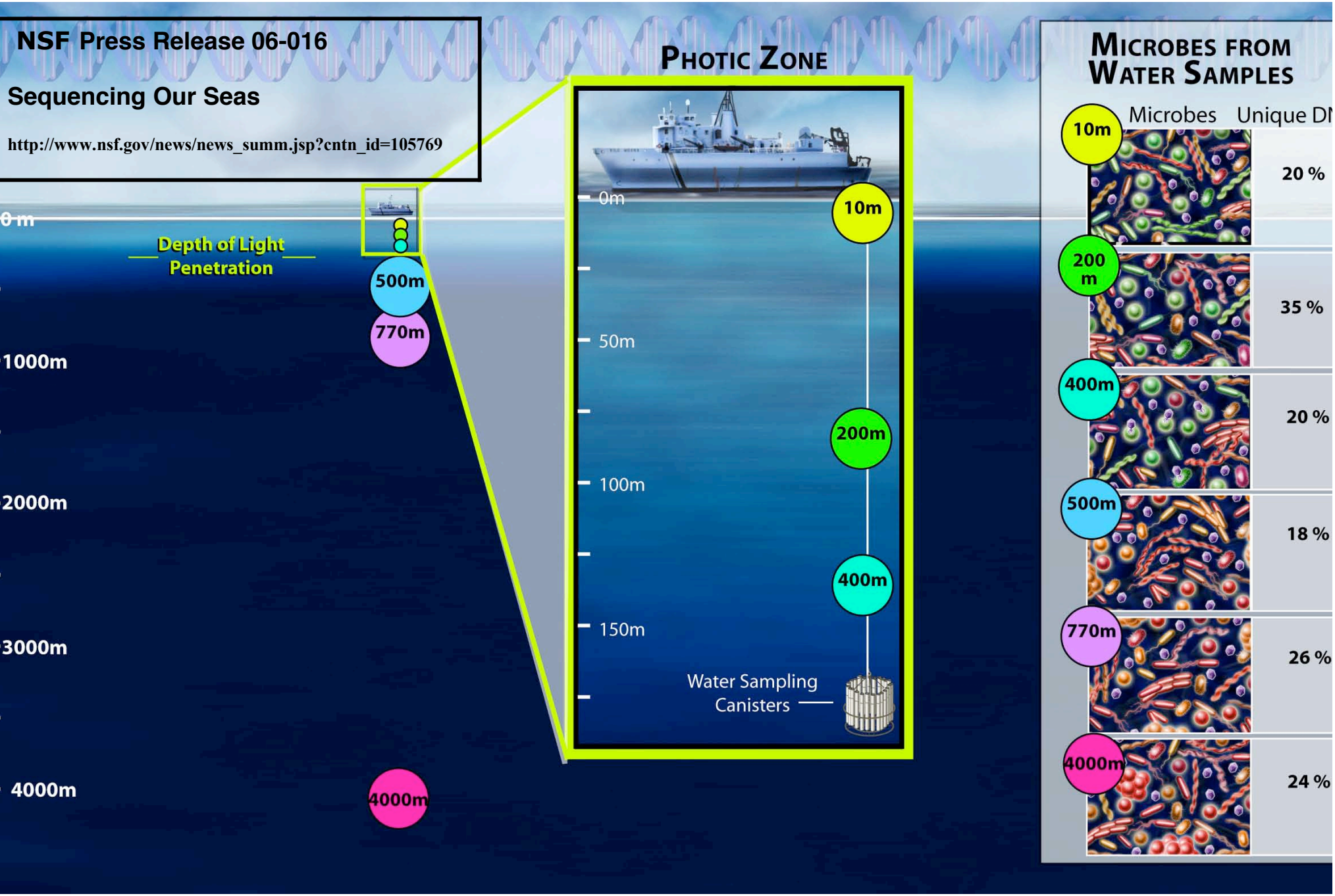
- Proteorhodopsin ecology/physiology

- Crenarchaeal metagenomics

- Comparative community genomics



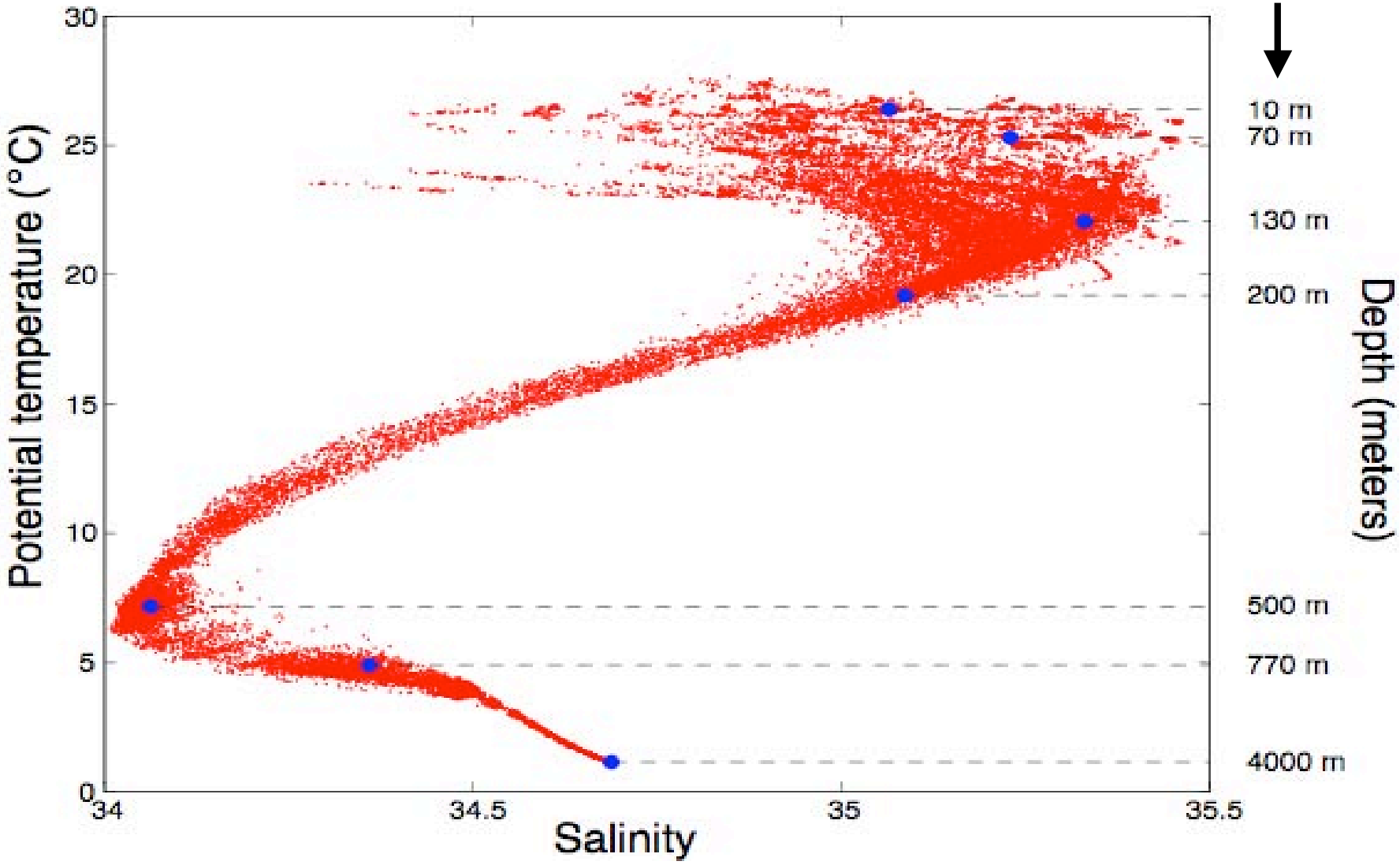
GENOMIC PROFILES IN THE PACIFIC OCEAN

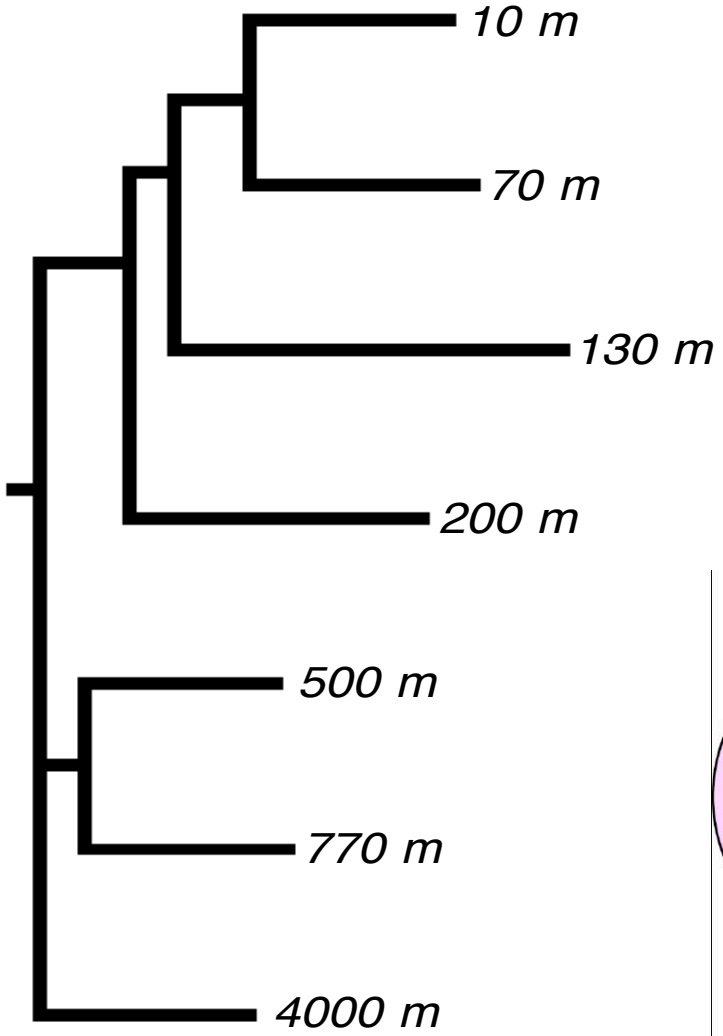


Community Genomics Among Stratified Microbial Assemblages in the Ocean's Interior

SCIENCE VOL 311 27 JANUARY 2006

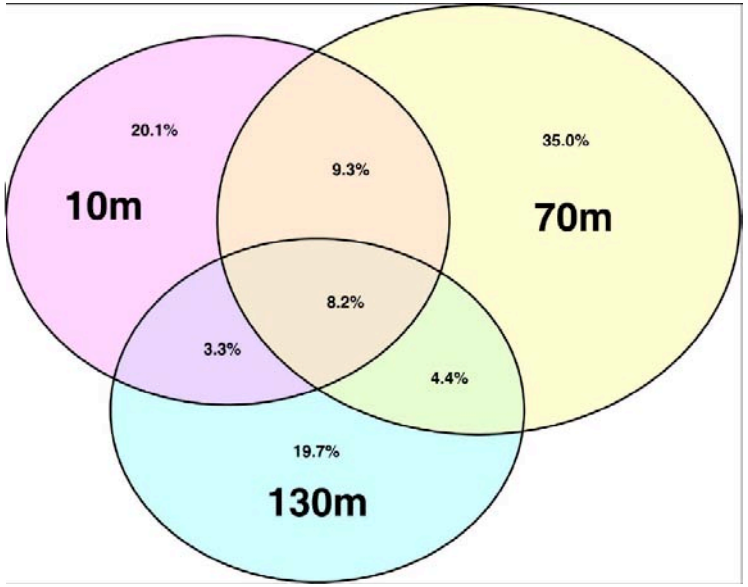
Edward F. DeLong,[1*] Christina M. Preston,[2] Tracy Mincer,[1] Virginia Rich,[1] Steven J. Hallam,[1] Niels-Ulrik Frigaard,[1] Asuncion Martinez,[1] Matthew B. Sullivan,[1] Robert Edwards,[3] Beltran Rodriguez Brito,[3] Sallie W. Chisholm,[1] David M. Karl[4]





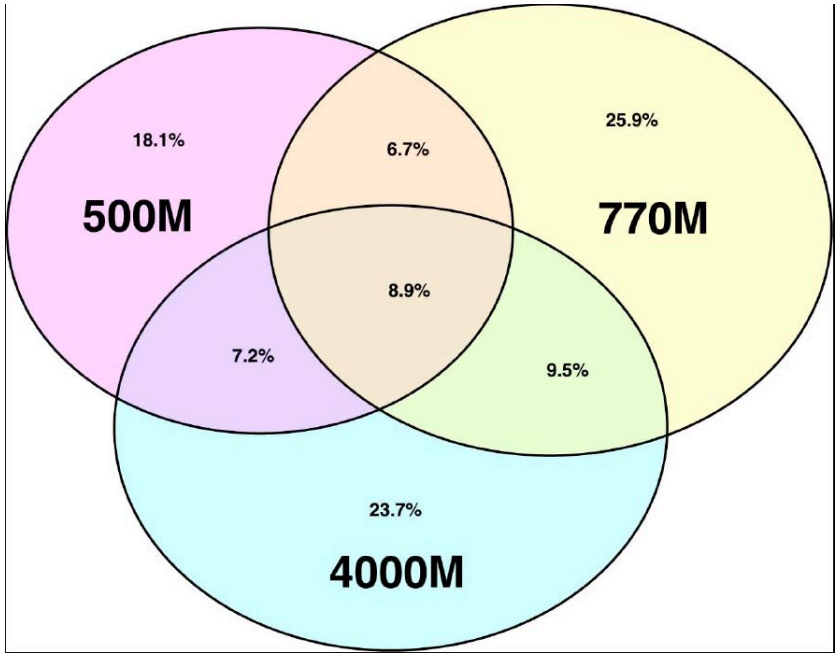
PHOTIC ZONE UNIQUE SEQUENCES

PZ



DEEP WATER UNIQUE SEQUENCES

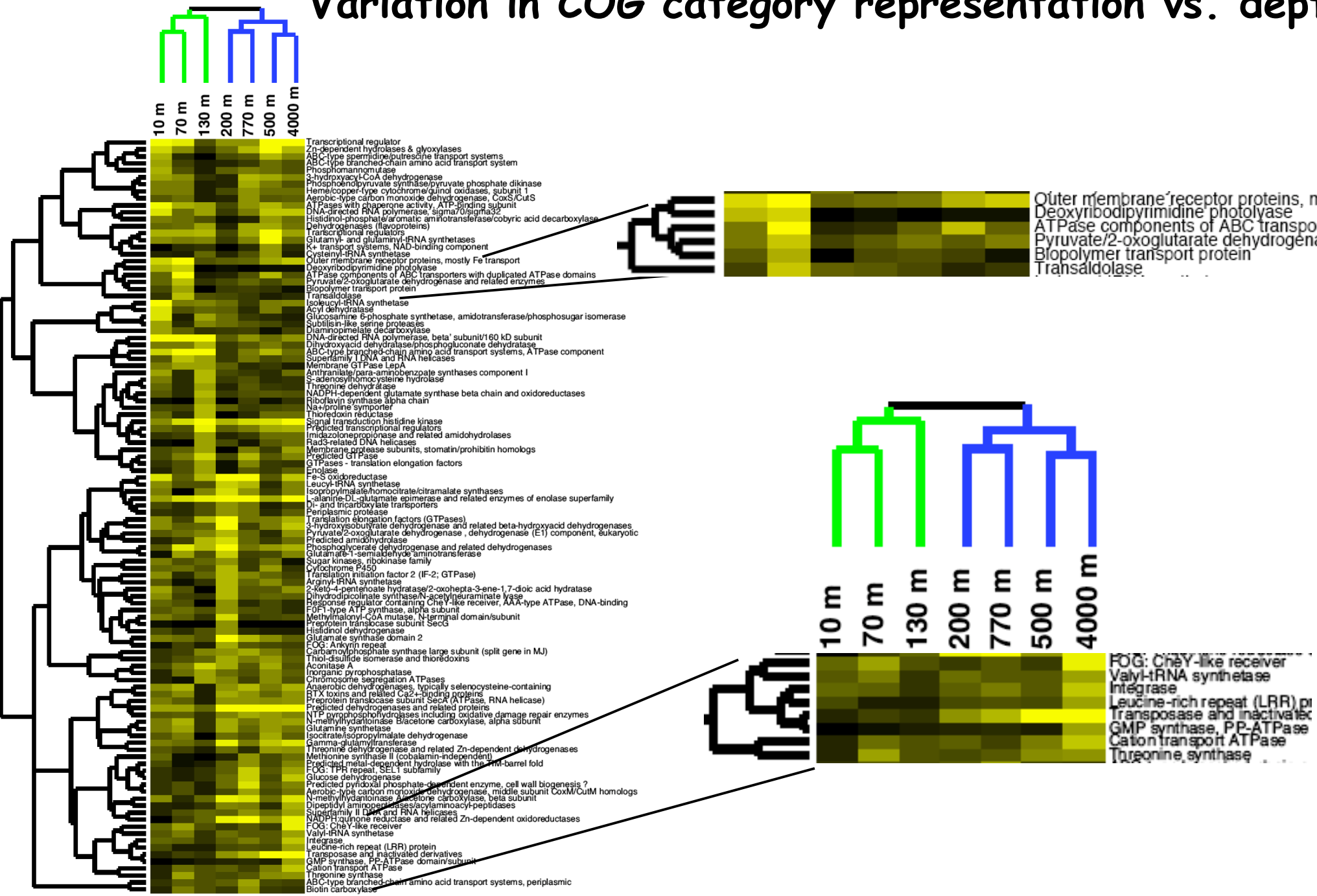
DW

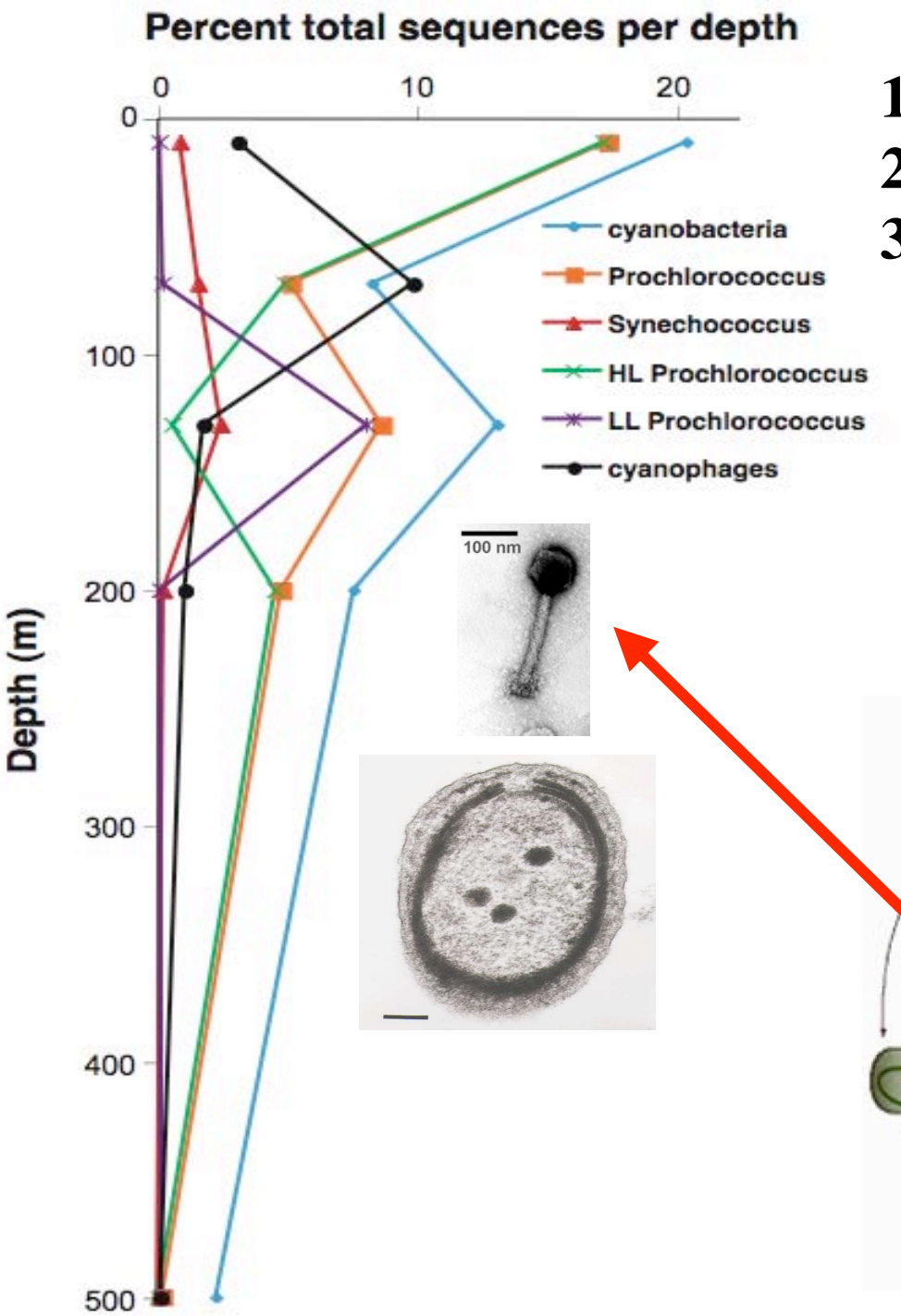


g.S8.

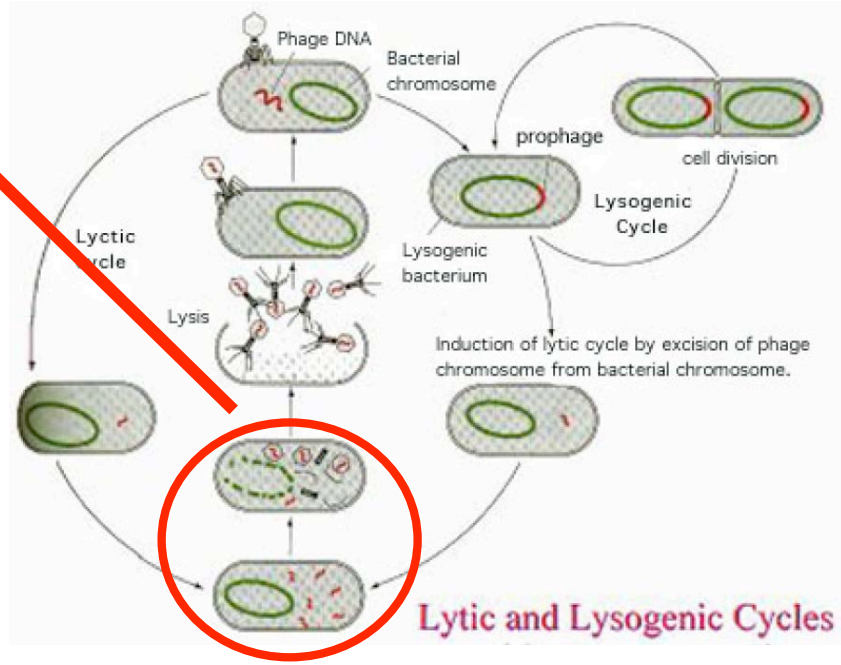
DeLong et al., Ms#

Variation in COG category representation vs. depth





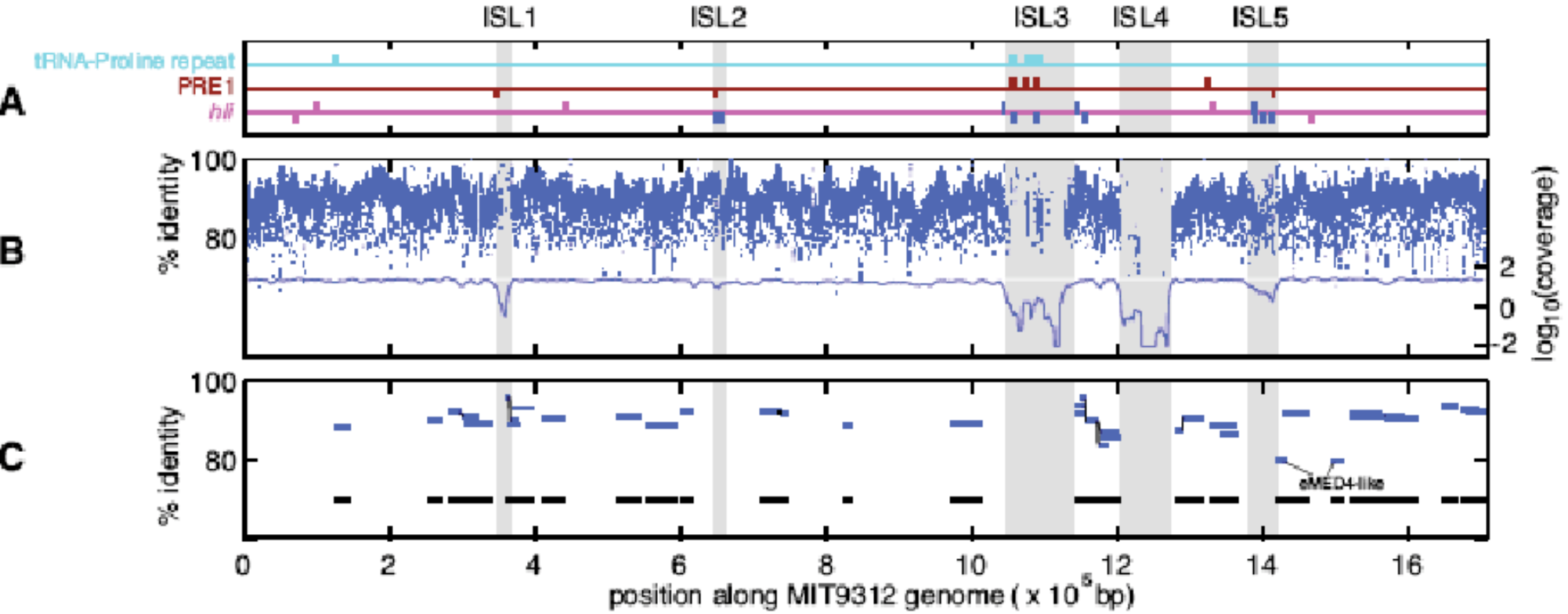
1) **Prochlorococcus phylotypes evident**
2) **Viral recovery maxima - 70 m**
3) **Viral recovery decrease below PZ**



Genomic Islands and the Ecology and Evolution of *Prochlorococcus*

Maureen L. Coleman,[1] Matthew B. Sullivan,[1] Adam C. Martiny,[1] Claudia Steglich,[1*]
Kerrie Barry,[2] Edward F. DeLong,[1] Sallie W. Chisholm[1†]

24 MARCH 2006 VOL 311 SCIEN

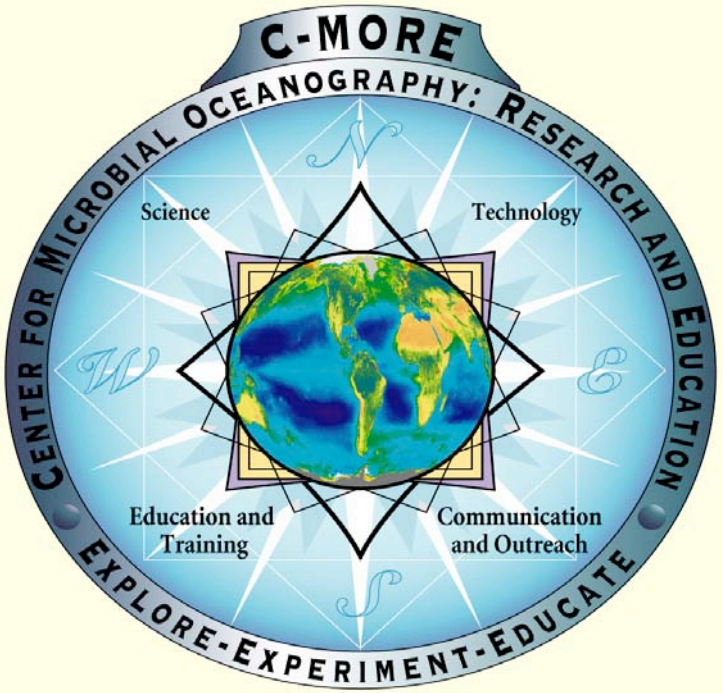


THE FUTURE ???

center for microbial oceanography: research and education

C·MORE *linking genomes to biomes*

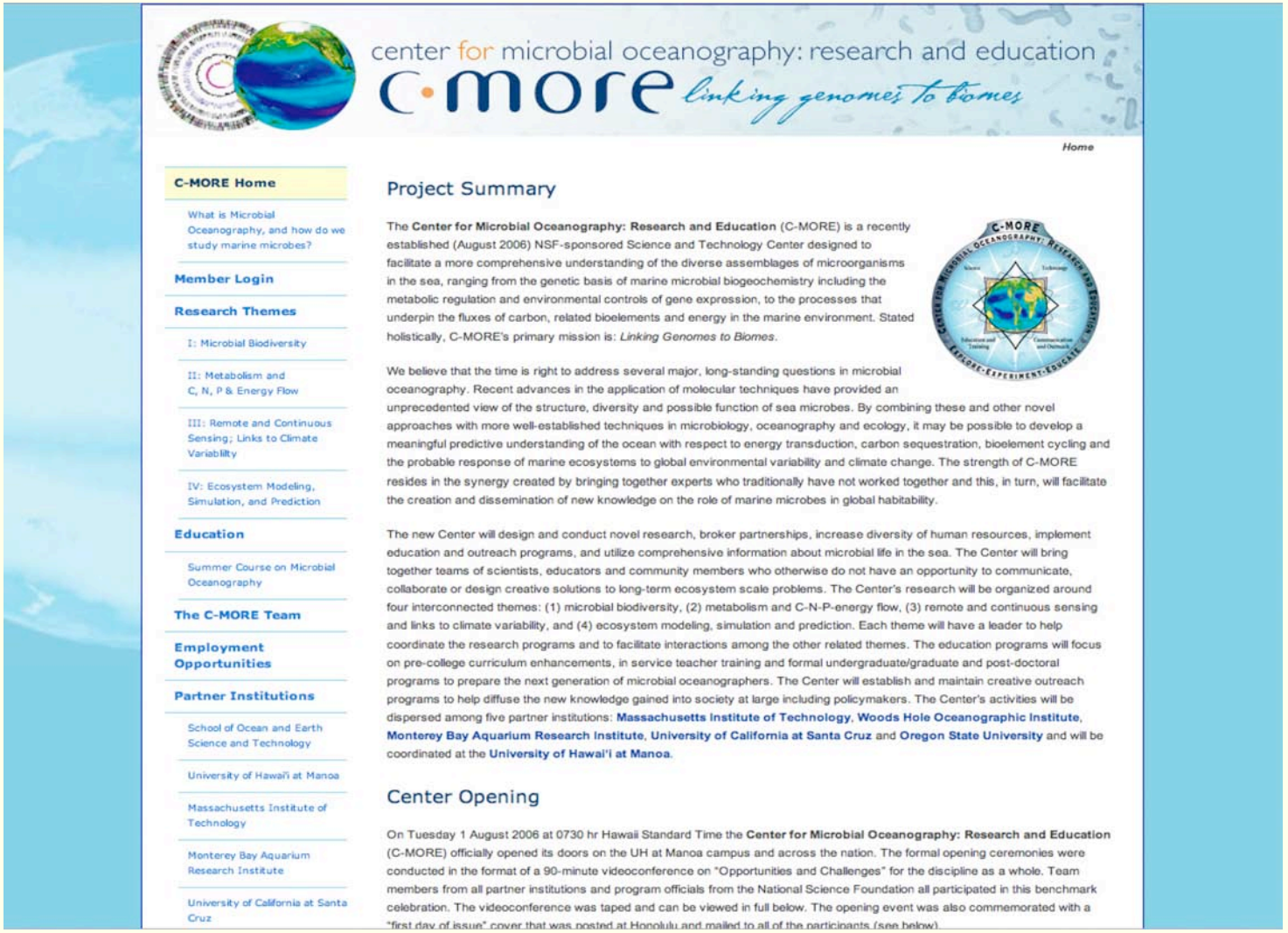
Director David Karl, University of Hawaii Manoa



- **Explore**
- **Experiment**
- **Educate**

soest
university of hawai'i

NSF



http://cmore.soest.hawaii.edu

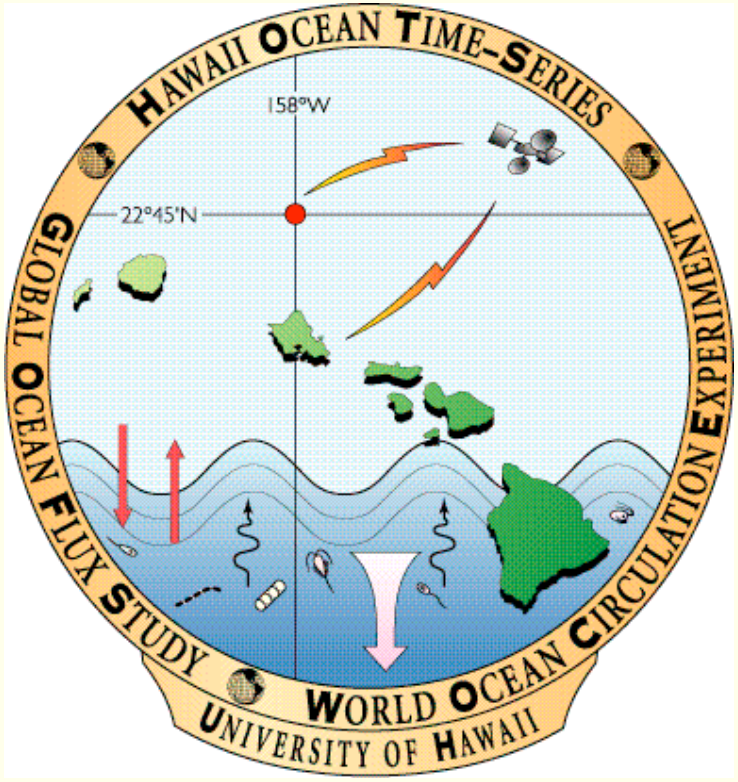
C-MORE Int. HQ – Univ. Hawaii

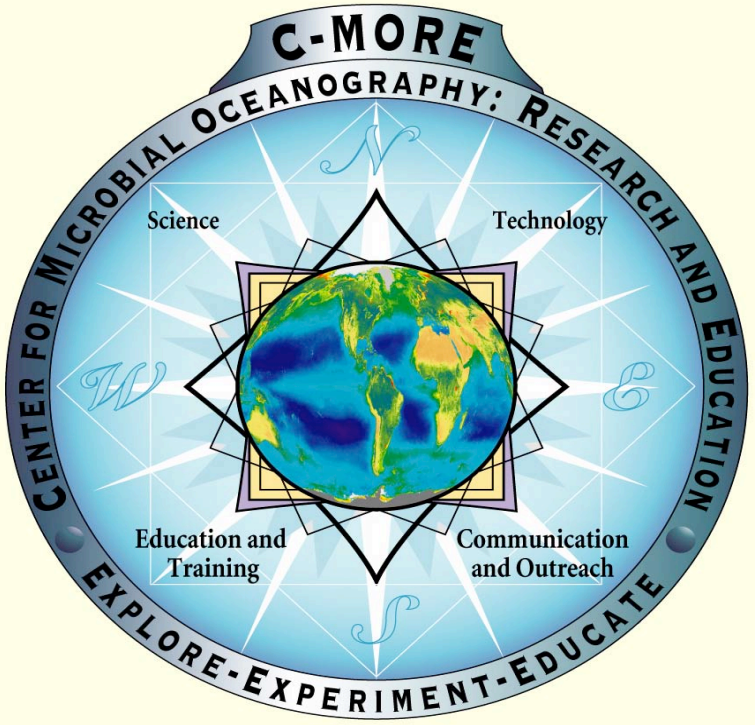
Honolulu, Hawaii, USA

center for microbial oceanography: research and education

C·more *linking genomes to biomes*

Director David Karl, University of Hawaii Manoa





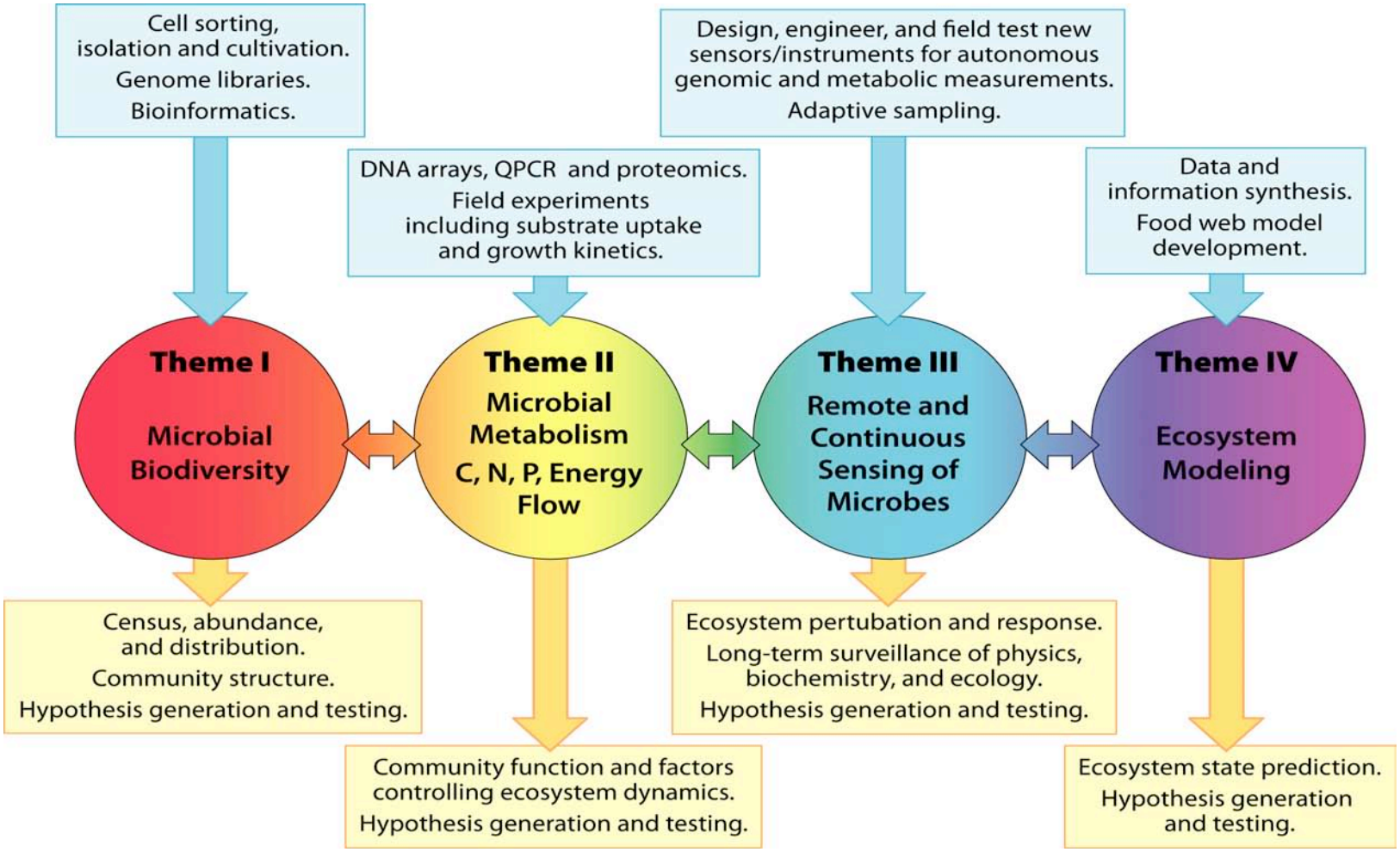
C-MORE GOALS:
TO UNDERSTAND

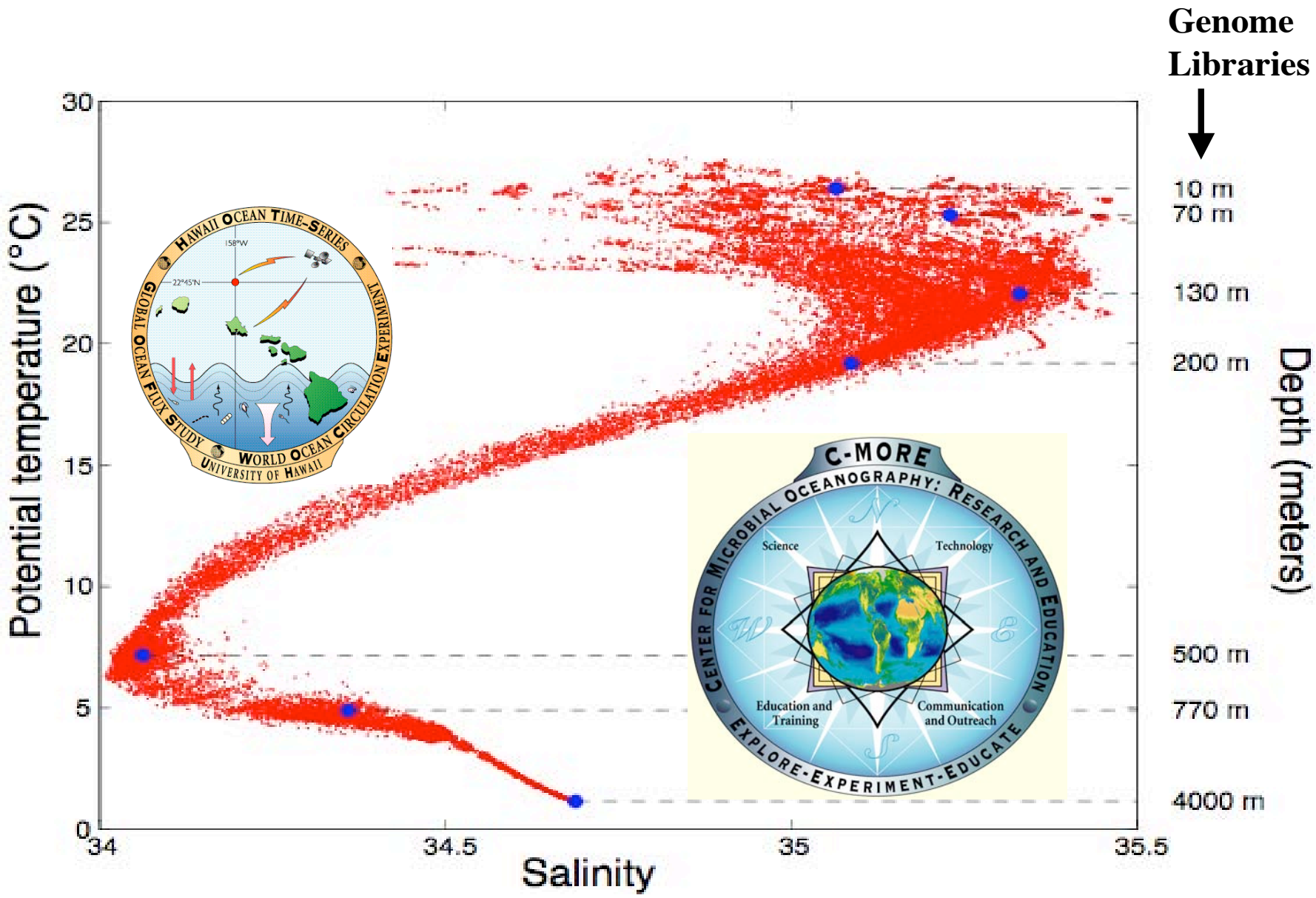
- Mechanisms that drive and sustain diversity & function in oceanic microbes (systems biology)
- Mechanisms that link organisms together in robust networks (ecosystems biology)

THE GRAND CHALLENGE

- Establish the "parts list" or blueprint: *genomics and phylogenetic, isolate diversity*
- Decode the assembly manual: *gene regulation, physiology and metabolism*
- Integrate across disciplines: *ecogenomics, ecophysiology and systems ecology*

C-MORE RESEARCH

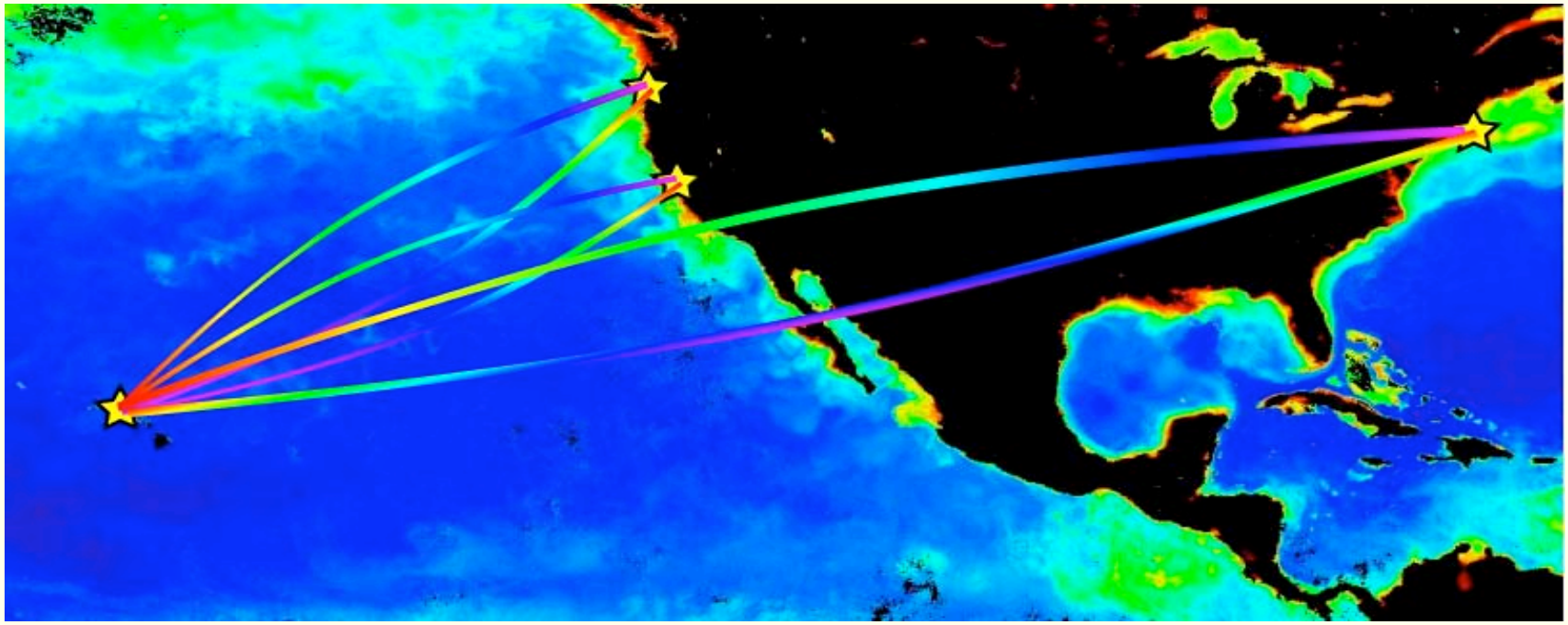



Genome Libraries
10 m
70 m
130 m
200 m
500 m
770 m
4000 m
Depth (meters)
Potential temperature (°C)
Salinity
30
25
20
15
10
5
0
34
34.5
35
35.5
HAWAII OCEAN TIME-SERIES
GLOBAL OCEAN FLUX STUDY
WORLD OCEAN CIRCULATION EXPERIMENT
UNIVERSITY OF HAWAII
158°W
22°45'N
C-MORE
CENTER FOR MICROBIAL OCEANOGRAPHY: RESEARCH AND EDUCATION
EXPLORE-EXPERIMENT-EDUCATE
Science
Technology
Education and Training
Communication and Outreach

C-MORE CONNECTIVITY

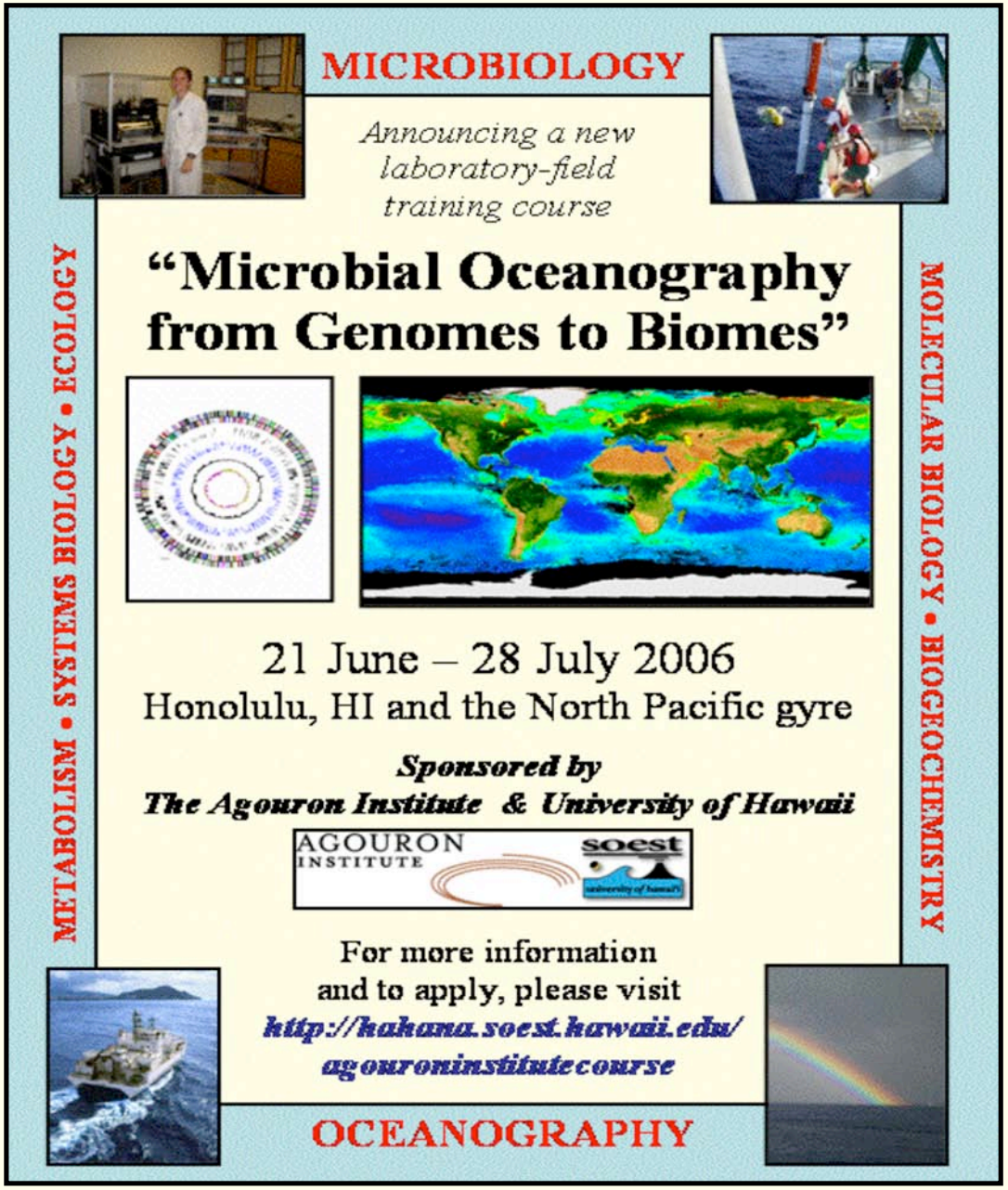
University of Hawaii = Lead Institution

MBARI • WHOI • OSU • UCSC • MIT



FORMAL EDUCATION & TRAINING

curriculum, teacher training, mentoring, outreach



C-MORE
"Summer at Sea"

If interested,
join us next summer
for our annual
Agouron Institute-
sponsored summer
training course

AGOURON INSTITUTE

DeLong Lab

- Jen Braff
- Kostas Konstantinidis
- Jay McCarren
- Chon Martinez
- Tracy Mincer
- Tsultrim Palden
- Vihn Pham
- Virginia Rich
- Dennis Ryan
- Yanmei Shi
- Xin He (urop)

PAST LAB MEMBERS

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- Niels-Ulrik Frigaard
- Steve Hallam
- Ramon Massana
- Alison Murray
- Vicki Orphan
- Christina Preston
- Christa Schleper
- Grieg Steward
- Marcelino Suzuki
- Jose de la Torre

Collaborators

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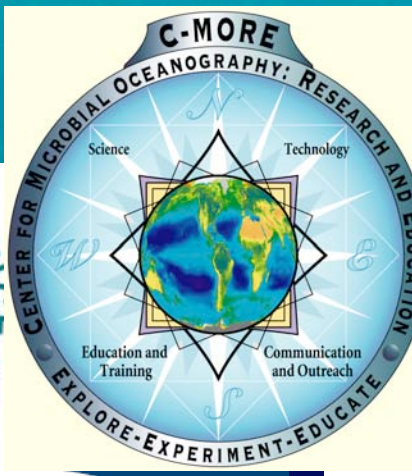
U. Hawaii - Dave Karl, Matt Church
Penn State, Stephan Schuster
The C-MORE Team



Gordon and Betty
MOORE
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