Co-directed by Etienne Bourgois and Eric Karsenti
The Plankton

THE INVISIBLE MULTITUDE

- BASIS OF THE OCEANIC FOOD WEB
- SEQUESTER ATMOSPHERIC CO₂ IN THE OCEAN
- GENERATE THE OXYGEN WE BREATHE
- THE MOST IMPORTANT BIOLOGICAL CARBON PUMP ON THE PLANET
- AFFECT AND ARE AFFECTED BY CLIMATE CHANGE

>90% of the biomass in the ocean
Protists:
0.1-10 million/litre
Zooplankton:
0.1-100/litre
Bacteria/Archaea:

0.1-1 billion/litre
Viruses and giruses: 1-10 billion/litre
Adding Biological Parameters into Oceanographic Research
TARA OCEANS
2009 - 2013
Tara Oceans Global Sampling
September 2009 – October 2013

- 210 stations
- > 1,500 CTD profiles
- > 40,000 samples for biology
  - Surface, DCM, meso
  - DNA, RNA sequencing
  - Microscopy
  - Flow cytometry
- > 2,000 nutrient samples
- > 1,800 HPLC samples
- > 900 carbonate samples
The Tara Oceans Analysis Pipeline

who is there, what do they do, with whom, and why?

A Holistic Approach to Marine Eco-Systems Biology

Eric Karsenti1, Silvia G. Acinas2, Peer Bork3, Chris Bowler3,4, Colombian De Vargas3,5,6, Jeroen Raes7,8, Matthew Sullivan9, Detlev Arendt1, Francesca Benzoni10, Jean-Michel Claverie3,11, Mick Follows12, Gaby Gorsky3,6,13, Pascal Hingamp3,17, Daniele Ludicone18, Olivier Jaillon15, Stefanie Kandels-Lewis1, Uros Krzic1, Fabrice Not3,5,6, Hiroyuki Ogata3,11, Stéphane Pesant16,17, Emmanuel Georges Reynaud18, Christian Sardet3,6,19, Michael E. Sieracki20, Sabrina Speich21, Didier Velayoudon22, Jean Weissenbach15, Patrick Wincker15, the Tara Oceans Consortium
Ocean Microbial Reference Gene Catalog

Global representation

68 stations
3 depths

40 million genes: Gene catalog is close to saturation

1,000 times more sequence than GOS sequence

Equivalent to 135 fully sequenced human genomes

Of 40M genes, 28% no annotation, rest (60%) mainly bacteria

Assessment of global viral communities

5,476 Viral communities. Only 39 previously known

Viral populations are regionally dominant, but widespread

Data supports seed-bank hypothesis for viral ecology

Saturation at around 130,000 OTUs
More than 10 times higher than the number of formally described marine eukaryotic plankton
Around one third cannot be assigned to any known taxonomic group
Determinants of community structure in the global ocean interactome

a.k.a The Ocean’s Facebook

The global plankton interactome – an integrated “network of networks”

Biotic interactions more important than abiotic interactions

Most interactions are positive …

Cooperation is more important than competition

... but diatoms are antisocial

Diatoms have few friends and they keep their competitors at bay!

The co-occurrence network can be superimposed on food chains and can predict parasitoid-host interactions.
The co-occurrence network can predict host-phage interactions that can be verified in metagenomes.
From the global ocean to the single cell ..... and back again
A case study : Diatom interactions with other plankton
An unorthodox collaboration between a diatom (Fragillariopsis) and a ciliate (Salpingella)

Flora Vincent (IBENS), in collaboration with Colomban de Vargas (Roscoff) and Rainer Pepperkok (EMBL)
An unorthodox collaboration between a diatom (Fragillariopsis) and a ciliate (Salpingella)

Flora Vincent (IBENS), in collaboration with Colomban de Vargas (Roscoff) and Rainer Pepperkok (EMBL)
An unorthodox collaboration between a diatom (Fragillariopsis) and a ciliate (Salpingella)
Identification of new morphotypes at other sampling sites

Colin, Vincent, Dolan; Unpublished
Adding Biological Parameters into Oceanographic Research
Real-Time Remote Sensing of Ocean Processes

Atlantic Meridional Transect
Contextual Data from Sampling, Satellite, Argo Buoys, On-Board Instruments and Gliders
Temperature is the main driver of microbial community structure.

Communities stratify by depth rather than region (all depths).

Temperature explains 62% of variance.

Surface samples
Temperature (and correlated oxygen) is by far the strongest factor.

Temperature explains 62% of variance.

All depths

PC1 (62% variance explained)

PC2 (5% variance explained)

Temperature (°C)

R² = 0.76

Principal conclusions of the papers so far:

- The first end-to-end description of a continuous global ecosystem.
- Ocean microbiome consists of ~35,000 OTUs (mostly known) and 40 million genes (mostly unknown).
- Diversity of eukaryotic plankton is huge (~130,000 OTUs) but is finite. Around 90% are new and there is a considerable unknown component.
- More than 5,000 viral communities described; >99% are new. Their distribution supports seed bank hypothesis.
- Biotic interactions are more important than environmental drivers. Most interactions between plankton are positive.
- Bacterial community composition driven largely by temperature.
- All the data are public.
- The analyses were performed on only 579 samples; the data deluge is coming!
All *Tara* Oceans data are public

40 million genes

Largest-ever DNA sequencing effort for ocean science.
Genetic sequences collected could represent tens of thousands of new species and ecosystem interactions.
Considering the size of the world’s ocean, there is much, much more to discover.

11,535 gigabytes

Size of the *Tara* datasets in the European Nucleotide Archive as of May 2015. This represents 12,581 gigabases - roughly equivalent to 135 fully sequenced human genomes.

Unlimited

Potential to discover new knowledge about life in the world’s ocean.

*Tara* Oceans data: www.ebi.ac.uk/services/tara-oceans-data
A three year expedition

• To explore marine planktonic ecosystems and their sensitivity to climate change-induced modifications to the ocean

• To popularize science

• To educate
September 5\textsuperscript{th} 2009: 
Departure from Lorient
March 31\textsuperscript{st} 2012: Return to Lorient
Visit of UN Secretary General Ban-Ki Moon: Informing Policy makers about the Key Role of Ocean Life
School kids and TARA OCEANS
COP21 and the Paris Treaty have recognized the importance of the ocean!

*Noting* the importance of ensuring the integrity of all ecosystems, including **oceans**, and the protection of biodiversity, recognized by some cultures as Mother Earth, and noting the importance for some of the concept of “climate justice”, when taking action to address climate change.

*Affirming* the importance of education, training, public awareness, public participation, public access to greenhouse gases referred to in the Convention.

**Conference of the Parties**

Twenty-first session
Paris, 30 November to 11 December 2015

Agenda item 4(b)
**Durban Platform for Enhanced Action (decision 1/CP.17)**
Adoption of a protocol, another legal instrument, or an agreed outcome with legal force under the Convention applicable to all Parties

**ADOPTION OF THE PARIS AGREEMENT**
Thank you!