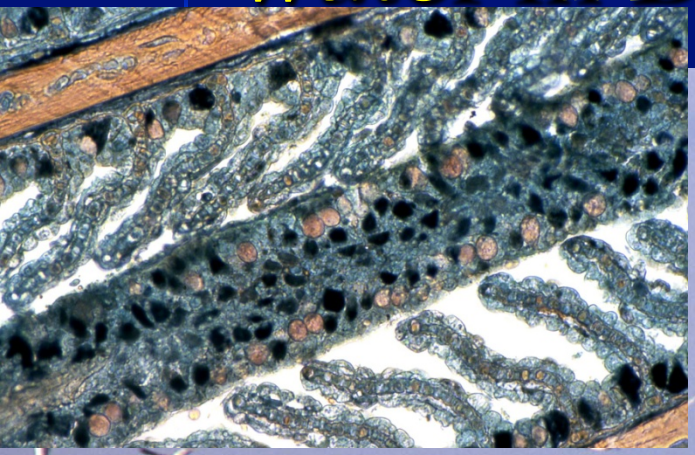
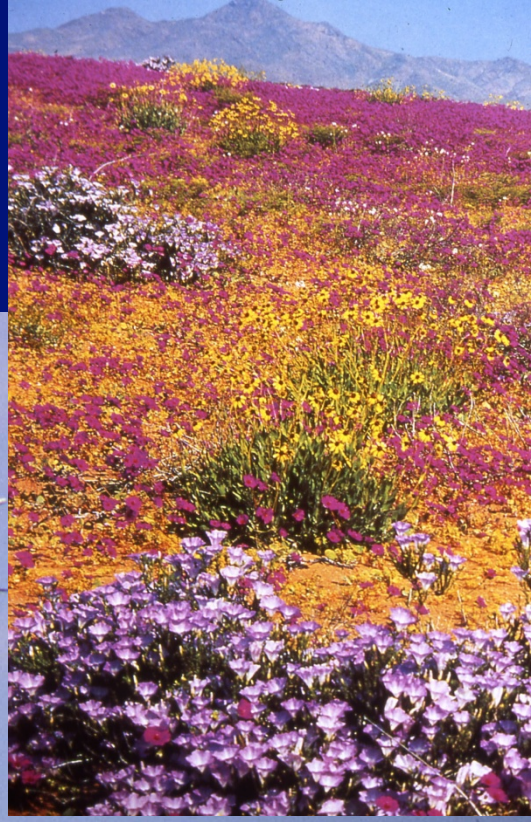
Water, a key molecule for Life
Water in Biodiversity



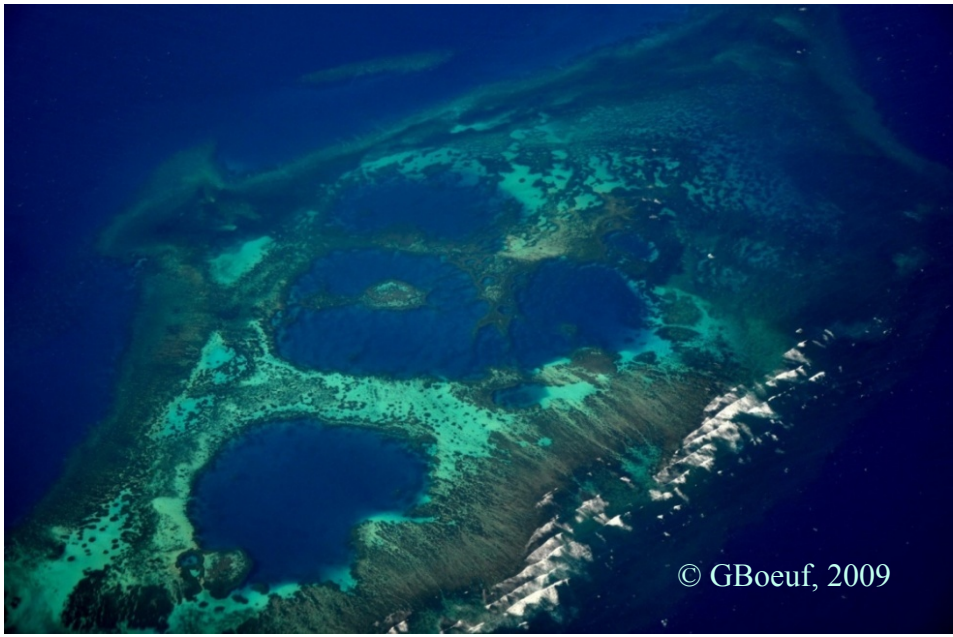


Gilles Boeuf, University Pierre & Marie Curie/CNRS,
Laboratory Arago, Banyuls-sur-mer and Muséum
National d' Histoire Naturelle, Paris, France

Vienna, Apr 2012

Biodiversity?

> 1.7 million of continental species



< 0.3 million of marine species

It is the living part of Nature, the living in its diversity and complexity


INSTITUT FRANÇAIS
DE LA BIODIVERSITÉ
JURANÇON
Roc du Bel A
BERGERA
1999
Château de
VIN JAU
1990
TOKAJI
ÁSZÚ
Clos Chevrel

Blue Planet

- Seas and oceans cover more than 71 % of the Earth surface, the blue planet, 99 % in volume,
- Life emerged in the « ancestral Ocean »,
- Salted water characteristics are very specific,
- 12 animal phyla (on 31) are only marine, 13 % of the known species, but 10 % of the living carbon biomass are due to bacteria of the subsurface layer, >50 % for phytoplankton productivity!

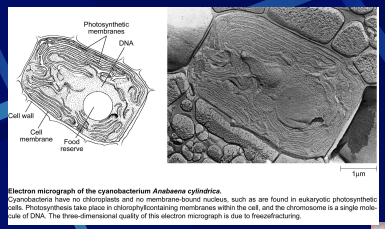
CSMonaco, 2004

Species diversity

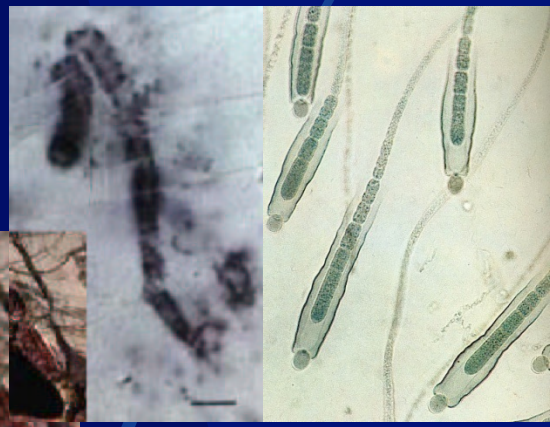
235 000 species whose 93 000 only for coral reefs

Origin and evolution of Life

Protocells emergence
RNA world
Cyanobacteria 3.5 BY ago

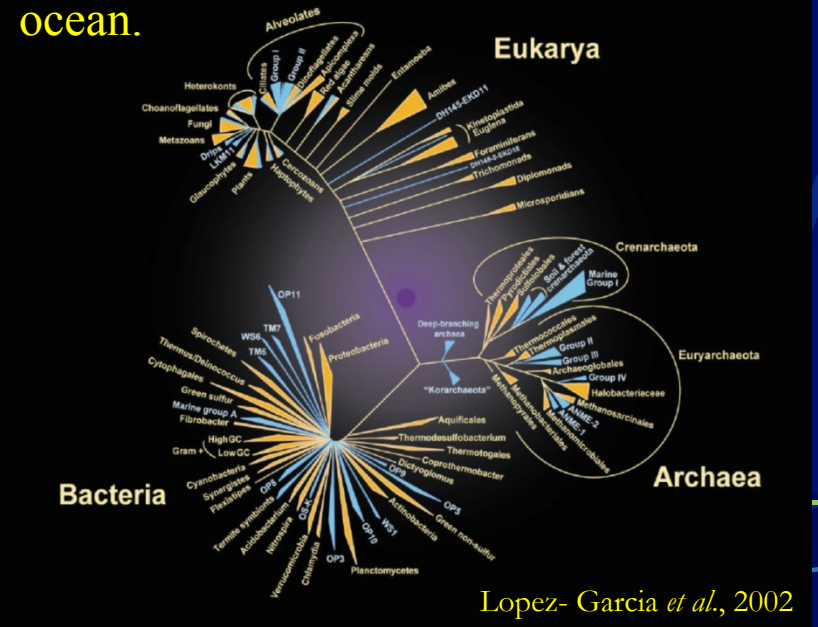


Electron micrograph of the cyanobacterium *Anabaena cylindrica*.
Cyanobacteria have no chloroplasts and no membrane-bound nucleus, such as are found in eukaryotic photosynthetic cells. Photosynthesis take place in chlorophyll-containing membranes within the cell, and the chromosoma is a single molecule of DNA. The three-dimensional quality of this electron micrograph is due to freeze-fracturing.



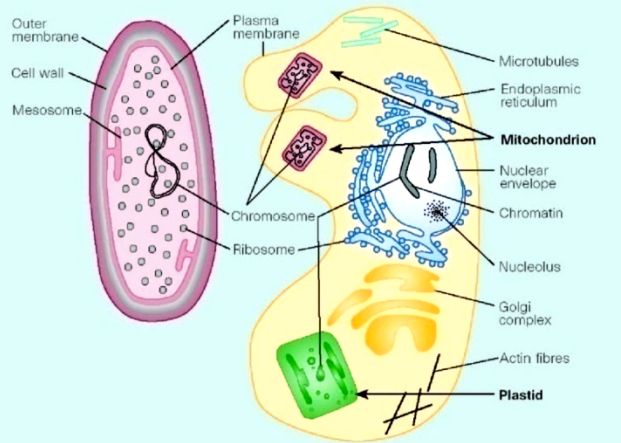
Critical events for the future occured in the ocean: development of the nucleus, « pluricellularity » (metazoans), capture of micro-organisms by cells which became afterwards organelles through symbiosis, mitochondria and plastid,
Later on, sex (1.5 By) also developped in the ocean.

Prokaryotics-Eukaryotics, 2 .2 BY,
Protozoans-metazoans, 2.1 BY
Organelles, 2100 (M) et 1500 (Pl) MY

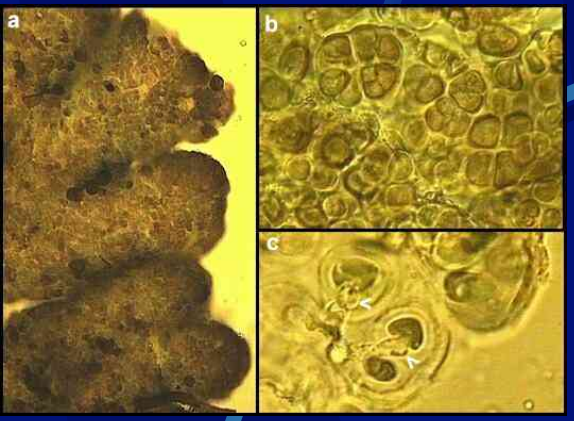


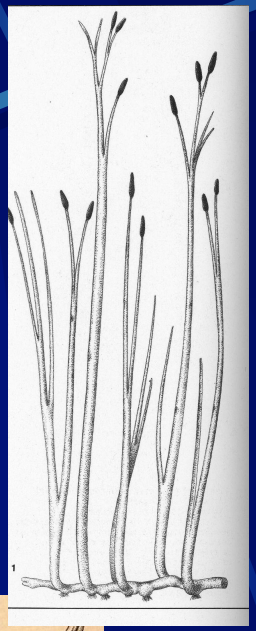
Lopez- Garcia *et al.*, 2002

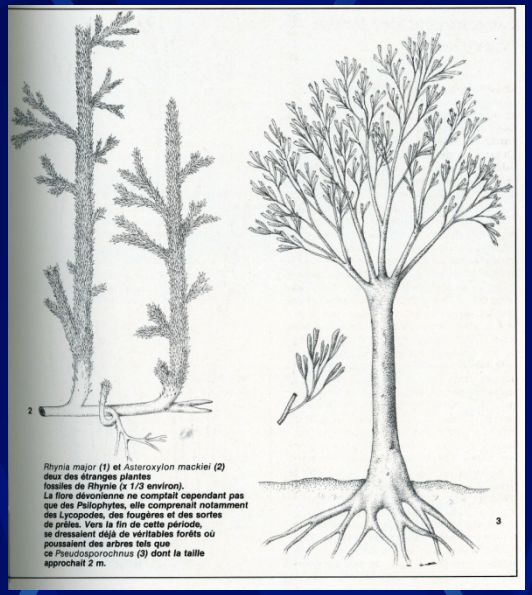
El Albani *et al.*, 2010

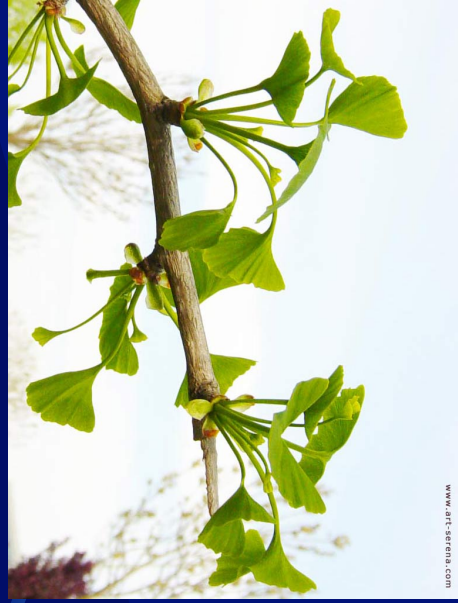


Getting out of the oceans

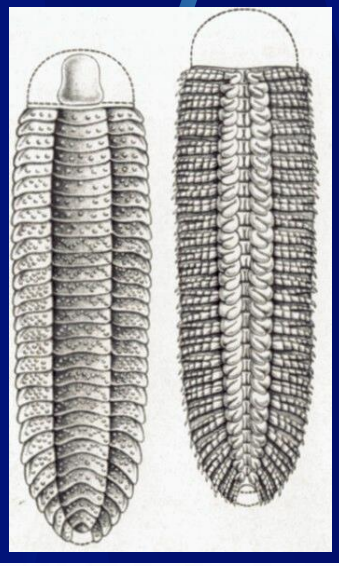


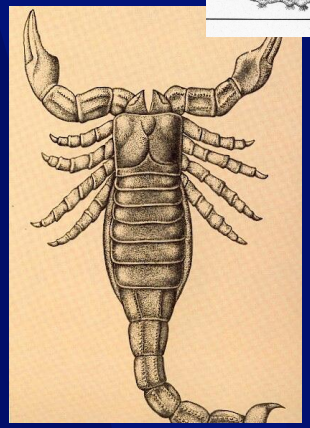




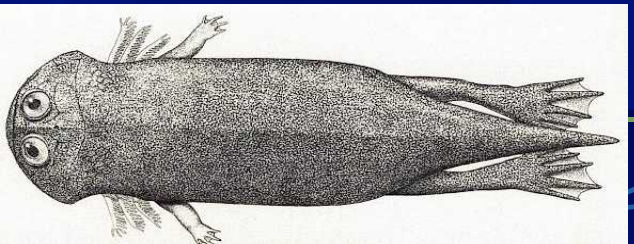


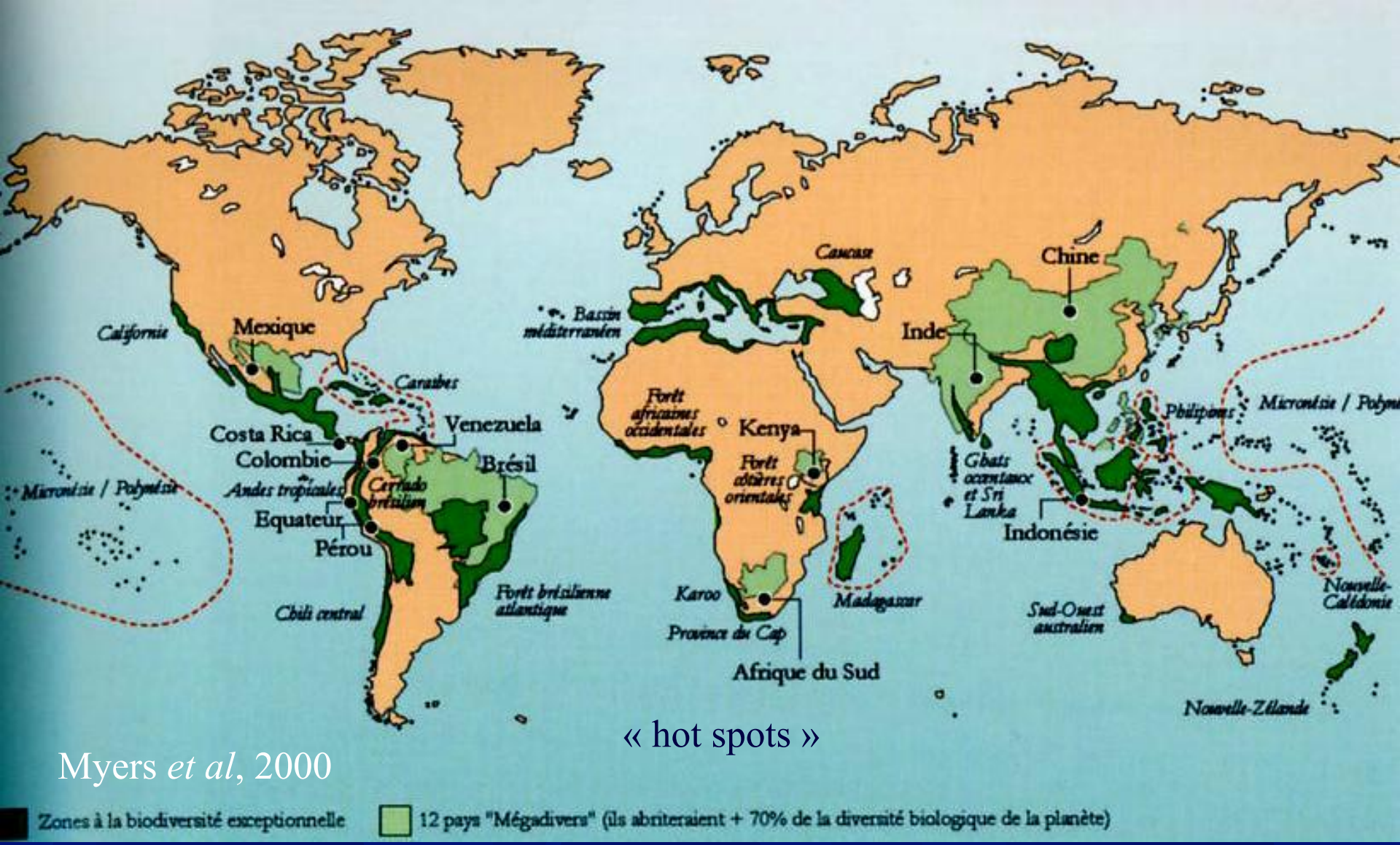
1 BY?





440 MY





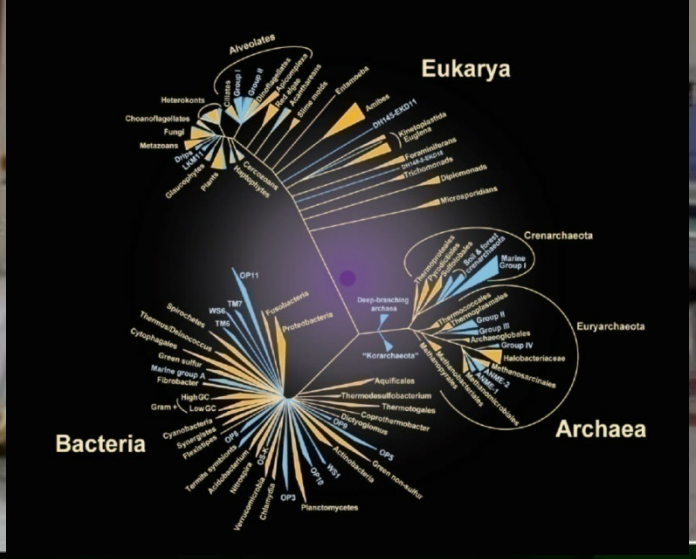
« hot spots »

Myers *et al*, 2000

50 % of sp on 7 % of the emerged lands, about 90 % on 10 %

Dubois, 2004

Biological diversity is very unequally distributed: 14 biomes used. There might be up to 14 M species on Earth (*Gaston & Spicer 1998. Biodiversity, an introduction)*



Naegleria fowleri

Giardia spp.

Cryptosporidium parvum

P Lebaron,, Lab Arago, Banyuls 2002

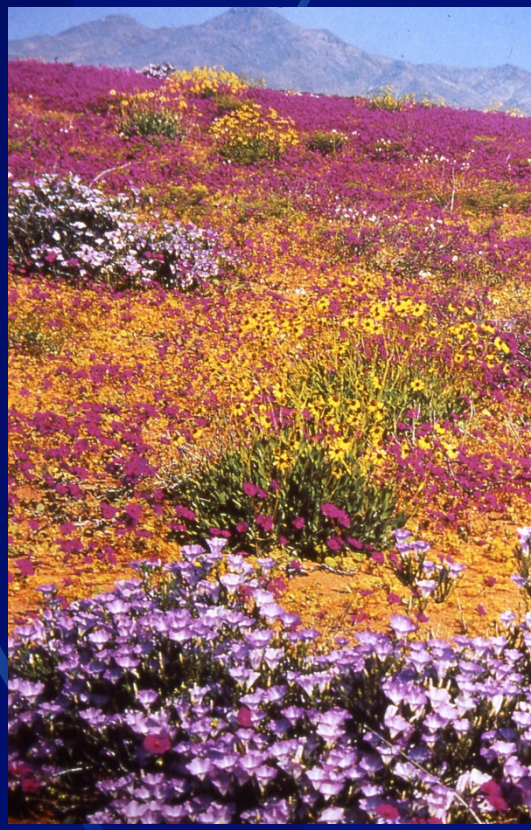
Legionella pneumophila

Escherichia coli

Virus et bactéries
Eau de mer naturelle

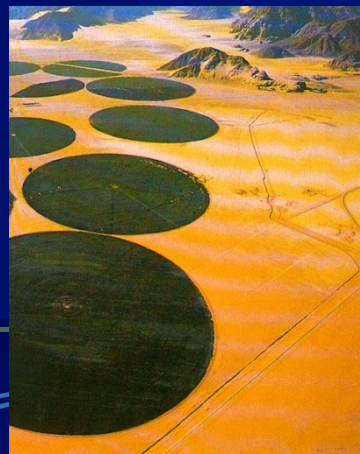
« …*Most organisms smaller than 1 mm occur worldwide wherever their required habitats are realised. This is a consequence of ubiquitous dispersal driven by huge population sizes . Metapopulations of microbial eukaryotes are cosmopolitan*…" Finlay & Fenchel 2004. "…*Current evidence confirms that, as proposed by the Baas-Becking hypothesis, 'the environment selects' and is, in part, responsible for spatial variation in microbial diversity. However, recent studies also dispute the idea that 'everything is everywhere' …** ». .Martiny *et al*., 2006.

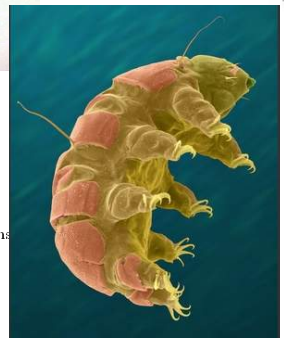
Water is essential for Life

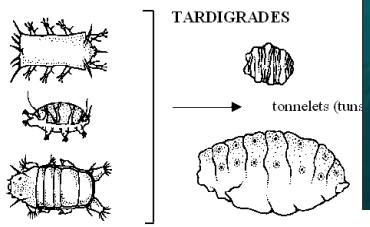


98 %

5 %







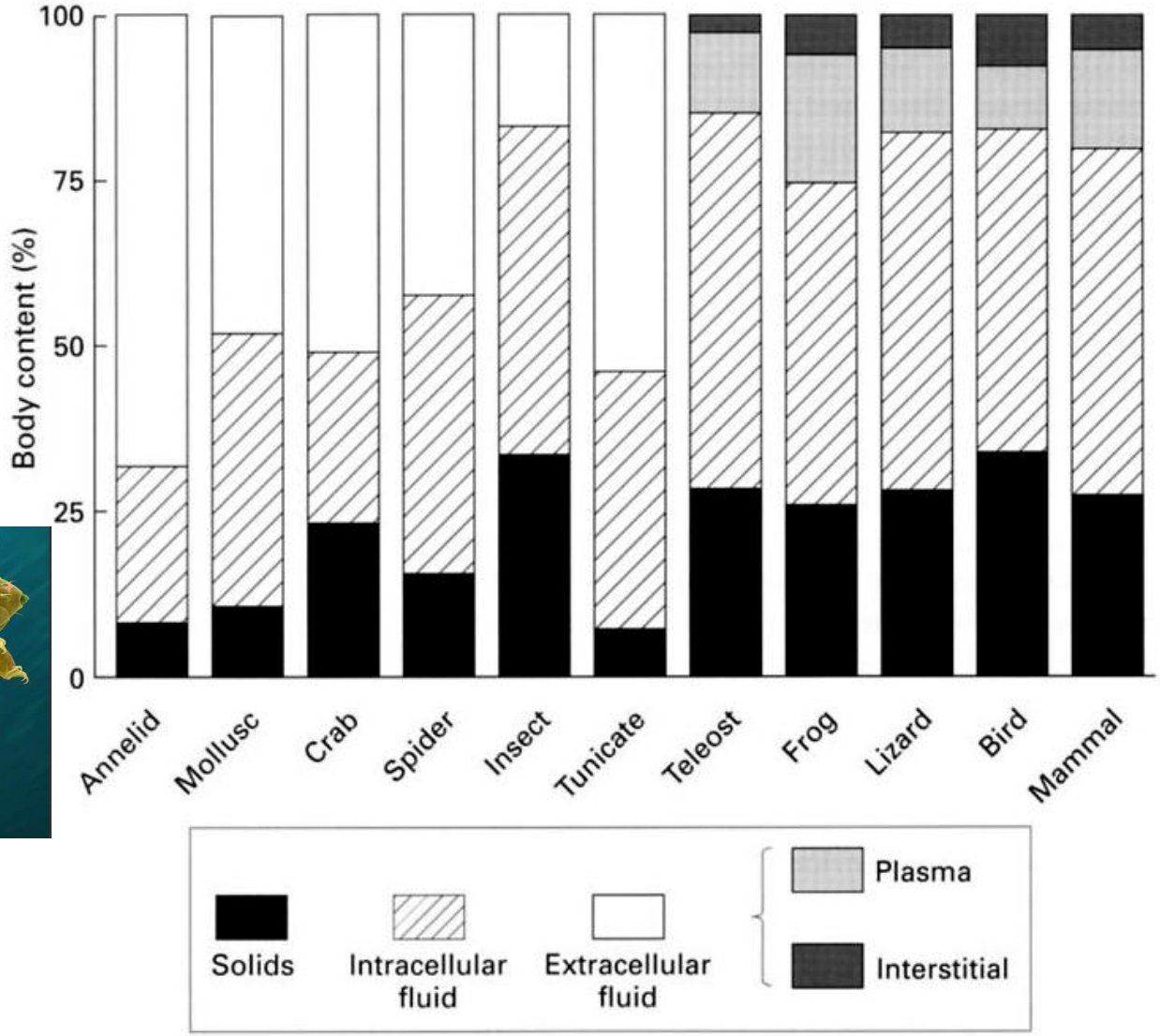
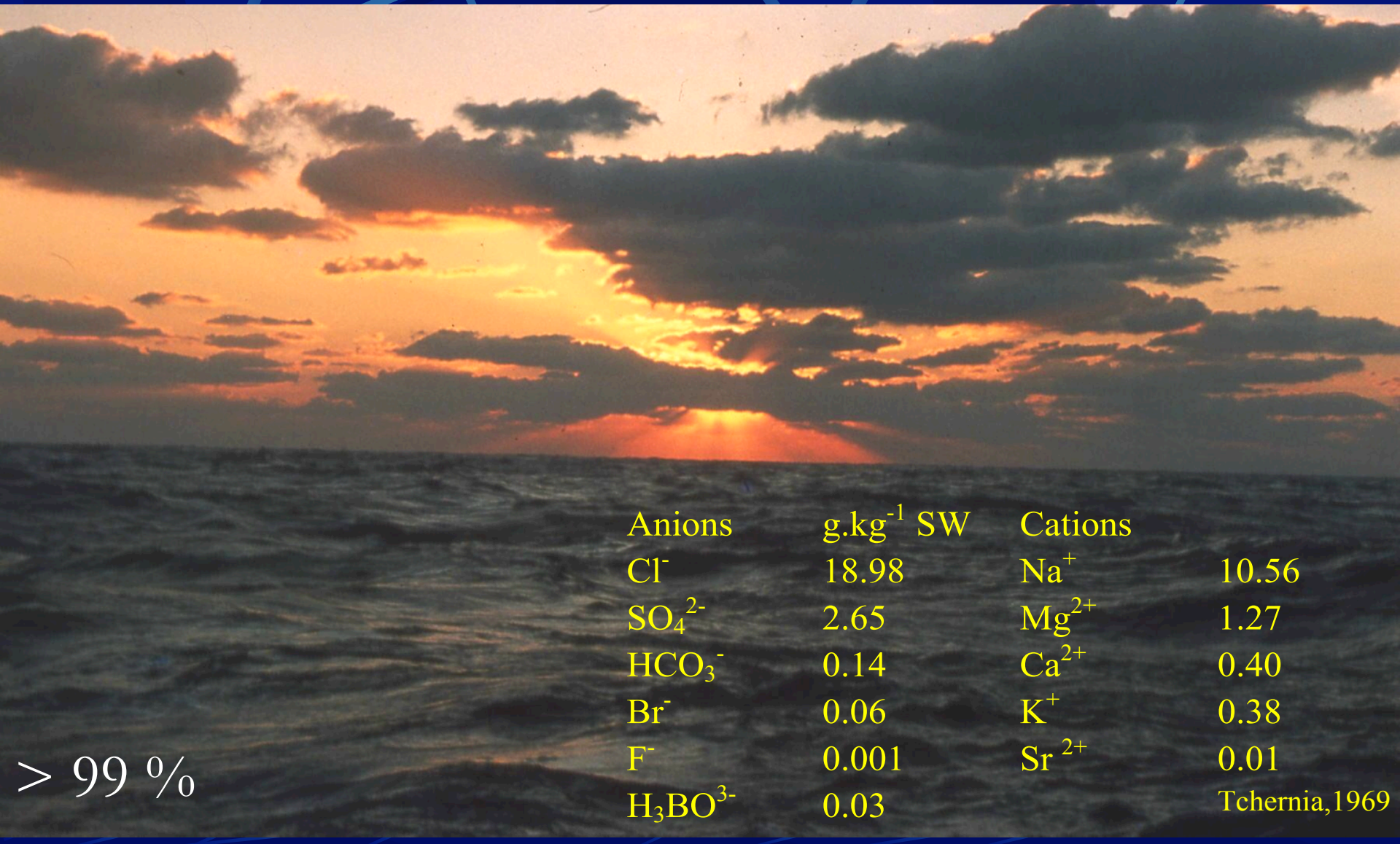


Fig. 4.1 Proportions of body solids, and the distribution of body water, in various fluid compartments for a range of animal taxa. (Adapted from Withers 1992.)

Water, the universal biological solvent

The open Ocean...



Anions	g.kg^{-1} SW	Cations	
Cl^-	18.98	Na^+	10.56
SO_4^{2-}	2.65	Mg^{2+}	1.27
HCO_3^-	0.14	Ca^{2+}	0.40
Br^-	0.06	K^+	0.38
F^-	0.001	Sr^{2+}	0.01
H_3BO^{3-}	0.03		

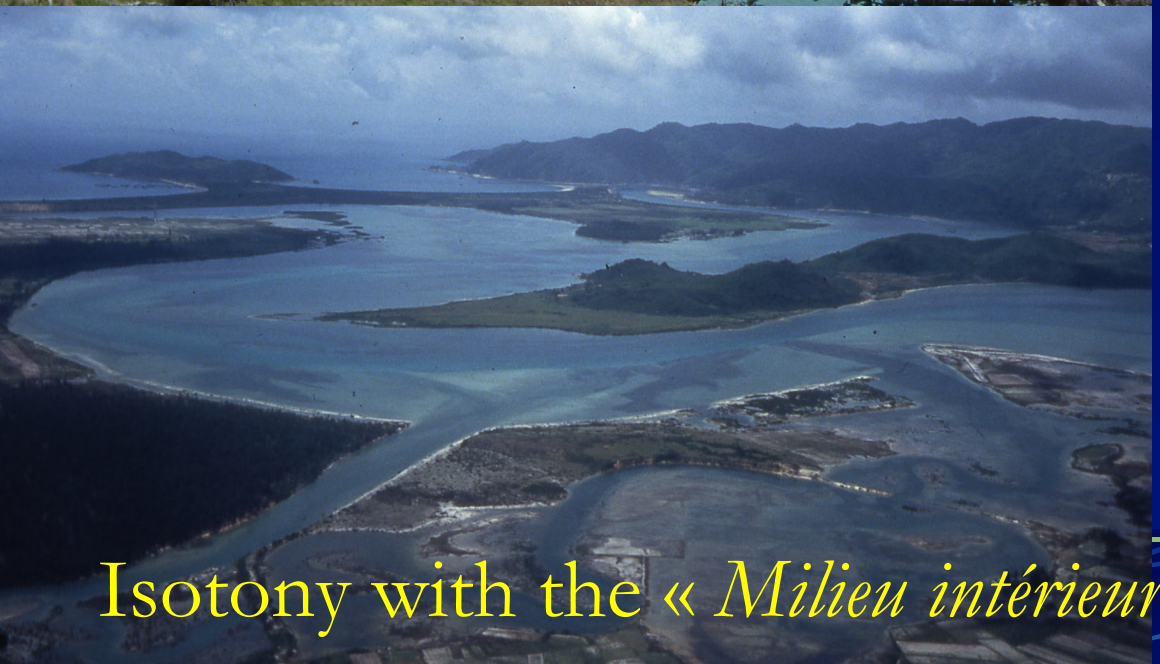
Tchernia,1969

> 99 %

The coastal Sea

> 55 % of the humans localised on the sea shore!

Brackish waters



Isotony with the « *Milieu intérieur* » ?

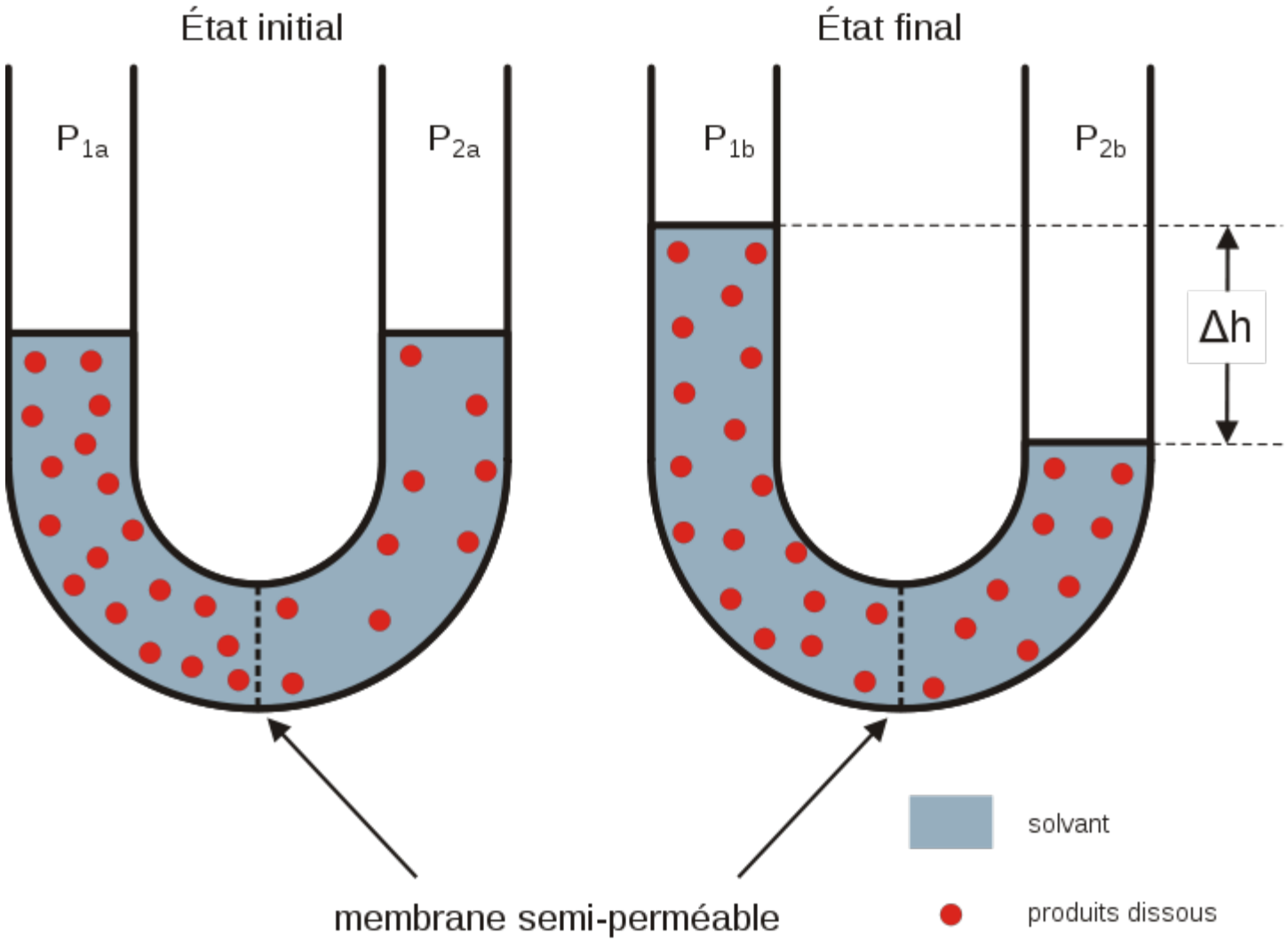
Fresh waters

FW (0.32 $g.l^{-1}$)

CO_3^-	35.15 %	Cl^-	5.68
CO^{2+}	20.39	Mg^{2+}	3.41
SO_4^{2-}	12.14	$(Fe, Al)_2 O_3$	2.75
SiO_2	11.67	K^+	2.12
Na^+	5.79	NO_3^-	0.90

Tchernia, 1969

Osmosis



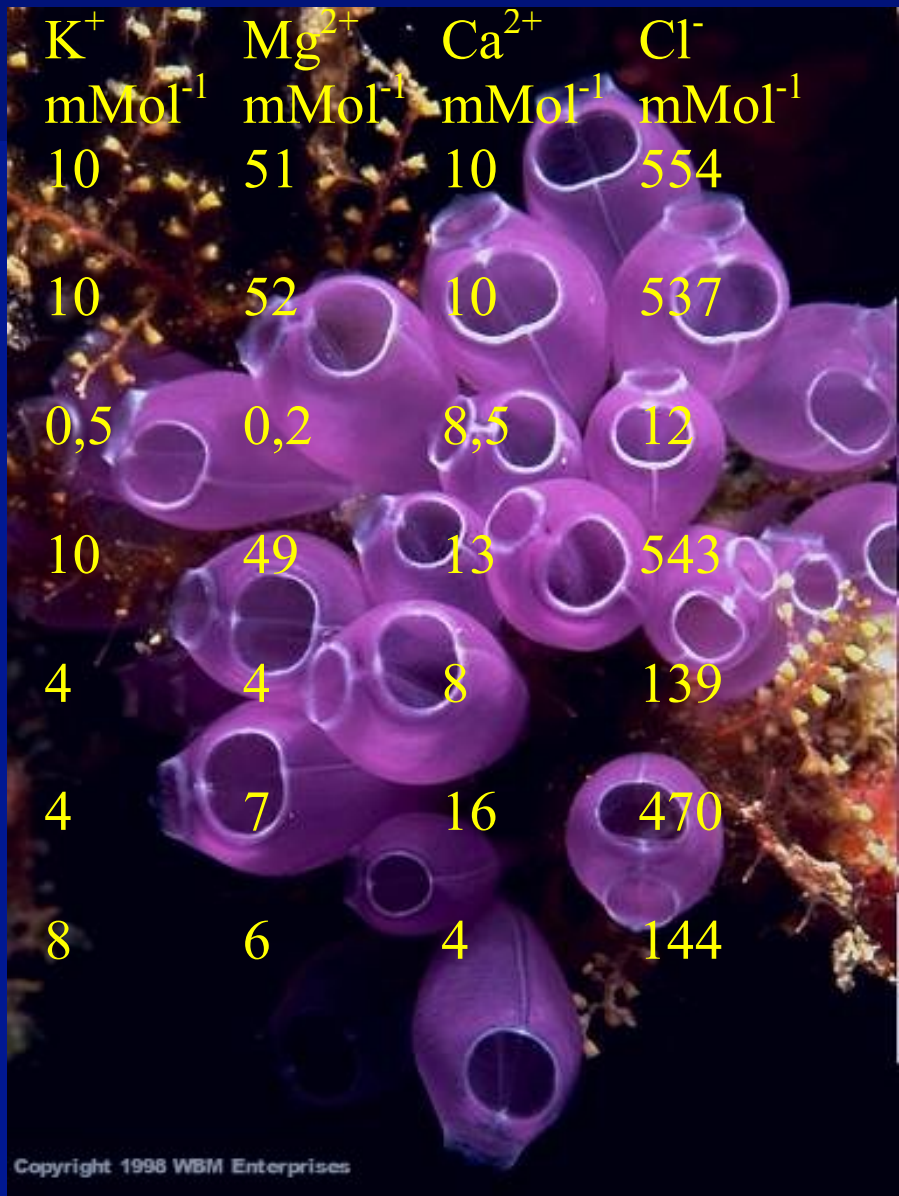
De H. Illewaert, 2011

Life in aquatic environments

- Very stable and homogenous medium, far from the coast, fixed composition,
- Third dimension, crucial, from the surface till the bottom, pelagos and benthos,
- Viscous and very dense medium,
- Continuous medium, questions of dispersion,
- Medium « protective » (radiations),
- Medium less favorable to endemism,
- Only one ocean?.

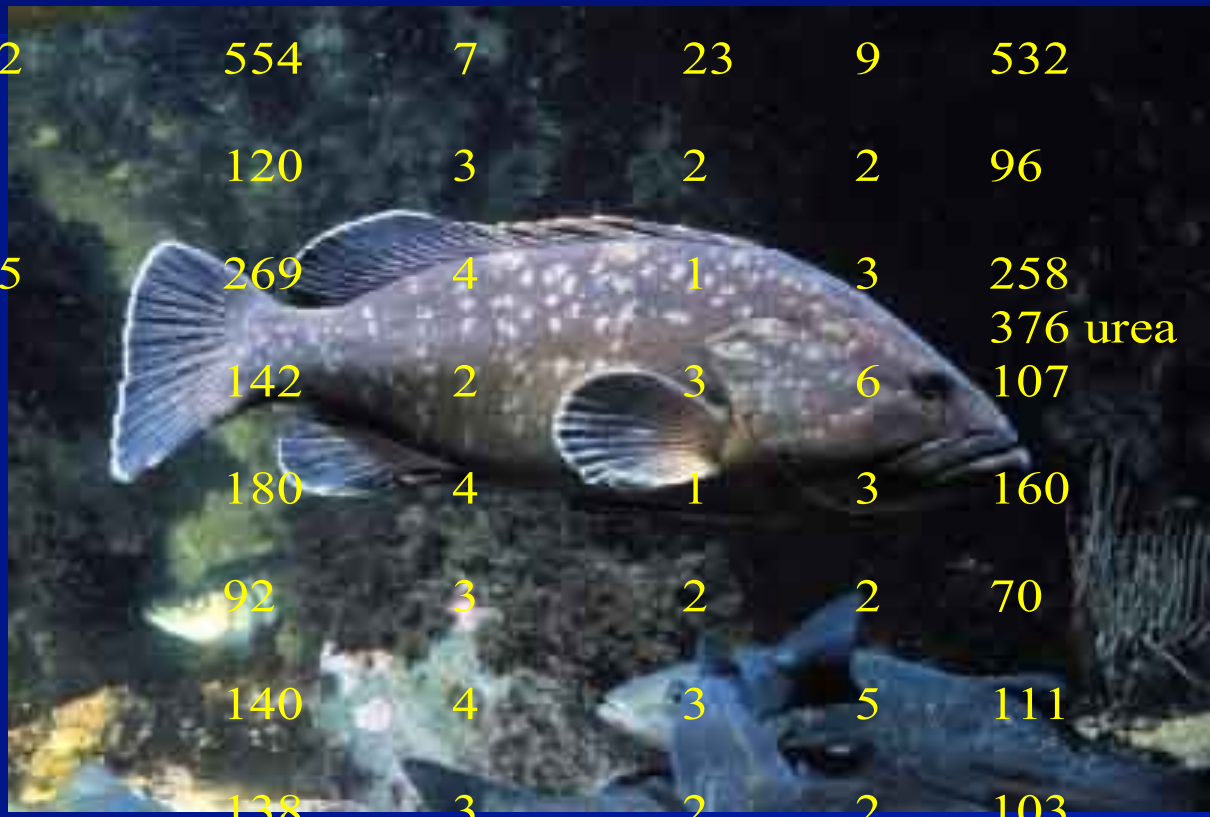
Composition depending on groups

	Habitat	Osmolarity $mOsm.l^{-1}$	Na^{+} $mMol^{-1}$	K^{+} $mMol^{-1}$	Mg^{2+} $mMol^{-1}$	Ca^{2+} $mMol^{-1}$	Cl^{-} $mMol^{-1}$
Jellyfish *Aurelia*	SW	1000	460	10	51	10	554
Annelid *Arenicola*	SW	1000	459	10	52	10	537
Mollusc *Anodonta*	FW	40	16	0,5	0,2	8,5	12
Mollusc *Aplysia*	SW	1000	492	10	49	13	543
Crustacea crayfish	FW	310	146	4	4	8	139
Crustacea lobster	SW	1000	472	4	7	16	470
Insect cockroach	terrestrial	325	162	8	6	4	144

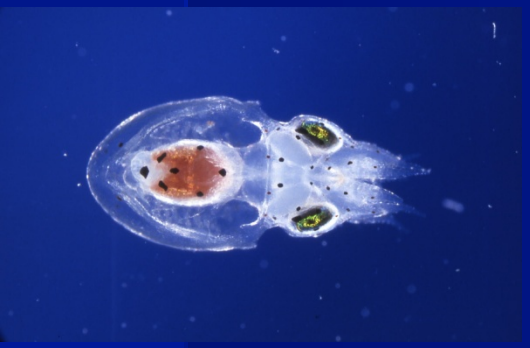


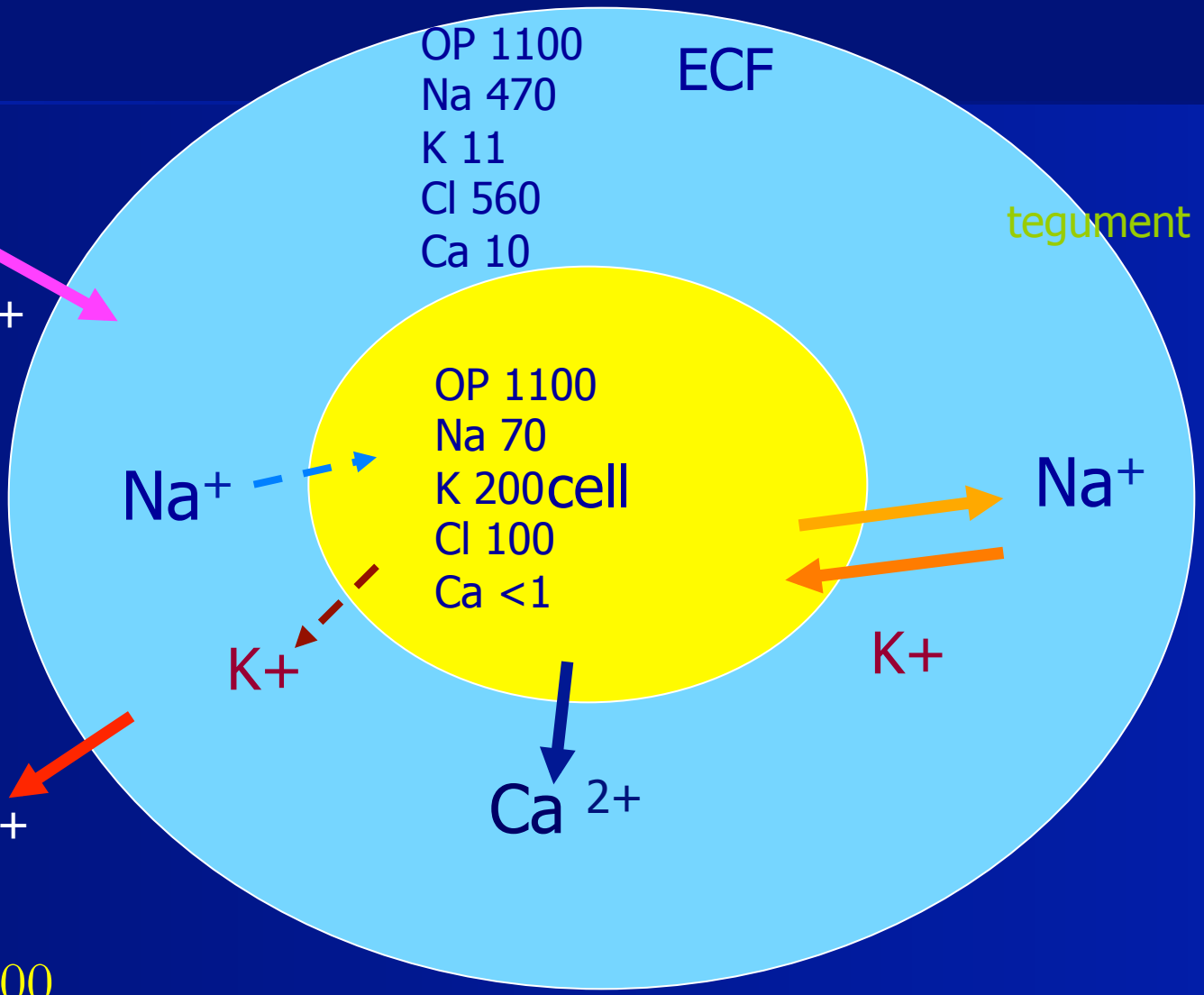
Composition depending on groups

	Habitat	Osmolarity mosM.l^{-1}	Na^+ mMol.l^{-1}	K^+ mMol.l^{-1}	Mg^{2+} mM	Ca^{2+}	Cl^- mMol.l^{-1}
Cyclostome myxine	SW	1002	554	7	23	9	532
Cyclostome lamprey	FW	248	120	3	2	2	96
Chondrichthian shark	SW	1075	269	4	1	3	258 376 urea
Teleost goldfish	FW	293	142	2	3	6	107
Teleost flounder	SW	337	180	4	1	3	160
Amphibian frog	FW	210	92	3	2	2	70
Reptile alligator	FW	278	140	4	3	5	111
Bird duck	terrestrial	294	138	3	2	2	103
Mammal human	terrestrial	302	142	4	2	5	104



Osmoregulation model in the Sea





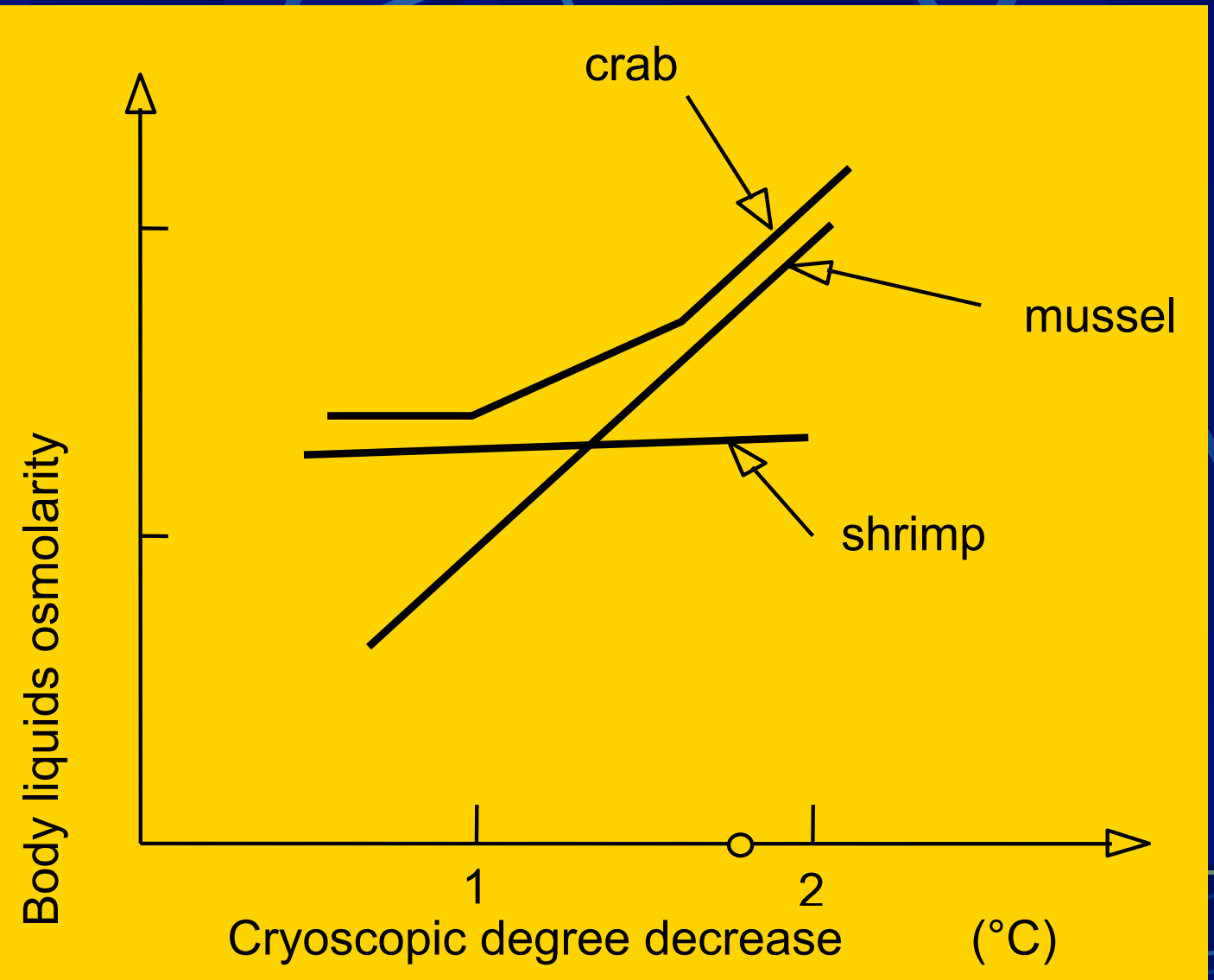
Willmer *et al.*, 2000

Salinity factor: aquatic organisms response

osmoconformers

osmoregulators

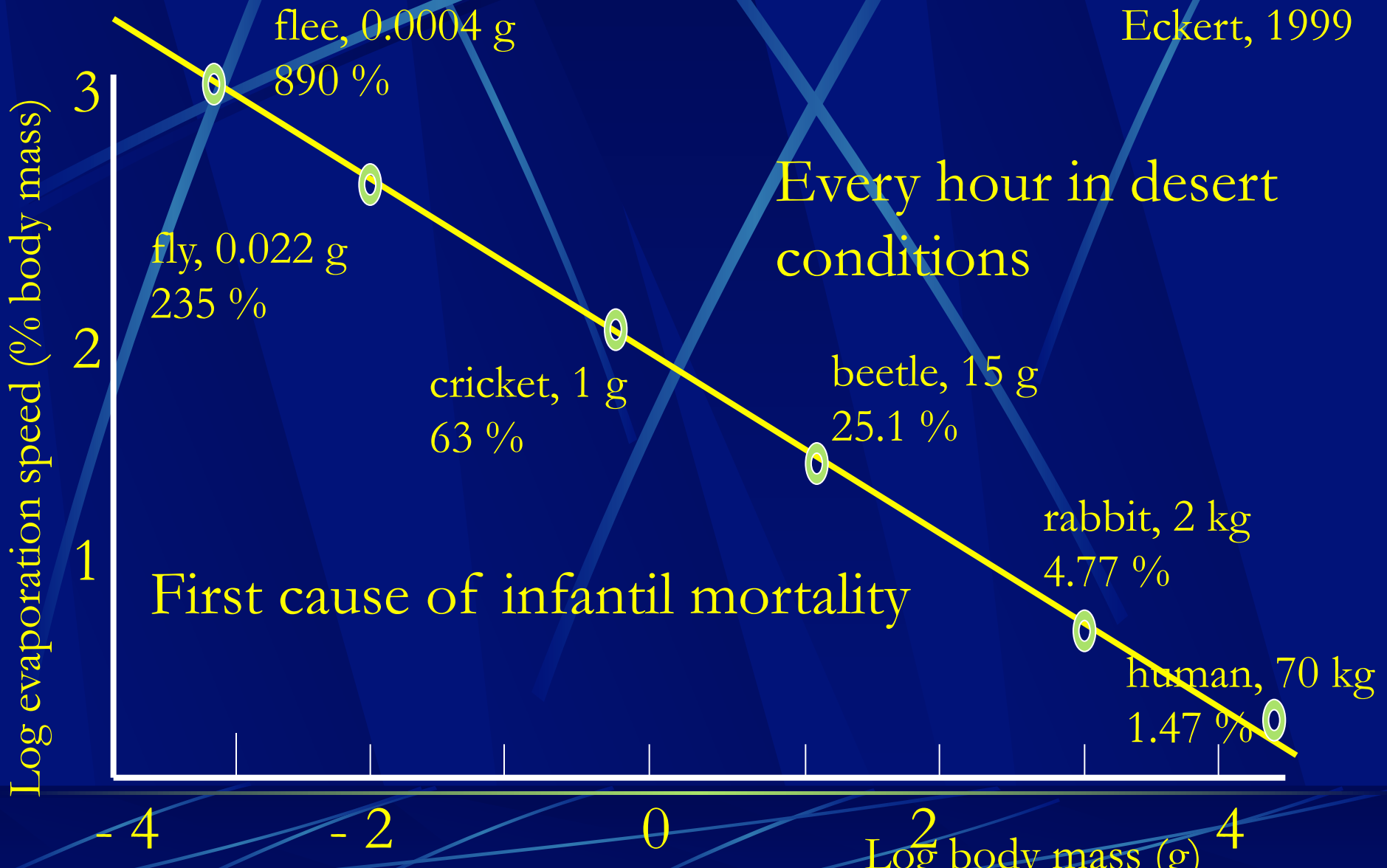
On the way of anisosmotic extracellular regulation…



Why ocean emergence only for two groups?

- Life emerged from water accidentally,
- But it is not accidentally if, at the beginning, only two groups, arthropods and vertebrates, were able to do it!
- The physical and chemical characteristics of water played a critical role in the establishment of life on Earth. All the crucial steps of life occur in water. Species developed first some simple answers, where organisms had the same composition as salted water. Then, some more elaborated strategies emerged, in order to survive in a more diverse set of osmotic conditions. Osmotic parameters constitute in the ocean the main environmental factor that limits the geographic distribution of animal species. Geographic dispersion, along with genetic isolation, are key components involved in speciation. If vertebrates and arthropods hadn't competed – developing strategies to regulate their extra cellular compartments – in order to colonies new and hostile terrestrial ecosystems while getting out of the oceans, a totally different set of organisms would have succeeded, and invaded some empty niches. The current profile of living organism would be completely different. Eckert, 1999.

Dehydration speeds



Exchanges animal-medium

Boeuf, 2011

Seawater

1050 mOsm.l^{-1}

Water balanced

iso-osmotic animal but no iso-ionic

salts

salts

hypo osmotic animal

water

salts

drinking

Freshwater

salts

hyper osmotic animal

water

urine

salts

Terrestrial

Water evaporation

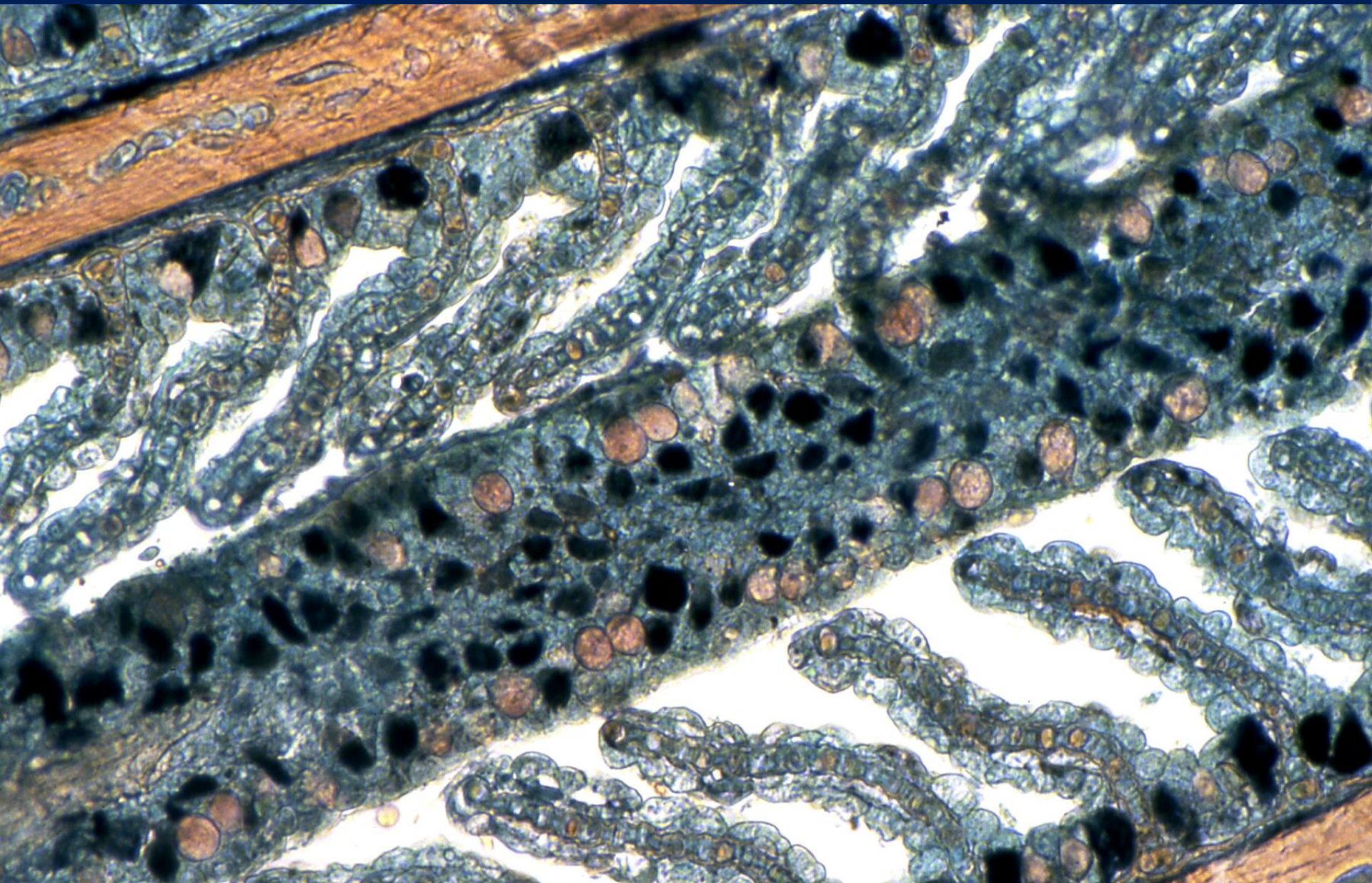
Water only inside

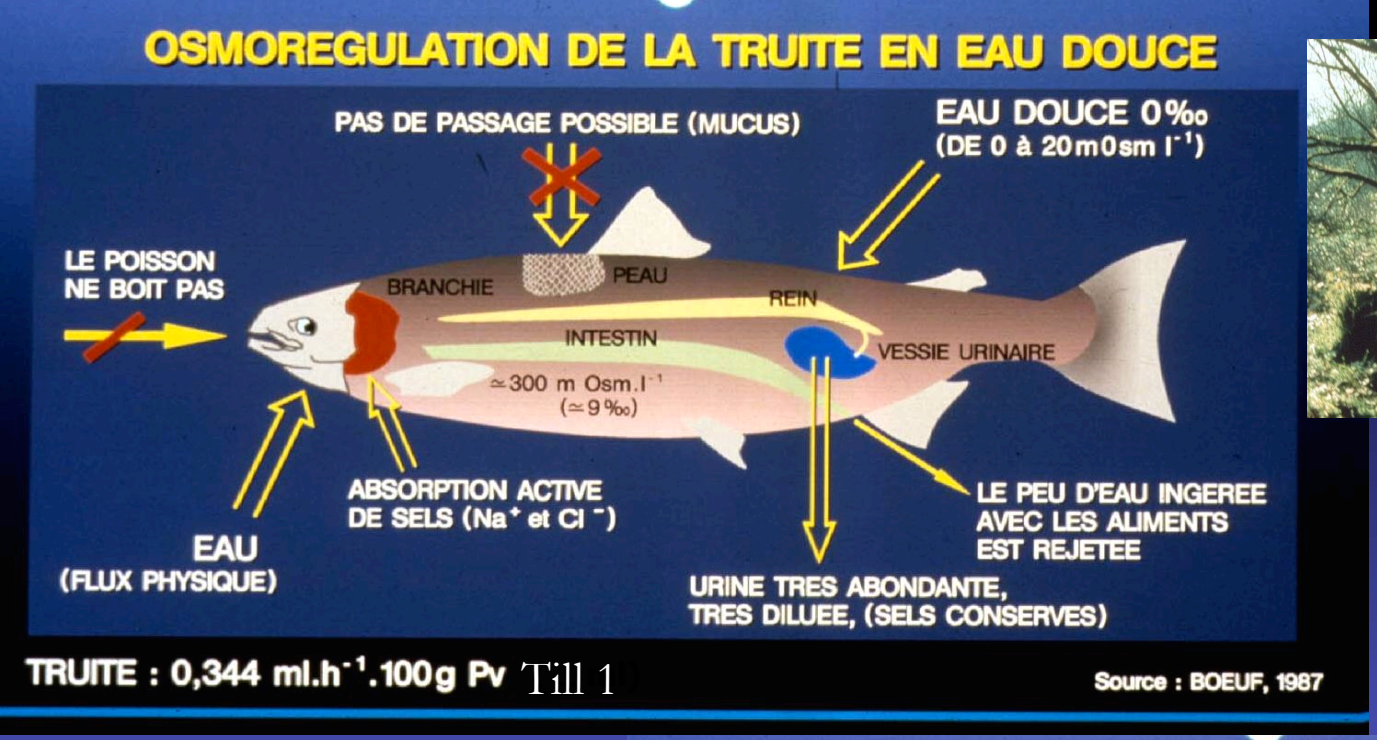
Salts (food)

Water (drinking)

urine, sweat

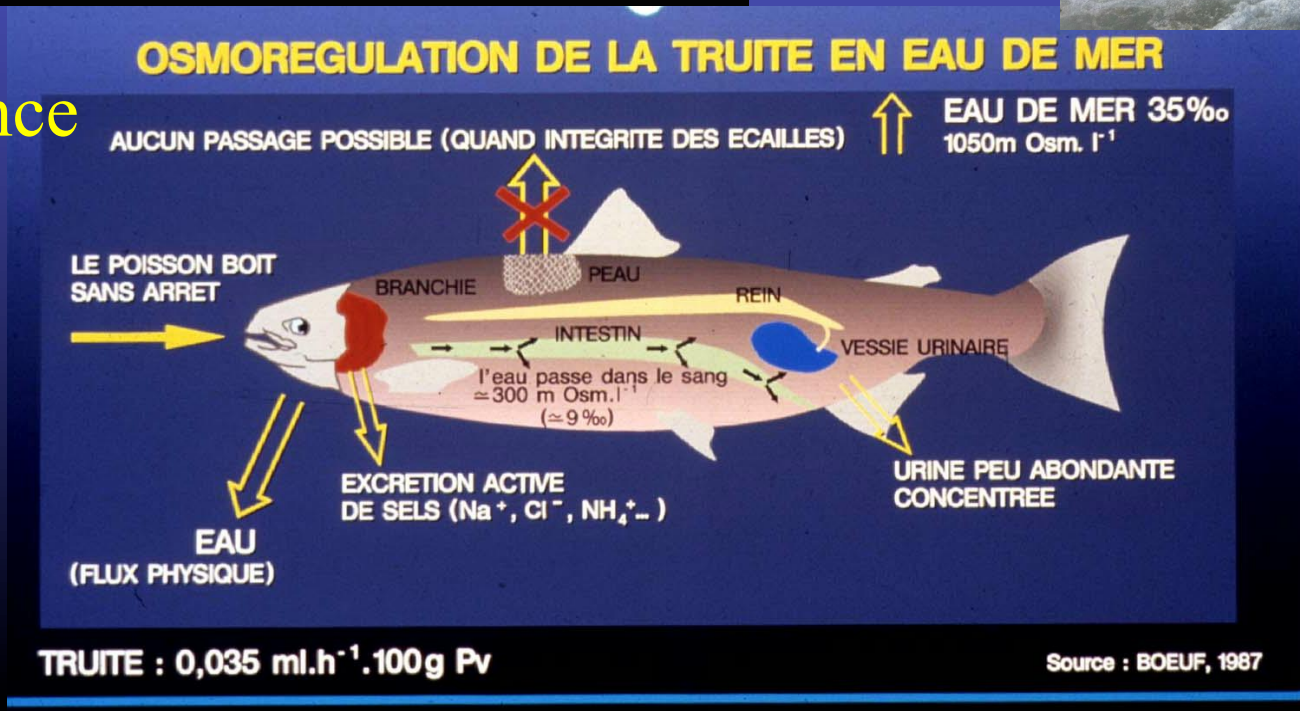
Gill structure

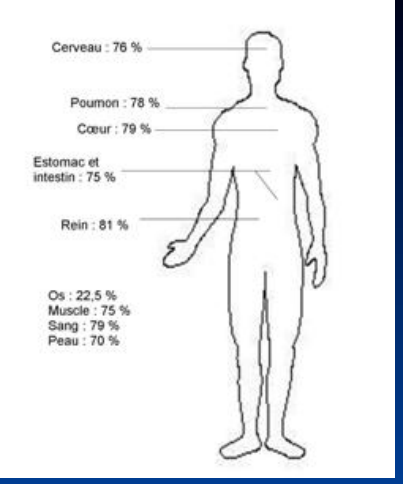




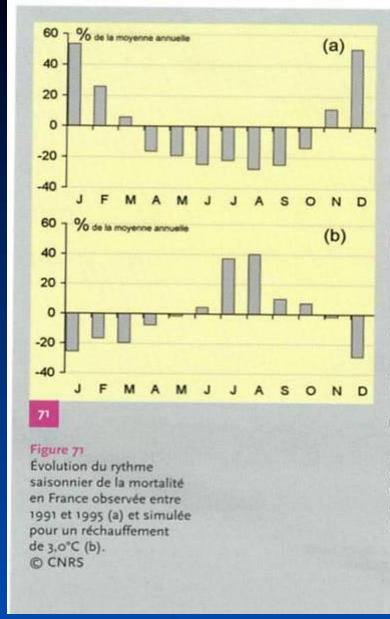
Migrator performance

(Boeuf, 1987)





Human and water



- 65 % in adult man, 60 in woman,
- 75 % in new-born child, 70 % 5 years child , 55 % old people, the total inside water of the humans: 273 km^3,
- 10-15 % water loss, dehydration and death, 1 month without eating, only a few 2-4 days without drinking,
- 2,5 l ingested per day: 1.5 l drinking, 1 l eating,

  2.5 l losses: 1 l urine, 0.1 l stools, transpiration 0.5 to 1 l, respiration 0.5 l; for the whole life 75 m^3.

Mediums

- *Milieu intérieur* human
- osmolarity, 302 $mOsm.l^{-1}$
- 100-105 mM Cl^-
- 138-142 mM Na^+
- 3-5 mM K^+
- Kidney cell and fluid 3000 $mOsm.l^{-1}$

- Sea Water, open ocean
- osmolarity, 1050 $mOsm.l^{-1}$
- 560 mM Cl^-
- 450 mM Na^+
- 11 mM K^+
- «extreme» : 2500 $mOsm.l^{-1}$

1/3 SW = physiological serum

Threatened Biodiversity

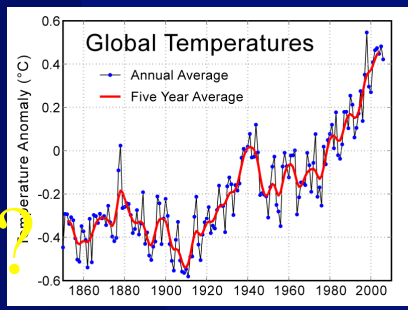
The 'fishing down' effect is ubiquitous. It describes the systematic extirpation of marine megafauna

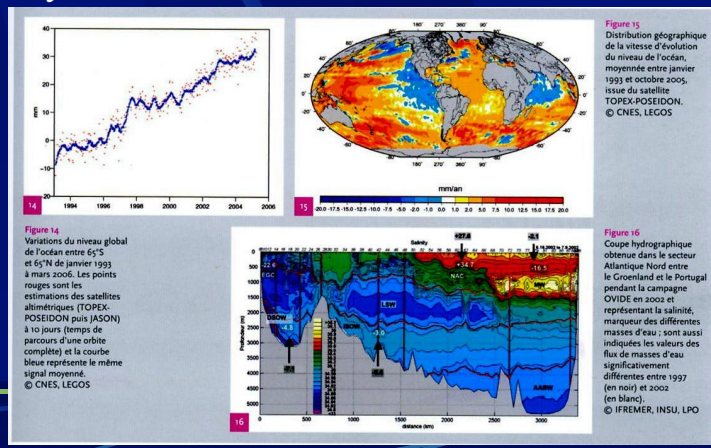
1 Destruction and pollution

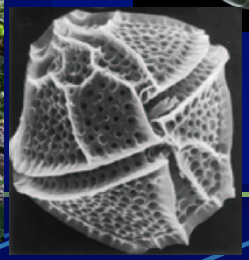
2 Overexploitation

Has the Earth's sixth mass extinction already arrived?

Barnosky *et al.*, 2011







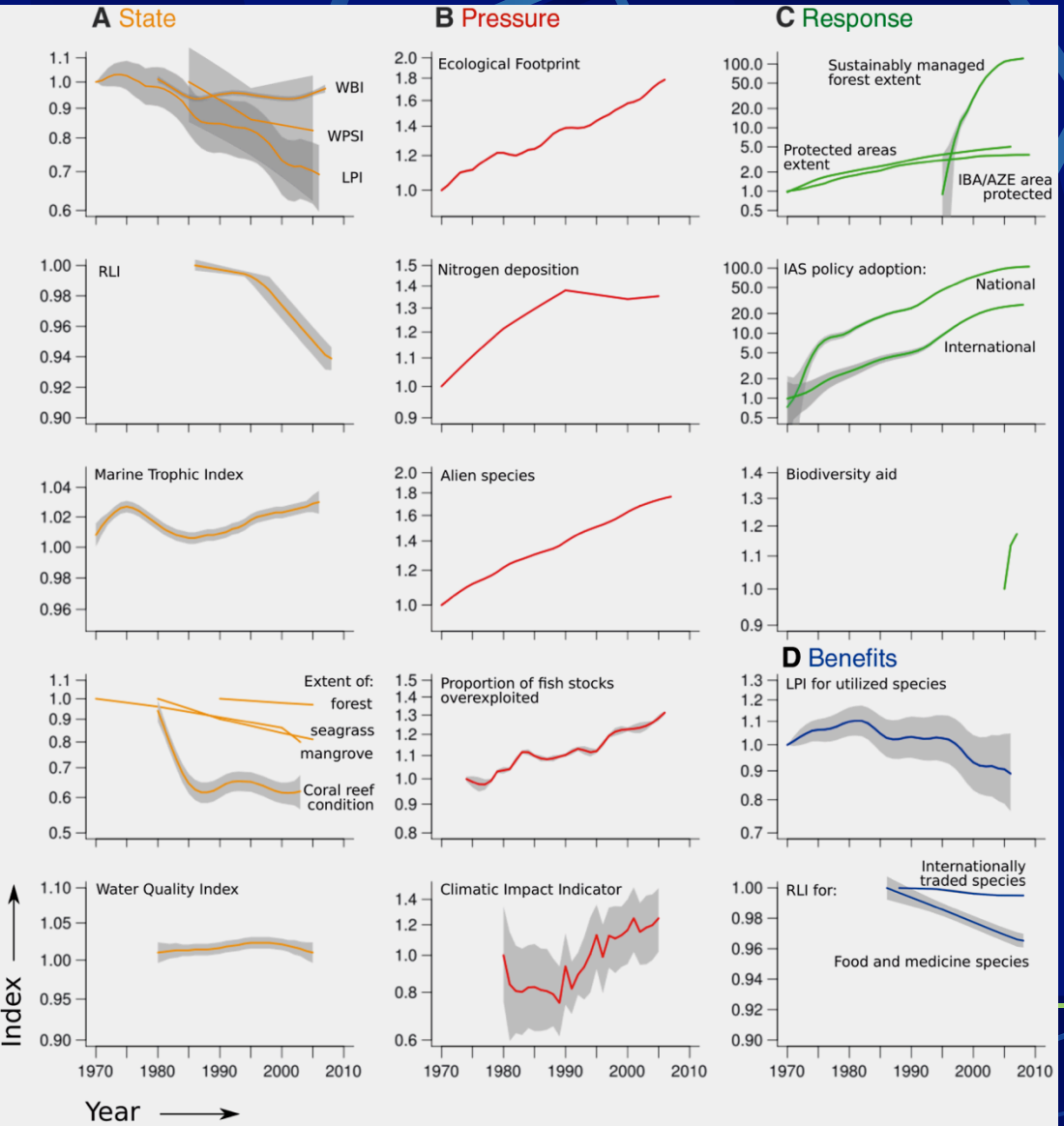
3 Alien invasive species

4 Climatic Change

Conference of Rio, June 1992,
Conference of Johannesburg, August 2002,
Conference of Paris, January 2005,
Conference of Unesco, Paris Januaray 2010,
Rio + 20?

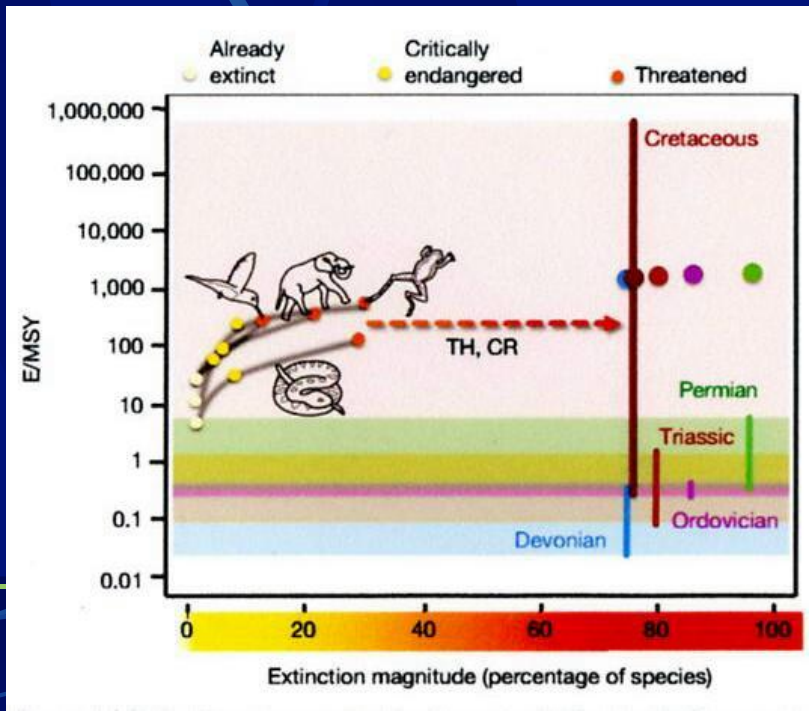
After eight years of « efforts »?

Butchart *et al.*, Science, 2010



Indicators trends for: A the state of biodiversity, B pressures upon it, C responses to address its loss, D the benefits human derive from it.

Barnosky *et al.*, Nature, 2011



Water

The Forgotten Biological Molecule

Edited by

Denis Le Bihan

NeuroSpin, France

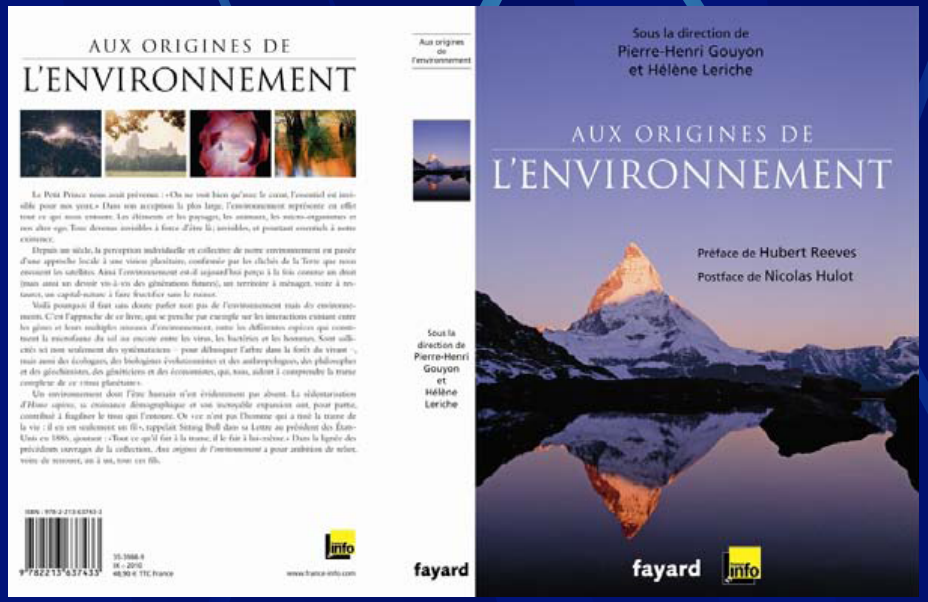
Hidenao Fukuyama

Kyoto University, Japan

PAN STANFORD PUBLISHING

Is the human able to adapt to himself?

Meeting MNHN, 29-30 October 2010 MNHN Symposium, 29-30 Oct 2010
Fondation des Treilles, 8-11 November 2011
Symposium MNHN, January 2013



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Conference of Paris for a global ecological governance

CITOYENS DE LA TERRE
Conférence de Paris pour une gouvernance écologique mondiale
2 – 3 février 2007

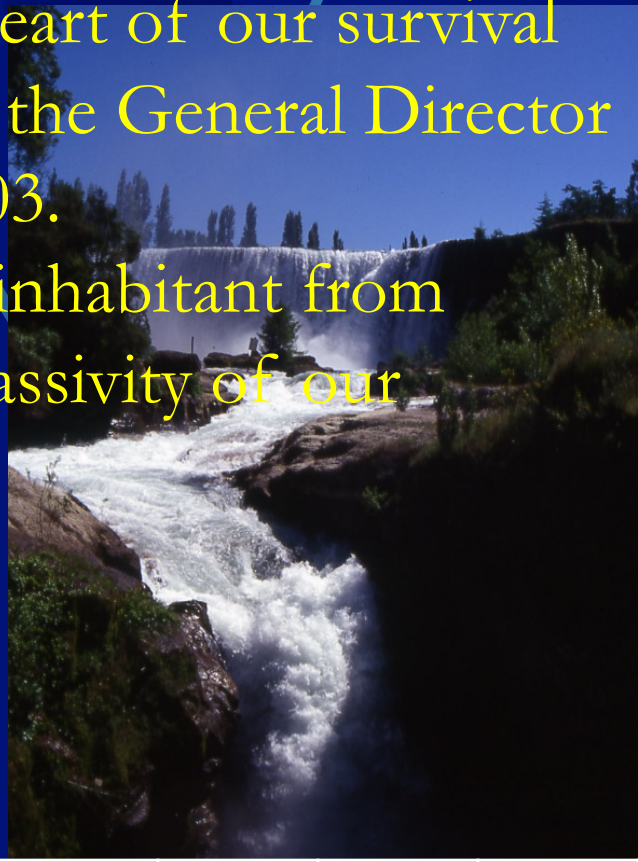
1. Fight against global warming
2. Act together to preserve biodiversity
3. Reduce pollution and preserve public health
4. Make water a shared stake
5. Invent ecological growth: change ways of thinking, production, and consumption
6. Enhance the international governance for the environment

Call of Paris for UNEP

Water reserves

« Among all the crisis of social or natural origins to whom human is confronted, water crisis is at the heart of our survival and survival of our Planet Earth » has said the General Director of the UNESCO, Koïchiro Matsuura in 2003.

Water will be available at 1/3 less for every inhabitant from today to 2020, very worrying attitude and passivity of our politicians!



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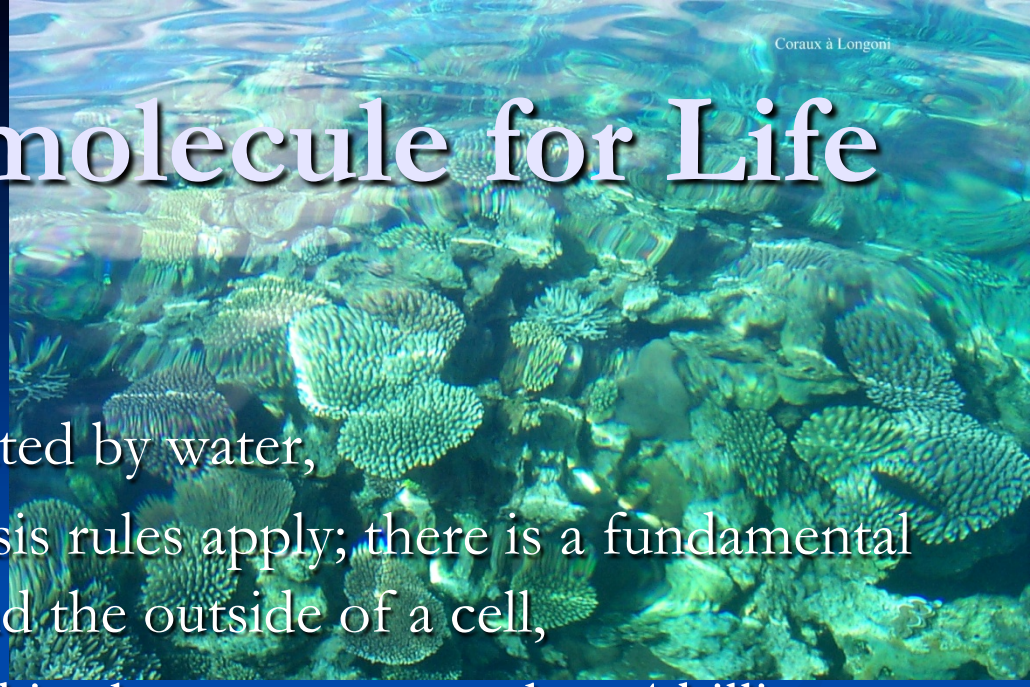
Water, a key molecule for Life



- All living organisms are constituted by water,
- It is the universal solvent, osmosis rules apply; there is a fundamental difference between the inside and the outside of a cell,
- Primitive life settled and evolved in the ocean, more than 4 billion years ago,
- One of the major event in the history of life was when the first organisms moved out of water. It happened quite recently on a geological scale,
- > 50% of the drinkible water resources of the planet Earth are used only by humans. What about tomorrow? Wars for water ?

Thank you for your attention!