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Ocean, Biodiversity and Resources

1.1. The history of life in the oceans

The Earth was formed 4,600 million years ago. From ancestral geodiversity originating from prebiotic chemistry, which gave rise to the set of chain reactions that produced the first structured sugar, nitrogen base and amino-acid molecules, "life" appeared in oceans, fairly quickly after the initial cooling and condensation of water, over 3,800 million years ago.

Duve [DUV 96], 1974 Nobel Prize Laureate, said, in *Dust of life* in 1996, that Earth was so ideally positioned with respect to the Sun that it would not be possible for life not to appear (i.e. it was bound to), while J. Monod referred to it as an improbable occurrence. The oldest known sedimentary rocks (Akilia Island, in South Greenland) containing carbon of biological origin date back 3,850 million years. We must imagine very primitive life at the start, based on a world of ribonucleicacid (RNA) and protocells [MAU 03]. Current deposits of stromatolite (rocks that precipitate bicarbonate), with very rich deposits in Australia, are very precious since, in their silicified parts, they contain the most ancient known fossils of microorganisms: cyanobacteria. These began their conquest of the oceans around 3,400–3,200 million years ago, at the time without any atmospheric oxygen. In the presence of water, photosynthesis produces oxygen and sugars from light and carbon dioxide (CO_2) due to specific pigments

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in the cells; this process began to take place on Earth around 3,500 million years ago. Oxygen started to diffuse beyond the confines of the aquatic environment around 3,200 million years ago; the current composition of the atmosphere, with its 21% of oxygen, dates back at around 100 million years, in the Cretaceous Era.

In this ancestral ocean, events occurred that were of critical importance both for the living world in general and for biodiversity:

– the appearance of the nuclear membrane and the individualized nucleus (prokaryote-eukaryote transition) around 2,200 million years ago;

– the capture of ambient cyanobacteria that would become symbionts and the organelles of the cell – mitochondria and plastids, with desoxyribonucleicacid (DNA) of their own – respectively, around 2,100 and 4,100 years ago;

– the appearance of multicellular organisms and metazoans around 2,100 million years ago.

Another exceptional occurrence took place in this ancestral ocean: the appearance of sexuality, first with prokaryotes, and later also with eukaryotes, which would prove to be essential for the explosion of biodiversity. Sexual reproduction allows for genetic mixing, which creates originality and unprecedented diversity: all individuals are different. A population endowed with sexuality evolves much more quickly. Furthermore, the prevalence of sexuality facilitates the development of an "arms race" between parasites and their hosts (coevolution and molecular dialogue [COM 01]), as genetic mixing ultimately leads to quicker "neutralization" of the parasite, and sexual selection that is clearly different to natural selection [DIM 05].

The exit of organized metazoan life from the oceans took place after the Cambrian explosion (570 million years ago), where the first plant life-forms (first vascular plants in the late Silurian, around 415 million years ago, with moss existing long before that) and terrestrial animal life-forms (arthropods and vertebrates, among others) would leave traces on the continents (myriapods, scorpions, later lungfish, rhipidistia and *Ichthyostega*, around 440 million years ago). Numerous new adaptations were developed, both by plants and animals; the transit to terrestrial life and air-breathing represent an exceptional occurrence in the history of life. The differences are fundamentally between aquatic and terrestrial animals. The former extract their oxygen from water through diffusion to the heart of the organism for small species, or through gills for larger ones. A volume of seawater at equilibrium with the air contains around 30 times less oxygen than the same volume of air. Anisosmotic aquatic breathers (whose internal environment is different to the surrounding water – e.g. fish) cannot develop too large an exchange surface (gills) due to the dangers inherent to the physical consequences of osmotic “flows” (water and electrolytes), with the animal losing water to the sea, or being “flooded” by river water. In fact, a fish is constantly subject to a difficult compromise, between developing a maximum gill surface, to capture the oxygen in an oxygen-poor and very changeable environment, and a minimum surface to help prevent serious water–mineral imbalances. Aquatic animals excrete ammonia and, for the vast majority, do not thermoregulate. By contrast, terrestrial animals must endure ultra violet (UV) rays, dehydration, a very different experience of gravity (consequently, requiring a much heavier and resistive skeleton and muscle mass), and must use excretion products that are not highly toxic or are non-toxic (such as, uric acid or urea). Much later, in the Triassic period, around 210 million years ago, after the third great species extinction crisis, the premises of thermoregulation were developed, and used to maximum efficiency first by large dinosaurs, and then mostly by birds and mammals. A very good example of the return to the ocean is the case of cetaceans, which began this reacclimatization to marine life based on the primitive terrestrial forms of artiodactyls (for example, hippopotami) similar to *Diacodexis*, and then amphibian forms (like the *Pakicetus* or *Ambulocetus*) around 55–50 million years ago, whose current giant forms (the largest animals to have populated the planet since the origins of life, which humans have been uncaringly massacring for 160 years) are very recent. Today, 12 *phyla* are exclusively marine animals and have never left the ocean (echinoderms, brachiopods, chaetnognaths, etc. – see Table 1.1). However, only two exclusively terrestrial groups (not *phyla*) exist: myriapods and amphibians. Additionally, the seas contain vast quantities of biomass: the bacteria in the subsurface layer of the ocean alone represent 10% of all carbonated biomass on the planet [PAR 94]. The marine environment has, therefore, played a decisive role in the history of life, and today the ocean continues to play a crucial role in the evolution of life and climate [BOE 08].

Today, we are searching for traces of “extraterrestrial” life, by concentrating efforts on DNA, amino-acids, Adenosine triphosphate (ATP), etc., without forgetting that the key molecule of life is water. The make-up of every living being contains water – ranging from a few percent, in the case of the “driest” organisms (e.g. plant seeds), to over 95%, for certain aquatic species (algae, jellyfish, ascidia, among others). The human body itself is made of two thirds of water; a human baby at birth has 75% of water and our brain has more than 80%. Water is life [BOE 12]: for example, take the borders of a Chilean desert which, every 10–12 years when it rains, becomes covered with flowers (along with vast numbers of insects) in the space of a few days, lasting a few weeks, and then “returns” to years of extreme aridity. This is natural; however, humans can also trigger explosions of life by irrigating the desert.

The departure from water was, therefore, a truly decisive event in the history of life. The ocean has been salty (essentially with sodium chloride) for a very long time, and today we are able to understand this stability in its salinity: the billions of tons of cations (calcium, potassium, magnesium, sodium, etc.) brought to the sea by the rivers since they began flowing, are compensated for: in the case of calcium, by the trapping of marine sediments and the formation of limestone; for potassium by the absorption of clay (see Chapter 4 in [MON 14a] and Chapter 2. Magnesium and sodium are retained in the oceanic ridges (serpentinization and clay-formation from pyroxenes and olivines). Serpentinization corresponds to the hydration of minerals, and alteration into clay corresponds to the deterioration into small grains of less than 2 μ in diameter. For anions, bicarbonates are constantly mixing with the atmosphere and biosphere, and for chlorides, which do not enter into any major biogeochemical cycles, we currently believe that chlorine was one of the original volatile elements that was dissolved in seawater initially and remained there (not much is carried by rivers today). This current salinity, of around 35 psu (internationally recognized “practical salinity unit”, corresponding to 35 g of sodium chloride per liter) causes osmolarity (meaning "osmotic pressure") of 1,050 milliosmoles per liter ($mOsm.l^{-1}$).

Marine life has always had to cope with this, and has developed a universal strategy of intercellular isosmotic regulation for which the vast majority (of animals only) of invertebrates and certain vertebrates have the same osmotic pressure (internal environment and cells) as that of seawater. Another strategy, which has arisen in certain crustaceans, referred to as extracellular anisosmotic regulation, has allowed for great migration capabilities and the ability to change environments, by maintaining the osmotic pressure of cells and body fluids within a very small range (between 300 and 400 $mOsm.l^{-1}$; humans are at 302); regardless of the external salinity. In fact, in this latter case, we can "die of dehydration" in seawater; the presence of salts causing outakes of water from the organism to the external environment through exchange surfaces in close contact (blood–water) with salt water, such as the epithelium of the mouth and gills (with seawater salts migrating in the opposite direction). Marine osmoregulators (for example, boned fish) have had to establish strategies for the constant intake of seawater and the evacuation of salts through the gill, with the kidney proving to be incapable of fulfilling this function on its own. One of the main problems posed by terrestrial life is the conservation of water and the struggle against dehydration [BOE 12]. The role of the kidney is, therefore, essential: think of the small kangaroo rat from the desert, which never has access to drinking water and produces urine that is nine times more salty than seawater. For its part, "terrestrial" biodiversity would develop later on, after the establishment of specific mechanisms, and took off massively in the Carboniferous Era, from 345 million years BC onward.

We will, therefore, take inspiration from certain aspects related to life in the ocean: first its age and its often much simpler organization, and second its productivity and specific diversity:

– Which renewable living resources will humans be able to take from the ocean (fishing and aquaculture)?

– Which molecules of interest will we extract from marine organisms?

– Which marine models will be pertinent for a basic scientific approach or the resolution of fundamental questions in the field of biomedicine?

1.2. Specifics of marine biodiversity

Marine biodiversity is a very special case [BOE 11]. The recognized diversity of species in the oceans accounts for no more than 13% of the set of living species currently known: i.e. less than 250,000. There may be two reasons for this. The first is that our knowledge – especially of deepwater areas and microorganisms, bacteria and microalgae – is still only very incomplete (so we considerably underestimate the biodiversity of the oceans). New methods, such as coupling between flow cytometry (a technique that entails launching particles, molecules and cells at high speeds through a laser beam in order to characterize them) and molecular probes (which reveal an organism with specific features), are currently discovering a totally unforeseen, extraordinary level of biodiversity. "Sequencing the ocean" (C. Venter, sequencing all the DNA in a given volume of filtered seawater) moves in the same direction; the data obtained appear, for the most part, to be revelations. The recent round-the-world expedition *Tara Océans* has also produced exceptional data. For all prokaryotes and very small eukaryotes, recent molecular approaches (sequencing of 16S and 18S ribosomal RNA, among others) produce astonishing results daily. Furthermore, and this is the second reason, it is also obvious that marine ecosystems and the way of life in a continuous environment (by the dispersion of gametes and larval stages) of the species that populate it, are less predisposed to strict endemism (the notion of living exclusively here and nowhere else) than in terrestrial habitats. There are many more barriers and segregations favorable for speciation (the evolutionary process by which new living species arise) on land than in the sea. This leads to significant differences in terms of specific diversity; marine ecological niches do not achieve the richness of terrestrial ones, which are much more fragmented and are more favorable to new species. The stability of the open ocean in deep waters, over at least the past 100 million years, is also extraordinary: in terms of pH, osmotic pressure and salinity, temperature, hydrostatic pressure linked to depth, dissolved gas content, etc. The closer we are to the coast, the more this fluctuates. Human activity is changing this; we will revisit this point later on. This stability is less prone to give rise to new species. Consequently, marine biomasses can be considerable, and the performance of phytoplankton alone, with its capacity for self-regeneration, accounts for over 50% of the planet's productivity.

Phylum	Genus or species	Pelagic	Benthic
Placozoa	*Trichoplax adhaerens*, very small flat animals, base form of invertebrates, 3 sp		X
Ctenophora	From 1 mm to 1.5 m, *Pleurobrachia*, *Beroida*, *Cestum*, *Velamen*… Burgess shale, 190 sp	X	
Xenoturbellida	Two known species, *Xenoturlla westbladi*, very small "marine worms" discovered in Scandinavia		X
Cycliophora	Microscopic animals transported by cold water lobsters, *Symbion*, two species		
Mesozoa	165 sp, small marine invertebrate parasites, *Rhombozoa* and *Orthonectida*		
Sipuncula	Sipunuculid worms, *Sipunculus vulgaris*, since the Cambrian, non-segmented, 1,284 sp		X
Echiurians	*Metabonellia*, *Bonellia*, *Prometor*… "marine worms", 234 sp		X
Phoronidians	*Phoronis*, *Phoronopsis*, etc., live in a cyclindrical tube, 31 sp		X
Brachiopods	With a lophophore, a crown of tentacles and a shell, 12,000 known fossils, 441 sp today		X
Echinodermata	Starfish, sea urchins, crinoids, sea cucumbers, etc. > 14,000 sp	X	X
Chaetognatha	*Arrow worms*, 120 species in 20 genus, *Spadella*, 280 sp	X	X
Hemichordata	Marine deutorostomes in the form of "worms", graptolite fossils, *Saccoglossus*, 143 sp		X
Cephalochordata sub-phylum	Amphioxus, *Branchiostoma lanceolatum*, *Assymetron*, 25 sp		X
Tunicata sub-phylum	*Urochordata*, Ascidies, 3,000 sp in four classes, *Styela*, *Didemnum*, *Salpida*, *Appendicularia*, etc.		X

Table 1.1. *Exclusively marine phyla (according to [BOE 11])*

This table is simply indicative of exclusively marine groups. How do we then chose them? *Cephalochordata* and tunicates are *sub-phyla* of *Chordata* (which have continental taxons), the *Kinorhynca*, *Priapulida* and *Loricifera* have been grouped within the *Cephalorhyncha* with the *Nematomorpha*, which are terrestrial; *Xenoturbellida*, *Cycliophora* and *Mesozoa* can be considered as valid *phyla*.

There are five to seven more terrestrial taxons today, compared to oceans, which is worthy of inquiry since initially life was exclusively marine, before the various great departures from the oceans, at different locations in different forms, 440 million years ago, for "developed" metazoans. The great Permian-Trias extinction played a primordial role with 96% of the extinction of species both marine and continental around 252 million years BC. The explosion of flower plant species, of insects and many other groups on Earth, around 130–110 million years ago, was decisive after the initial radiations (explosion in the number of species deriving from a single ancestral one) starting from the Carboniferous period. The coevolution between plants and pollinators, and the appearance of an infinite number of new niches, have often been proposed to explain the acceleration of speciation in continental environments of this era [BOE 11, BOY 10]. It is also evident that dispersion phenomena of reproductive products and larvae in the oceans played an important role in the distribution of current species and biogeography. Endemism is notably considerably more limited in the ocean, the stability in deep water and the continuity of this gigantic environment explaining this. If it is not rare to find living species over a few km^2 on land, then we do not know of any examples of such confined species in the sea. The large variety of methods of reproduction in the sea also draws from dispersion phenomena in water bodies, with males and females not constrained to being in close proximity. Thus, do connectivity and the much weaker variations in environmental factors create the great stability in the ocean at large and the particularly specific characteristics of the biodiversity that it houses? Coastal systems, intermediaries with strong land-related influences, are subject to much greater variations.

Finally, we must not forget that biodiversity is much more than just specific diversity, which includes both species and their relative abundance. The meaning of the word "biodiversity" has been interpreted in many ways but generally expresses the "genetic information which contains each elementary unit of diversity, be it an individual, a species or a population". This determines its history, past, present and future. Even then, this history is determined by processes that are also components of biodiversity. In fact, today we group different approaches under this term together:

– the study of fundamental biological mechanisms that explain the diversity of species and their specific features and that require us to further study the mechanisms of speciation and evolution;

– the most recent and promising approaches in the field of functional ecology and biocomplexity, including the study of material and energy flows and the great biogeochemical cycles;

– the utility of nature as goods and services for mankind in their capacity to provide food, high-value substances for medicines, cosmetic products, etc., molecular probes or even obtaining ancient ancestral and original models for fundamental and finalized research, in order to resolve agronomical or biomedical questions;

– the establishment of conservation strategies for preserving and maintaining a natural inheritance consisting of a naturally expected heritage by/for future generations. We must also particularly insist on the fact that inventories and descriptive lists are not sufficient to specify what the biodiversity is: much more important are the relations established by the living beings between each other and their environment.

1.3. Renewable living resources

Humans have been fishing since ancient times, certainly tens of thousands of years. As soon as they reached shores, they began to collect shells, algae, etc. As in agriculture and continental environments, humans have been farming certain marine species on the coasts for at least 4,000 years (Egypt, China, etc.). The use of renewable living resources being very well outlined elsewhere in this work and in others in the collection “Seas and Oceans”, I will limit myself to only a few generalized remarks here.

The latest statistics available from the Food and Agriculture Administration (FAO) in 2012, for the year 2011, give values of 78.9 million tons (Mt) for maritime fishing, 11.5 Mt for continental fishing, 19 Mt for algae (with only one for fishing) and 63.6 Mt for aquaculture (of which 19.3 Mt are for the sea), thus a total, of all the groups and aquatic environments combined, of around 173 Mt (see also Chapter 4.

1.3.1. *Fisheries*

Until the 1950s (apart from some very particular stocks already, herring from the North Sea and especially whales, etc.), we did not really record any tax-related overexploitation of fish stocks in the world. This was all accelerated after the end of the Second World War and the establishment of the intensive practice of trawling and the big ocean seine or with huge drift-nets. The question that has already been posed, “will fishing disappear, due to a lack of fish?” [CUR 12, CUR 13]. The collapse of the Newfoundland cod stock at the beginning of the 1990s after 500 years of “harmony” between harsh, but not excessively destructive, fishing across all of the countries bordering the North Atlantic (see *Pêcheurs d’Islande* by Pierre Loti) and the maintaining of the stock has been a symbolic example of “modern overfishing”. Today, the FAO tells us that three quarters of the world’s fish stocks are fully exploited or overexploited. In a 2006 paper, Worm *et al.* [WOR 06] had even announced the “end of fish” before the end of the half century.

From around 30 million tons of world marine products (including algae) in 1950, this statistic has changed to 80–90 Mt in the 1990s and has practically remained unchanged since (bar certain fluctuations in industrial fishing, during the *El Niño* years) despite increasingly sophisticated (and formidably efficient) methods of animal detection and fishing techniques. In fact, fishing activity forms a strange type of exploitation that is still active, and which dates back to prehistory, in a world of finite resources. Of course, living marine resources are by definition renewable, however, the recent crossings of exploitation "thresholds" have shifted certain stocks toward an overtaking of the limit of "renewability", with "natural" recruitment no longer being sufficient. As long as a certain threshold is not crossed, we can always attempt, with adapted and firmly controlled measures, to restore the resource, with this holding true particularly when it comes to fishing. However, the pressure of fishing activity, always being the largest, oldest and most interesting for the market, has not ceased to increase and we can clearly see this by examining today's landings: increasingly smaller fish, in increasingly smaller quantities. Species have reacted over a short amount of time, of less than 30 years, by adapting and allowing younger, smaller individuals to reproduce. However, in the context of severe climate change in the ocean, everything is made more difficult: less food, increasing salinity, temperature and acidity, new hypoxia zones, the introduction of new species, the mass destruction of coastal ecosystems, pollution, etc., this is beginning to have a major impact. Also, the diversion of coastal fisheries toward deep waters is not reassuring: a lack of knowledge, long-lived, scarce species, with late sexual maturity, essentially all that must rightly not be fished. It is not the same parties that exploit coastal and deep water zones. We must remember, however, that currently this is only being practiced by a minority and that more than 80% of the fishing fleet is made up of small fishing boats (Figure 1.1).

Figure 1.1. *The small-scale fishery units of the Iquique port in northern Chile, exploit horse mackerel, sardines, mackerels and anchovies, and sometimes amberjacks and swordfish*

The main problem remains the more global approach of “natural expenditures” in particular in the most productive zones situated at the interface of continents and oceans. This is, therefore, clearly a question of ecosystem-based fishing approaches. Another problem corresponds to “industrial” fishing (for making fish flour) which, using large ocean seiners, captures millions of tons (in fact, a quarter of the world’s resources) of open-sea fish of which the flesh is evaporated in the deserts on the coast of Chile or Peru in order to be transformed into oils or flours for world livestock farming (see also Chapter 2 in [MON 14b]).

Regarding marine living resources, and to make stocks as long-lasting as possible, the access to these resources must be legislated and limited. Different methods exist and are being tested, however, political incentives and dialogues with anglers have remained primitive. Open-sea resources are clearly starting to become very attractive.

Deep-sea fishing must, therefore, be rethought. If we want to ensure a long-lasting future for this activity, new exploitation methods must inevitably be discovered, being more economical in fossil fuels, respectful of the resources and biodiversity, and most notably better adapted to the regenerative capabilities of stocks. The approach must be consistent [CUR 12] and better integrated with other human ocean activities. A question, therefore, arises: why not emulate the continental environment, and massively develop marine farming?

1.3.2. *Aquaculture*

Contrary to popular belief, aquaculture is an ancient activity that dates back to Egypt and China at least 4,000 years ago. Aquaculture is in fact “water farming”, be it plants or animals. It can act as a strong support for fishing activities by, for example, helping to release young specimens of different species back into the sea or other bodies or streams of water, thus enabling the capture of the resulting adults. This is what has been communally referred to as sea-ranching, a very extensive aquaculture system. This can also be intensive and consist of farming animals in enclosed conditions (floating cages, reservoirs, bodies of water, etc): the animals are, therefore, in high density and are fed by the fish farmer. Intermediary systems also exist – e.g. oyster farming on beaches which, while they self-propagate within that environment, are nevertheless present in a much higher density than in a natural environment; carp in ponds, where numbers are not always fed. There is also production aquaculture, where we produce the animal's meat using primary production (oysters, etc.) and transformation aquaculture, where we "transform" an animal protein into another animal protein for a more economically valuable species (carnivores, salmon, turbot, tuna, etc.). Today, the species of interest for aquaculture essentially consist of molluscs (bivalves, as in oysters, mussels, scallops, clams, etc. and gastropods such as periwinkles or abalones (Figure 1.2)), prawns (notably those in the Penaeidae family, or "gambas") and varied freshwater, brackish and seawater fish (carp, eels, sheatfish, trout, tilapias, sturgeons in freshwater, milkfish, serioles, wolves, dorados, flatfish, salmon, tuna, etc.).

Even though we only consume a few species from terrestrial environments (cow, pork, mutton, chicken, guinea fowl, goose, etc.), we consume many more aquatic species (at least a few dozen "routinely").

Figure 1.2. *Production of juvenile abalones in a hatchery in Chile*

Aquaculture, very comparable in its identity to agriculture and by representing a form, is nonetheless very different on some fundamental points:

– farmed species are not mammals or birds, and therefore do not control their internal temperature (ectotherms): this leads to exceptional abilities in transforming food, but also allows for the existence of very small larvae (for example, only 80 µg for a turbot larva at birth), which makes enclosure techniques very sensitive;

– these species live and breathe in water and this fluid, which is very particular compared to air (density, viscosity, thermal behavior, etc.), leads to certain problems for purification, the content and access to oxygen, the transmission of pollutants, renewing bodies of water, the cost of heating or cooling, etc.;

– many species are carnivorous, and it is certainly the first time that humans have been known to farm zoophagous animals in order to consume their meat.

When we observe production statistics, when we have already seen that fishing has been in complete stagnation over the last 20 years, or even in decline (regardless we must by all means fish less in the future), aquaculture is in constant growth, which is an interesting fact and is interesting to note in the works related to "large-scale agriculture".

	1989	1995	2000	2005	2011
Animals	12.3 Mt	24.5	33.3	47.3	63.6
Plants	4.2	6.8	9.5	12	18

Table 1.2. *World productions in aquaculture (data from [FAO 12]), in millions of tons*

Today, aquaculture, for all aquatic environments, greatly surpasses fishing in value (100 million euros) and is matching it in terms of produced biomass. It is in freshwater that production has greatly increased, however, efforts in saltwater are also progressing. Aquaculture is mostly predominant in Asia, and China produces two-third of global resources on its own. This fact is not a coincidence;

Asian populations have been integrating these “fish farms” into their way of life for a long time.

With the idea, which is effectively very logical, being to limit samples from nature through fishing and to “replace” missing aquatic proteins (especially in the context of ever increasing demand, for demographic reasons and also in the interest of “healthy produce”) with aquaculture, the implementation is not that simple. Aquaculture is clearly a massive success, however, it must establish itself as a longer lasting process, in todays’ highly changing and sometimes even unpredictable environment: climate changes, the rise of the sea level, temperature, salinity, acidity, increasing hypoxia in the world’s waters, loss of diversity, arrival of “exotic species”, wild and varying access to the coast spurring heavy conflicts between involved species, pollution (including that produced by aquaculture), etc.

Moreover, outside of its role in the production of proteins, aquaculture can form an activity that complements fishing, since these two activities are not systematically incompatible with each other, as opposed to how it is often portrayed in France. We must simply observe what is happening in Japan or on the west coast of North America, for example. Through aquaculture, and due to modern enclosure techniques, we can produce a system confined to larvae or even better, juveniles, and then release them into the natural environment that heavily contributes to the maintenance or development of the resource. This is obvious for Pacific salmon for which the juveniles or smolts are released in the hundreds of millions into the north Pacific (sea-ranching) and which, once the adult stage is reached, are captured by fisheries on the return migration route. Thus, 70–90% of coho salmon caught by Canadian and American fishermen are born in fish hatcheries. Examples of restocking or sea-ranching are present not only with salmonids, but also with cod, sturgeon, scallops, prawns, etc.

The inverse system also exists (capture-based aquaculture), and one of the best examples is the farming of seriole, a silver fish, in Japan [NAK 08]. Juveniles are caught at sea in spring by fishermen and put into farms in large floating cages. They are then, after having been fed with fresh or frozen fish meat, gathered after 6–18 months and put on the Japanese market. This is the most widely produced species of “strictly marine fish” today in the world (160,000 tons in 2010). Scallops are put into farms in Chile from fished juveniles and supply the scallop farms that produce excellent produce for exporting. Wild animals can also be well “enclosed” by fishers into sea or land structures and be preserved living, fed or not, in order to be put on the market when the prices are at their highest (for example, the large bluefin tuna in Australia, Spain, Japan and Croatia).

Although world aquaculture is an extraordinary success and represents a fabulous source of protein for the future (over one year: +10% for plants, +8% for animal produce), at least three unavoidable questions must be asked.

1.3.2.1. *The farming of carnivorous species*

One of the essential questions has to do with the future of farming of carnivorous species, which require animal proteins for their diet. Can we continue to fish a quarter of all halieutic resources of the planet, directly useable by humans, in order to provide animal protein to farms (both aquatic and terrestrial, which the latter can do without)? And can we continue doing this, if it is possible? Answering these questions will require constant contact between private groups and public organizations. Certain works show the deleterious effect of current practices [NAY 00] not only by ocean fisheries, but also by aquaculture itself. The best obtained food transformation rates hover around 3.5 kg of caught fish to produce a gain of 1 kg of farmed carnivorous animal biomass when they are fed with artificial food (50% fish flour in the food, sometimes 70%) and of more than 5–6 kg (up to 12 for tuna) when they are fed with fresh fish. This has for a long time highlighted the different attempts that have been developed to both reduce fishing efforts devoted to the production of fish flour and also reduce the proportion of fish flour used in fish foods. Efforts have been made with trout and certain marine fish to replace animal proteins in the diet with others, of plant-based origin: soy, peas, lupin, rapeseed with certain zoophagous species (for example, trout) having been farmed without any animal-based foods. The prospects probably exist, however, certain species cannot be produced without the use of animal-based flour or oils. We have also progressively increased the quantity of lipids in food in order to reduce the impact of phosphorus and nitrogen on the environment.

It is clear that the farming of algae and mollusks, as well as that of omnivorous fish, is much more promising. These fish are much less "appreciated" in the market, however, they prove to be extraordinary transformers of the primary biomass and help to feed hundreds of millions of humans in South-East Asia, China, Africa or South America. They are the ones that explain the progression of the global production numbers. Often, in these regions, the only accessible animal protein is of "aquatic" origin.

Aquaculture can also provide meat of excellent quality at high prices for "high-end" markets in rich countries (the Japanese *hirame*, a flat fish or turbot, for example, sturgeon caviar and imperial prawn meat) as well as "cheaper" meat (even if it is of as good quality on a biochemical level and in its composition) of tilapia, catfish or mullet to feed poorer populations. Asian pangasia and catfish have thus flooded the European market. Carp and tilapia can be farmed in "medium" quality water, loaded with ammonia and poor in oxygen. The returns (rate of ingested food/weight gain of the farmed animal) are sometimes extraordinary, such as with tilapia in India. Mollusks are also very interesting since they are very "profitable", however, they return little meat (the shell weighs a lot) and often reach prices that are too high for the majority of populations. Mussels are particularly interesting, however, they are very sensitive to the water quality and are not exempt from dangers to the consumer if a certain minimum of precautions are not taken.

1.3.2.2. *Impact on the environment*

The impacts on the environment can be very significant for certain types of farming. In fact, depending on how intensive production is, semi-extensive or extensive, we can speculate that disturbances will not be the same. One particular species can be produced according to three types: salmon or shrimps, for example, from sea-ranching (juveniles released into the ocean) to a large-scale hatchery in basins or cages. How does the quality of the ambient water affect the quality of the farmed aquatic organism? How can the latter disrupt the quality of the water? For most species, water of the best possible quality is essential, and this often involves a "fuse" for the environmental impact; the farmer cannot overpollute if he wishes to not poison himself. In terms of pollution, large concentrations of aquaculture pose serious problems if the body of water is not constantly and sufficiently renewed. In Norway, the marine farm installations are changed every 5–10 years in order to avoid problems of "autopollution". Farming in oligotrophic lakes quickly poses serious environmental issues, such as in Chile. Moreover, calculations performed on the waste produced by aquaculture farms have allowed for a minimization of the impact where currents, from tides or other sources, are strong that ensures the dilution of the problem. The reduction of the protein concentration in the dietary rations (increase of lipids) has allowed for a considerable reduction in environmental impacts (excretion of nitrogen and phosphorus), however, this has led to farming produce which is increasingly rich in fat. Increasingly, we have established links between the quality of the water (including the reduction in oxygen content) and the occurrence of infectious illnesses; this is evident in shrimp farming, in all parts of the world with the "white stains" disease (viral) currently in South America as well as elsewhere, and recently with early mortality syndromes, a "cocktail of phages and bacteria".

Aquaculture arrangements themselves can destabilize coasts if they are "pharaonic": shrimp farming in Thailand or Ecuador, for example. Mass destruction of the mangrove is taking place all over the planet and seriously affects recruitment for fish stocks. Furthermore, "fish farmers" often buy their juveniles from fishers that catch them in these mangroves. A better respect for the coastal ecosystem is unquestionably needed which, being "ill", would no longer allow for farming (recurring epizootics). In developed countries and this is the case in France and more largely in Europe, property is expensive and access to the coast is increasingly more difficult. Aquaculture can only be achieved in the long-term in an elaborate setting for development and integration of economic coastal activities: competition with industry, tourism, etc. Organization and true political will are required.

1.3.2.3. *Introduction of species*

Another important question is that of the introduction of species [BOE 02] and the "wild" dissemination of animals or plants on the planet. Thus, the Pacific oyster is present almost all over the world today, as is the rainbow trout; African and Asian tilapias are in tropical America, the Atlantic salmon is in the Pacific Ocean, in Canada or in Chile, the French scallop is in Peru, Chinese carp in western Europe, etc.

On top of the danger presented for local wild stocks (there is no existing aquaculture without escaping animals), examples of introductions of pathogens, viruses, bacteria or parasites are a common occurrence; epizootics and the quasi-destruction of the European oyster in France are other examples, the start of a serious viral disease (Isavirus) with the Atlantic salmon in Chile in 2008, etc. A dive into the Etang de Thau in France is now similar to being in a Japanese ecosystem such is the extent of Japanese algae seeds that have been regularly introduced with Pacific oyster spats since the 1970s. Japanese prawns introduced into the Red Sea have now invaded the Mediterranean Sea. There are, therefore, a large number of examples.

1.3.2.4. *Zootechnical research*

One important area of zootechnical research is necessary to accompany the development of aquaculture. This must be accomplished:

– in the area of nutrition: for fish, shrimps and mollusc farms;

– in pathology and prophylaxis. As soon as animals are gathered, epizootics are triggered, often linked to a deterioration of the ambient environment; vaccinations must be frequent, which are not conceivable for shrimps and mollusks;

– in genetics: family selection, "typing" of strain, genetic modification, trangenesis, etc.;

– in physiology: development, growth and farm breeding.

All of this makes up what is called the "biological basics of aquaculture".

1.3.2.5. *The future of aquaculture*

The reason that aquaculture is so well developed, especially over the last few years, is because it bases itself on very ancient empirical principles from Asia and because it was an integral part of the culture of certain populations. However, the recent remarkable progress ("invention" of salmon farming, shrimp farming, mollusk enclosures, production of algae seeds, selection of fast-growing strains better adapted to reproduction, etc.) are of course due to important efforts of fundamental and finalized research. In 1974, a Norwegian salmon reached 2 kg in four years; today, it weighs 6 kg at 18 months, and 18 kg at 30 months.

Have we progressed too fast? The current state of shrimp farming (3 million tons today), which has led to enormous profits for some persons in a very small amount of time, is puzzling, with repeating viral diseases all over the world. The majority of farms are completing their last harvests in Peru, and Taiwan as well as China have seen their production collapse in one year. Some have "restarted", sometimes with a new species (*P. orientalis* replaced in China by *P. vannamei*, introduced from America). Salmon farming has managed well up until now, and sea production is concentrated in three countries: Norway, Chile and France. However, Chile encountered a serious crisis between 2010 and 2012 after the introduction of a virus. Environmental problems are serious, the question of fish flour being at the center of debates, and the quality of the meat, being too high in fat, is being questioned.

Trout farming in freshwater in France no longer has room to develop. French oysters, which required two to three years to reach marketable size, sometimes require five or six today, with oyster production areas being saturated. The emergence of the farming of new species of marine fish allows for a remarkable diversification of produce. However, the hatchery stage is still a very delicate process, the eggs being very small and the animals far from developing at the same speed as penaeid prawns (six months to a year per cycle). New mollusks, which indicate necessary to use an hatchery stage (we cannot catch juveniles in nature, and reproducers must be held in captivity), appear in farms.

In fact, the remarkable increases in global production are due to these species of algae or omnivorous fish that are cultivated or farmed in Asia. “Chinese” aquaculture methods (produced on the site as pork, duck and fish) is fascinating with its apparent simplicity, but is it really this simple?

Tomorrow’s aquaculture will imperatively need to be more conscious of the environment and be well thought-out and integrated into the layout schemes of coasts (or bodies of water in freshwater). This is essential for a sustainable management. It will allow the feeding of hundreds of millions, or even billions, of humans by harmoniously supporting fishing and making it possible to achieve better prices (allowing to manage the first bargain). Aquaculture allows for sowing to then lead to cultivating, which has always differentiated agriculture from harvesting. However, we must also avoid the recent severe production crisis affecting an overly production-focused agriculture and always keep the specifics of the aquatic environment in mind as well as the species that inhabit it [BOE 02].

1.4. Ocean and public health

The inter-relations can be of varying types; we will recall five of them (in accordance with [FEN 99a]):

– the role of the ocean in large physical phenomena and the evolution of the climate. These inter-relations relate to the physical phenomena associated with the movements of “sea water”: marine currents, violent winds creating storms, tornadoes, hurricanes, giant waves, tsunamis, etc. Through their mechanical effects, they can be very destructive and injure or kill many humans;

– liquid and its physiology. This also involves not only physical aspects but also physiological aspects: asphyxia from drowning after upsurge of water in the respiratory airways, decompression accident after breathing of compressed air during hyperbaric diving, etc.;

– the dangers of the fauna and flora. Many marine species are venomous and produce powerful toxins (ingestion or contact):

jellyfish, ciguatera (CFP), cones, rays, stonefish, scorpion fish, etc. Certain large species can also attack humans and put their lives in danger (great white sharks, barracudas, moray eels, great salt water crocodiles, etc.);

– microalgae blooms and red tides. Certain species of microalgae can (or similar symbiotic bacteria) contaminate through ingestion and/or free highly toxic substances into the environment (many dinoflagellates), which "eliminates the competition", thus creating real environmental problems. Furthermore, they sometimes form large biomasses under favorable conditions (red tides): the main kinds involved are *Pfiesteria*, *Alexandrium*, *Prorocentrum*, *Gymnodinium*, *Dinophysis*, *Pseudonitzschia*, etc. They produce formidable toxins that can be paralyzing (PSP), amnesic (ASP), neurotoxic (NSP), diarrheic (DSP), etc.;

– infectious illnesses generated or transmitted through seawater [BOE 07]. Certain pathogens (*Vibrio* and *Mycobacterium marinum*) originate from marine environments. Others carried by dirty seawater are preserved without difficulty such as *Salmonella*, *Legionella*, *E. coli*, *Shigella*, *Leptospira*, *Listeria*, *Morganella*, hepatitis viruses, *Poliovirus*, *Calcivirus*, etc. *V. cholerae* can easily be transmitted through marine zooplankton organisms. Certain parasites, originating from marine fauna, are transmittable to humans who consume raw food (*Anisakis simplex*). In fact, the ocean can be the cause of a whole series of illnesses in the general sense, and certain medical implications exist since humans have been frequenting the sea. We can also add the current effects of coastal pollution that can often be harmful to our health, however, this remains tied to human activity and waste, the ocean acting solely as the carrier, since everything eventually ends up on the coast.

1.5. Research of molecules of interest of marine origin

Over 50% of medicines sold in pharmacies correspond to natural products (or synthesized from natural products), and over 25,000 of these molecules are from marine organisms. Although plants on Earth are genuine champions when it comes to chemical arms, animals are also relevant (and more capable of providing us with molecules of interest) in the sea, since many no longer move once they have reached the adult stage. Certain molecules have reached common usage: anticancer Ara-C (which counters acute myelocitic leuchaemia and non-Hodgkin lymphoma), antiviral Ara-A (anti-herpes), isolated sponge nucleosides, byrostatin (from bryozoa) activator of the kinase C protein (which counters leuchaemia and myeloma), bacterial antivirals (anti-HIV), etc. [FEN 99b]. Thirty percent of these substances were found in sponges. From micro and macrophyte algae, we can add proteoglycans, immunostimulants, antivirals, polymers with a high capacity for chelation, anti-fertilizing polysaccharides, agar and pectins, cosmetic substances, dermo-regeneration-based UV coating, etc. Microalgae, genetically modified (GM) or not, are harvested in photo-reactors and allow for the efficient production of different types of molecule. A specific product, such as hexopolysaccharide HE800, was obtained from a marine bacteria and is efficient in bone regeneration. We could then reproduce these examples, and every day new molecules of interest would "appear", with systematic sieving being in action. We can take, for example: ecteinascidin 743, a complex alkaloid (anticancer drug for ovaries and solid tumors), discodermolide, a powerful immune suppressor and anticancer drug (breast, interactions with the microtubular network), halichondrin B, pseudopterosins (anti-inflammatory [FEN 99b]), antibiotics and antivirals in marine bacteria. The National Institute of Health in the United States of America is leading an active political movement for the constant research of new active principles.

In another area of products, different neurotoxins, tetrodotoxin, saxitoxin, conotoxin, lophotoxin, okadaic acid (inhibition of phosphatases), other molecules such as jaspamid, swinholid A (binder of intracellular actin), adociasulfate 2 (inhibitor of kinesin) have been isolated and are used in pharmacology. Molecular tools have also been identified and put on the market; phycoerythrin (linked to an antibody in flow cytometry), aequorin (which emits light in the presence of Ca^{2+}), GFP (green fluorescence protein of jellyfish and in living tissue), DNA vent polymerases (hydrothemalism), etc.

Many species living in high densities at sea are sessile and have had to maintain a considerable genetic polymorphism. They cannot escape unfavorable conditions by fleeing, the most immediate and efficient reaction of the “mobile living”, and have therefore over time had to develop very efficient defense mechanisms (non-specific immunity molecules allowing for cloning and the sequencing of peptides and different “defensines”). Mussels are a very good example, as they often live in very fluctuating environments (temperature, salinity, varying fluids, lighting, etc.) that are often contaminated. An immobile marine animal is “like a tree”, and we estimate that it is 50 times more likely to find molecules of interest compared to a mobile terrestrial animal [BOE 09].

Extreme environments have also allowed for the emergence of an extraordinary biodiversity with many of these particular species offering very interesting characteristics: life at high or very high temperatures, or in cold environments on the ocean floor (2–3°C), environments at high pressure (minimum –1,800 m, 180 atm), in absence of light, oxygen, the presence of sulfur and metals, chemosynthesis, numerous symbiotic bacteria, “protected” DNA, novel interactions between protein and DNA, etc. As a result, we have certain remarkable and reliable hyperthermostable polymerase enzymes. Marine organisms have, therefore, provided countless molecules of interest including invaluable molecular probes. Today, continuous sieving programs for biological activities are currently pursued by different countries or large pharmaceutical laboratories.

1.6. Research in marine models (regarding their originality and specificity)

Since 1865, C. Bernard said “[...] there are experiments that would be impossible with certain species of animal and the intelligent choice of a suitable animal is often the essential criterion for success and the solution of a very important physiological problem [...] comparative physiology is one of the richest gold mines for general physiology [...]”. More recently, the remarks of A. Krogh (Novel Prize in 1920) have become fundamental principles: “[...] for each problem in physiology, there is an ideal living model [...]”. Finally, in 1997, F. Jacob (Nobel Prize in 1965) added “[...] in order to tackle an important problem, to have a reasonable chance of finding a solution, the biologist must select a suitable organism [...]". The world ocean offers many possible species of a "happy disposition" or offering "suitable organisms". Many species of animals and plants (for the time being, less so in the sea) have been used, and in our first approach we will turn our attention to the various Nobel Prizes in physiology and medicine that were obtained based on the works of marine species. The different fields involved correspond to immunology (cnidarians, annelids. mollusks, echinoderms, tunicates, fish, etc.), cellular biology and oncology (mollusks, echinoderms, arthropods, fish, etc.), neurobiology (mollusks, arthropods, fish, etc.) and physiology in the general sense (arthropods, fish, etc.).

In 1882, Elie Metchnikoff, by using starfish larvae, made a very interesting observation on the universality of a mechanism that he would refer to as phagocytosis. He scrapped the basis of non-specific immuno-defense and highlighted the importance of this mechanism as the most ancient strategy of immunity. He opened the door to a new research in cellular and comparable immunology that would be decisive for the understanding of reactions to infections and infectious illnesses in humans. He would receive the Nobel Prize for his works in 1908.

The same year, Otto Van Warburg (Nobel Laureate in 1931) demonstrated the increase in the consumption of oxygen following the fertilization of a sea urchin ovocyte: echinoderms, an exclusive and ancient marine group (they were already well differentiated during the Cambrian explosion of life, 550 million years ago), produce enormous quantities of gametes (millions to billions), which after *in vitro* fertilization lead to transparent, synchronized embryos fit for microinjection. Tim *et al.* [EVA 83] would identify an essential protein in the control of the regulation of the cell cycle, cyclin B, synthesized and regularly destroyed during each cell division cycle. Related to kinase Cdc2, discovered in yeast by Nurse *et al.* in 1976 [NUR 96], it forms a dimer [LEE 87], which makes up the famous Meiosis Promoting Factor (MPF) (MPF, which would then become M-phase Promoting Factor). It was starfish ovocyte-based purification of this universal factor that would provide the proof to the composition of the heterodimer MPF, active in every M-phase cell. Its inactivation during the anaphase requires proteolysis and its reactivation of protein synthesis. Tim Hunt and Paul Nurse would share (along with L. Hartwell) the Nobel Prize in 2001 for the identification of this compound, which would be renamed to Cdk1/cyclin B once it was found to be the first element in a larger family of kinases that controlled the cell cycle as much as gene expression [DOR 02]. This was a definitive advance in the understanding of cancer genesis.

The zygote (fertilized egg) of a sea urchin would also serve in the explanation of post-fertilization calcium waves, which would depend on intracellular chemical messengers restricting polyspermy [LEE 97] and the variations of the intracellular Ca^{2+} post-fertilization (calcium enters and exits the cell) required for triggering the development of the zygote (cADP-ribose waves and NAADP). Many mammalian cells respond to c-ADP ribose that binds with ryanodine receptors (neuromuscular disorders in the case of dysfunction). Echinoderms remain of great interest today in comparable physiology, even more so since a complete genome [GEN 07] has recently been obtained.

Paul Portier and Charles Richet, who embarked upon the R.V. of Albert I, Prince of Monaco in 1901, experimented with the toxicity of venoms secreted by the tentacles of oceanic great oceanic physalia jellyfish. They exposed the quick death of dogs after a second injection (at least 15 days between injections) of non-lethal doses. They, therefore, discovered the exacerbated immune reaction, anaphylactic shock [RIC 98]. Richet would go on to win the Nobel Prize for his works in 1913.

More recently, at the start of the 1950s, Alan Hodgkin and Andrew Huxley experimented with the transmission of nerve impulses. They came up with the brilliant idea of using a squid axon, with a cross-section around 1,000 times larger than that of mammals, which allowed them, in an era where electronic microscopes and digital methods did not exist, to use their glass electrodes. They highlighted the movements of ions on both sides of the plasma membrane of the neuron and proposed a mathematical model, still in use today, which helps in the understanding of the workings of the nerve cell. They managed to analyze the conductive properties of multiple channels working at the same time and demonstrated how an influx of Na^+ ions depolarizes the membrane in a transitional manner, and how an efflux of K^+ repolarizes it. They would go on to receive the Nobel Prize in 1963.

Even more recently, at the end of the 1980s, E. Kandel worked on the molecular basis of memory and was himself also interested in a marine model, a gastropod mollusk, an *Aplysia* (sea slug). Its central nervous system, at its most developed, contains no more than 20,000 neurons. These are of a large size and are individually recognizable, and animals were trained to memorize certain behaviors. He demonstrated that the passage from one memorization of a few minutes, to another of a few days to weeks, is determined by the establishment of new synaptic connections, which are themselves linked to activations or suppressions of specific proteins (CREB 1 and 2) under the control of c-AMP dependent kinase proteins. These works are fundamental for applications in neurodegeneration disorders [KAN 86]. He recieved the Nobel Prize in 2000.

Other very important discoveries have been possible with elasmobranche (sharks and rays), since the characteristics of the immune system [LIT 96] are similar to that of the human fetus (IgM, innate antimicrobial antibodies, cellular receptors to T cells and antigens of the major histocompatibility principle, MHC). This has led to original strategies for treating lupus erythematosus and rheumatoid arthritis. Squalamine, a steroid taken from these animals, is a powerful immunomodulator and antimicrobial. These same models have also led to interesting applications against glaucoma. The rectal gland of sharks has led to the rapid purification of different proteins such as the Cl^- channel (CFTR) and the Na^+-K^+-ATPase due to its richness in these constituents.

For the clubbed tunicate, in 1997, Scofield [SCO 97] “unravelled” the basis of self and non-self immune recognition. These animals are concomitant hermaphrodites, however, autofertilization never occurs. This author demonstrated certain molecular mechanisms related to tissue and cell compatibility due to specialized cells and autorecognition molecules. Serum agglutination between hemocytes and spermatozoa is produced within the same individual. These results would influence the understanding of the HIV virus' targeting of its infected cells.

We could even mention the approaches toward the vestibular/otolith system and balance disorders due to a small fish, Opsanus, or retinal function and vision due to crab photoreceptors [PAS 97], or the study of carcinogenesis with infectious bases (retroviral neurofibromatosis [SCH 96]) with the damselfish, the o-acetylated forms of hepatic gangliosides (indicators of tumors, melanoma and infant neuroblastoma, etc.) in trout, the plasticity of excretory tissue in producing ammonia or urea for tilapia or again Opsanus, genes encoding aldose reductase (incongruous expression in the case of diabetes) or osmotic response elements (OREs) in certain fish [FER 96], etc. Many examples exist in very different fields.

For example, over the course of life, the continuous expression of type 1 Insulin-like growth factor (IGF) receptors in different target tissues would explain the continuous growth of aquatic ectotherms [ELI 97] without any sign of stopping on calcified structures (turbot-based research). The chlorine channel has been cloned and sequenced from the rectal gland of the dogfish, then from the gill of the Atlantic salmon (two genes present), and the use of sequence comparisons has been successful for addressing the consequences of the genotype of a mutation on the phenotype of cystic fibrosis [CHE 01]. The isolation and characterization of the first neurotransmittor membrane receptor, the acetylcholine nicotine receptor, have been achieved with the torpedo ray [CHA 98]. This research would lead to applications for eventual treatments or the prevention of congenital myasthenia, nocturnal epilepsy of the frontal lobe or even sudden infant death syndrome.

The involvement of the Pax-6 gene was highlighted in the 1990s in the establishment of the rostrum and eyes in numerous biological models, from drosophila to mice. Its invalidation leads to the absence of eyes and overexpression to the differentiation of numerous ectopic eyes. Thereafter, similar sequences would be found in other groups of more ancient invertebrates (tunicates, mollusks lamellibranchs, nemerteans, etc.) or even in the form of a precursor, in jellyfish. A proteorhodopsin has been identified in cyanobacteria, red algae and in a dinoflagellate, *Erythropsis* [GEH 02, GHE 05]. The "eye saga" is, therefore, a very ancient history that probably dates back to the first pre-Cambrian explosion of life (800 million years ago), in any case much earlier than the establishment of central nervous systems (“brains”). More recently, an interesting investigative work on coral has helped to reveal GnRH-type peptides: would they eventually prove to be present since the origins of metazoans [TWA 06]? These peptides have been cloned in bivalves.

The Nobel Prize in chemistry attributed to Osamu Shimomura in 2008 recognizes the works carried out in the 1960s in the characteristics in green (and also sometimes in red) marine jellyfish proteins. The use of the gene encoding this protein as a “reporter” (gene that expresses itself and indicates a new function in the cell) in the laboratory in molecular biology has revolutionized certain techniques and highlighted the remarkable expression of this protein.

Another interesting aspect in the use of marine material corresponds to the use of mother-of-pearl from bivalve shells (large pearl oyster) or gastropods (abalone) or even fragments of coral. They have been used in bone regeneration with success: they have an efficient capacity for growth and do not lead to rejection. We can observe very clearly under the microscope the bone nodules being formed on the dense mat of osteoblasts activated by the mother-of-pearl [DEB 05].

Very recently, some major marine genome groups have been entirely sequenced (fugu, tunicate, sea urchin, amphioxus and very recently *Oikopleura*) bringing fascinating comparative elements. Amphioxus is the foundation of vertebrates along with tunicates (ascidia, [DEL 06]) and represents an excellent diploid hinge model, before the later polyploidy that affected vertebrates: for example, the same receptor binds IGF-1, IGF-2 and insulin but growth hormones (GHs) and prolactin are not yet produced. The interest in amphioxus has recently resumed, and it could become a turning point for “evo-devo”-type approaches (links between molecular genetics and developmental mechanisms in comparative approaches) [BER 07]. *Ostreococcus tauri*, a small prasinophyceae, was sequenced (12.6 megabases) in 2006 and represents an extraordinary model: it is the smallest known free eukaryotic cell, and if it shows the same “sophistication” in genes and proteins for the synthesis of complex carbohydrates as *Arabidopsis*. For example, it will only have a “few essential genes” for the control and regulation of the cycle [DER 06]. We could, therefore, multiply the examples; many current and future works will only confirm the pertinence of marine models [BOE 07].

1.7. Conclusion

Life in the ocean is the most ancient on Earth and has led to the differentiation of millions of species since the origins of life. All current oceanographic surveys for the identification of biodiversity and specific marine diversity have only confirmed our very limited knowledge of this environment (perhaps 15% of defined species). Recently, *Tara Océans* has provided a lot of additional data. However, aside from this impressive diversity, these species offer ancient characteristics of organizational simplicity. It is clear that nothing is simple when it comes to the living (even for the first cyanobacteria), however, organization plans and physiological functions are often simplified for experimenters with these living beings (for example, organization and transparency of embryo). The deep water marine environment is very distinctive and can offer exceptional living conditions in terms of external stability (temperature, salinity, pH, hydrostatic pressure, level of dissolved oxygen, lighting, etc.): regarding temperature, for example, certain fish spend their entire life in waters that fluctuate by less than one-third of a degree over a whole year. They are better thermoregulated than humans without any energy cost. Homeostasis of the internal environment, which for so long has been costly to achieve, allows for “life in a constant environment” and has of course allowed for exceptional capacities for adaptation and acclimatization, however, their energy costs are very high, and these strategies are very recent in the history of life (less than 5% of the total duration). This is why, at sea, the vast majority of these species has maintained an internal environment close to the composition of seawater. The strategies in coastal waters are different, since the environment is heavily affected by the presence of the continent: a coastal lagoon in France can, therefore, fluctuate from a few degrees in winter to over 30°C in summer at the same location; salinity, pH and composition can also fluctuate considerably.

From the beginning of life and for billions of years, the salinity of seawater and the corresponding osmotic pressure have been very important factors. After the initial responses that were simple, and for which the internal living environments corresponded to the composition of seawater, strategies were later developed for survival in various osmotic environments. Animals are limited in their geographic distribution by environmental factors of which one of the most important is the osmotic nature of aquatic environments. Geographic dispersion, followed by genetic isolation, is a fundamental mechanism in speciation. Without the competition between arthropods and vertebrates for conquering hostile environments after the emergence from oceans, with the establishment of regulation mechanisms of extracellular space, other groups would have diversified to fill these "vacant" terrestrial niches and the living world would be very different to what it is today [ECK 99]. Across all marine evolution, salinity (and by extension osmolarity) has played a decisive role in adaptation, acclimatization and speciation phenomena, with haline barriers being important physical elements.

The aim of marine models is linked to these ancestral aspects and organization plans. Often today, we use classic models, and observe this in all major scientific papers, with models of study being very restricted (human, mouse, rat, drosophila, when not simply isolated cells), and it becomes understandable, the level of knowledge, the existence of efficient tools, the "transferability" to humans, being decisive characteristics. However, biodiversity offers an extraordinary and essential platform for investigation. Today, it is heavily under threat, with humans eliminating species [BAR 06, BLO 05, BOE 07, BOE 10] at a speed between 100 and 300 times faster than what would be "naturally expected". Thomas *et al.* [THO 04] predicted the disappearance of a million species before 2050, exclusively linked to global warming. Different arguments, both pertinent and unavoidable, encourage us to protect this specific diversity and maintain it, despite constraints tied to demographics and the needs of human development. For this, we mention the productivity of ecosystems, which is superior with a higher diversity, their better capacity to resist invasive species, the role of biodiversity in large biochemical cycles, the upkeep of renewable living resources that are essential to the survival of mankind, a spectacular reserve of species for providing medication cosmetic products, etc.; ethical reasons that are inseparable from purportedly "developed" societies [BOE 08]. An often neglected aspect, which has been looked at in this chapter, is this pertinence for finding models of study for fundamental questions, or for the solution to key problems and essential applications that can be extracted. In this field, ocean species play an important part. Fishing resources are not the only ones, and aquaculture is being continuously developed. Humans must absolutely learn to better respect and manage this marine environment, apparently so massive yet fragile and deteriorated, in order to better preserve ecosystems, stocks and biodiversity.

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