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ASSOCIATION OF EUROPEAN MARINE BIOLOGICAL LABORATORIES EXPANDED

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# History of Marine Biological Stations: contributions to Science and Social Challenges

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## Abstract

**The sea is not the normal living place for us, humans. It is not our habitat and during a big part of our history it has been the pass way, or the void, in between lands. Therefore, the organisms that inhabit the oceans and their characteristics have been mostly unknown during centuries. In our difficulty to approach the sea, we have faced the need of developing special skills and infrastructures. We need vessels and specific sampling methods, but also research infrastructures and shelter places permanently placed near the seashores. In general, most of the biodiversity in all the oceans and seas can be found in the coastal areas, since the interface between land and sea allows the blossoming of life. The study of this biodiversity is in fact the mission of marine biological stations since their conception in the XIXth century, as early as 1843 with the "*Laboratoire des dunes*" opened by P.J. Van Beneden in Ostend (Belgium). By 1910 more than 40 such institutions were opened across the European geography and most of them are still active today. Presently, 758 marine biological stations in 98 countries have been catalogued by UNESCO in its 2017 "Global Ocean Science Report". These are institutions that were created to shelter travelling scientists; "rest stop sites" that offer research equipment, protection, trained help and background knowledge to visitors. In this 150 years long journey, marine organisms have provided avenues for basic science at the forefront of research through the utilization of marine model organisms. In the same way, marine life has provided opportunities to exploit resources useful for the humankind (fisheries, marine aquaculture…), while the development of "Blue Biotechnology" holds the promise to contribute to the socioeconomic development of maritime regions. The analysis of the history of these institutions, their missions and visions, their funding streams and their resilience throughout time provide important learning lessons towards the long term sustainability of marine biological stations as special Research Infrastructures and of marine biology research programs in the XXIst century.**



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# 1. Introduction

The sea is not our habitat and during a big part of our history it has been the obstacle that we needed to trespass in between lands of opportunity. In our difficulty to approach the sea, we have faced the need of developing special skills to study the organisms that inhabit the oceans. We need vessels and specific sampling methods, but also research infrastructures and shelter places permanently placed near the seashores. The study of this biodiversity is in fact the mission of marine biological stations since their conception in the XIXth century.


The first European maritime station was opened in 1843, in Ostend (Belgium). The two oldest stations that have remained permanently active were opened in France, in Concarnau the first one (1859) and in Arcachon the second one (1863)[1],[2]. In 1910 there were dozens of marine stations spread across Europe, from Spain to the Russian Arctic and from Greenland to the Adriatic or the Black Seas. Only in the French state, at the beginning of the twentieth century, there were 14 such institutions, plus another one in Algiers that was French at the time. A detailed description of the more than 40 marine biological stations in Europe by 1910 can be found in the report by published Charles A. Kofoid[3]. He travelled across Europe for a year with

[1] Egerton, F.N., 2014. History of Ecological Sciences, Part 51: Formalizing Marine Ecology, 1870s to 1920s. *Bull. Ecol. Soc. Amer.* **95**, 347-430.
[2] Tydecks, L., Bremerich, V., Jentschke, I., Likens, G. E., Tockner, K., 2016. Biological field stations: a global infrastructure for research, education, and public engagement. *BioScience*, **66**, 164–171.
[3] Kofoid, C.A., 1910. The biological stations of Europe. *United States Bureau of Education bulletin. no. 4.*



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a mission of the Bureau of Education of the Department of the Interior of the United States of America. The objective was to analyse the governance, organization and structure of European marine stations to apply the learned lessons in the construction of the institutions planned in the United States, more specifically the Marine Biological Association of San Diego, now Scripps Institution of Oceanography, founded in 1903. Europe was the mirror to look at the beginning of the biological research of the sea.

These institutions depended heavily on Universities, while some were created as independent institutions by science-promoting associations such as the Société Scientifique d 'Arcachon or the British Marine Association in Plymouth[3]. Some were installed in pre-existing buildings such as hospitals, fever houses, castles, boat keeping warehouses, oyster houses, and monasteries. Others deserved specially dedicated and purpose-built buildings. Some others took shelter in the form of removable wooden huts or stranded/floating vessels that allowed mobility. Some were operating only seasonally during the periods along the year in which biodiversity flowered. Some opened to visitors specifically in summer during the vacations of University Professors and researchers[3,4]. Others remained open throughout the year, although in most cases with a very limited number of in-house researchers, technicians and administration staff.

Presently, 758 marine biological stations in 98 countries have been catalogued by Unesco in its “Global Ocean Science Report” in 2017. These are institutions that were created to shelter travelling scientists; “rest stop sites” that offer research equipment, protection, trained help and background knowledge to visitors. Which were the reasons to open such research infrastructures devoted to conduct investigations (and teaching and education) of the coastal Biology in Europe? And, how is it possible that these institutions born in the XIXth century have survived to the XXIst century facing the handicap of their elevated “unit-cost” consequence of their emplacement in the periphery? In this 150 years long journey, marine organisms have provided avenues to conduct basic science at the forefront of research through the utilization of marine model organisms. In the same way, marine life has provided opportunities to exploit resources useful for the humankind (fisheries, marine aquaculture…), while the development of “Blue Biotechnology” holds the promise to contribute to the socioeconomic development of maritime regions. The analysis of the history of these institutions, their missions and visions, their funding streams and their resilience along time provides important learning lessons towards the long term sustainability of marine biological stations as special “Research Infrastructures”. This understanding may underpin the need to secure the future of marine biology research programs in the XXIst century in association to infrastructures placed where biodiversity is present.

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[4] Yonge, C.M., 1956. Development of marine biological laboratories. *Sci. Prog.* **44**, 1-15.



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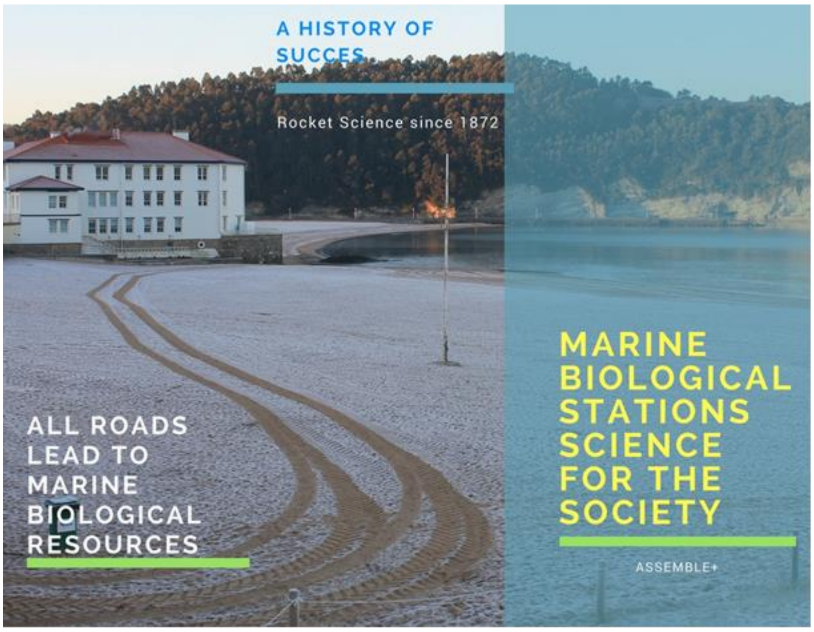
# 2. Objective

The analysis on the history of marine biological stations in Europe, or more widely expressed, the history of the European marine biological stations regardless of their geographical situation (Antarctica, Antilles…), fulfils many objectives with the focus of analysing the prospects for their durability. Marine biological stations are peripheral by definition (geographically, economically, politically, scientifically), many of them dependant of bigger and more central institutions such as Universities, this increasing their unit costs. In spite of that, these marine research infrastructures have shown high resilience along history and capacity to reinvent themselves, with lessons worth taking on board towards the long term sustainability of our facilities and the fulfilment of our mission in the XXIst century… also within the European ESFRI landscape of research infrastructures.




Marine Science is surfing the successful wave of outreach activities and mass media releases like the BBC “Blue Planet” nature documentary in the very last decade. The same occurred before, with Jacques Cousteau that filled the brains of generations of European citizens with marine organisms and ecosystems, possibly at the birth of a common social awareness on environmental issues. Showing that attractive tip of “Marine Biology” iceberg is important, but in reality marine biological research is envisaged as an activity of low socioeconomic relevance. A thorough analysis of our history, the people that made it possible and the science conducted since the XIXth century shows that marine biology research developed through access to marine biological stations has been in the front line of biological research and education. That needs to be shown to stakeholders and public in general. Nobel Prizes in Physiology and Medicine and in Chemistry, have been awarded to researchers utilizing marine organisms and working in Marine Biological Stations. Marine biotechnology and marine



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aquaculture are two of the five emerging sectors of the Blue-Growth strategy of the European Commission. The United Nations has decided on a "Decade of Ocean Science for Sustainable Development (2021-2030)". With the objective to raise awareness and empathy on the socioeconomic cornerstone constituted by Marine Biological Stations, this task in the project Assemble+ has taken the shape of a "**Coffee Table Book"**, which illustrates their beauty and value in a didactic, visual and understandable way.



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# 3. Book, list of contents and authors

The book will be published by the Basque Academic press and extra financial support for the edition (4650 euros) have been obtained from the University funds to allow the printing of more books than originally planned and that can be covered with the money allocated in Assemble plus.

List of contents of the coffee table book "**HISTORY OF EUROPEAN MARINE BIOLOGICAL STATIONS: CONTRIBUTIONS TO SCIENCE & SOCIAL CHALLENGES"**

**Preface**: Definitions for Marine Biological Stations

1 - HISTORY OF MARINE BIOLOGICAL STATIONS

Access to biological diversity on site, organizational issues and institutional changes (association to Universities, public, private…), the link to public aquaria, the buildings, the people, the funding, the places, endurance through history:

"From so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved"

2 - MARINE BIOLOGY RESEARCH

Marine biological resources and marine model organisms: fundamental research in biological/medical sciences

- MBSs the cradle of embryology, physiology, cytology, comparative …., bacteriology, rediscovery of genetics, modern microscopy
- Taxonomy
- Fisheries and aquaculture
- Environmental biological-observatories
- Rocket Science in the frontiers of biological research
- Marine Biotechnology
- The last frontier in bioprospection and biodiscovery

3 - MARINE BIOLOGICAL STATIONS IN EUROPE

Each chapter has been assigned to authors in the marine stations themselves. Authors were really willing to do the job, centering their writing on very specific contents that should encompass conception and building, mission, governance, funding streams, research and marine model organisms, teaching, training and outreach.

3.1 - Station Biologique de Roscoff, Roscoff (1872)
3.2 - Stazione Zoologica Anton Dhorn, Naples (1872)
3.3 - Scottish Association of Marine Science, Oban (1883)
3.4 - Marine British Association, Plytmouth (1888)
3.5 - Flanders Marine Institute, VLIZ (1843)
3.6 - Interuniversity Institute for Marine Science, IUI, Eilat (1968)
3.7 - Newly created stations: PiE-UPV/EHU (2012) and ECIMAT-UVigo (2006)
3.8 - European Marine Biological Stations in polar environments (Arctic, Antartic)



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4 - TEACHING AND OUTREACH, SCIENCE DISEMINATION, CITIZEN SCIENCE

5 - ASSOCIATIONS OF MARINE BIOLOGICAL STATIONS (forming a community):
NAML
MARS and WAMS
Euromarine (community of scientists)
Global marine observatories

6 - EVOLVING MARINE BIOLOGICAL STATIONS IN THE XXIst CENTURY: Redefining the concept for MBSs, EMBRC-ERIC paramount for the future

List of authors

- Chapter 1 and 2: Ibon Cancio (University of the Basque Country)
- Chapter 3: Showcases, marine biological stations as examples:
  = VLIZ and Belgian marine stations: Klaas Deneudt (VLIZ)
  = Roscoff: Bernard Kloareg (former director of Station Biologique de Roscoff)
  = SZN: Claudia di Somma (librarian of SZN)
  = SAMS: Dr Anuschka Miller (SAMS Head of Communications & Director of the Ocean Explorer Centre)
  = MBA: Heidi Tillin (MBA)
  = IUI Eilat: Amatzia Ganin, Simon Berkowitz
  = PiE-UPV/EHU & ECIMAT: Ionan Marigomez (University of the Basque Country), Ricardo Beiras (University of Vigo)
  = Arctic/Antarctic: Melody Clarck (BAS) and Piotr Kuklinsky (IOPAN)
- Chapter 4: Jack Sewell, John Parr, Elaine Bastos (MBA)
- Chapter 5: Mike Thorndike (WAMS, Sven Lovén Center for Marine Infrastructure)
- Chapter 6: Adelino Canario (CCMAR)

Two artists enrolled in the postgraduate course of the University of the Basque Country, Angelica Zambrano and Inma Martin have produced illustrations for the book.

Problems faced during the writing have been linked to the fact that authors were contributing through invitation, so drafts have arrived with a long delay. We are at the moment now of editing all the texts and still waiting for 2 chapters and 2 showcase texts to arrive. Edition of the book will be initiated in January.

Type of edition. 500 to 1000 copies, 256 pages. DINA4, glossy paper in colour. Copies will be distributed among marine stations in Assemble plus, to be used internally and as present in addressing stakeholders and financing bodies.

In the next sections we shall extract a summary of some of the contents of the book: reasons for the opening and resilience of marine biological stations (sections 4 to 8), and a summary of one of the showcased marine stations (Appendix 2). Appendix 1 shows the minimal bibliography employed for the writing of the book. Everything leads to the conclusions of this task and the learning lessons obtained after studying the history of marine biological stations.



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# 4. Natural History: putting some order in the warehouse of nature

The 19th century was that of naturalistic exploration. Of course, exploration voyages in the sea were abundant before, including the first circumnavigation by Juan Sebastian Elcano whose trip began exactly 500 years ago, in 1519. Exploration in all cases was done in the name of the "Empire" and for the implementation of transport routes to access ultramarine territories, so they could be explored and eventually exploited. However, the 19th century brought new approaches. Both in the commercial and in the "armed" exploring fleet financed by different nations, there were also naturalists on board[1,4,5]. Sometimes it was the ship's doctor who was in charge of such naturalistic obligations. It must be understood that the study of "Natural History" was an important part of medical academic studies, and that in the XIXth century there were still no higher education programs in Biology, Geology, Chemistry or Sciences in general. The clearest examples of these explorer naturalists are Charles Darwin (1809-1882) and his voyage on board of the "HMS-Beagle" (1831-1836) or Thomas Henry Huxley (1825-1895) and his trip as assistant surgeon on board of the "HMS-Rattlesnake" (1846-1850) to Northern Australia and New Guinea.

Among all such voyages, the beginning of oceanographic research but also that of marine biological research, can be traced back to another British expedition, the Challenger expedition (1873-1876) on board of the "HMS-Challenger". Her mission was the physicochemical exploration of the seas of the world, with the intention of obtaining information to lay telegraphy cables in the oceanic bottom between Europe and America. By the way, her additional mission was the exploration of biodiversity in the depths of the sea. This was one of the first vessels that excluded canyons and guns in favour of research equipment. On that voyage the Challenger Deep in the southern end of the Mariana trench was discovered, establishing the vertical distribution of living organisms down to 8000 meters, when it was believed that deep sea bottoms were inhabited. The Challenger expedition gathered 4717 plant and animal species from different seas of the world[1,4] and they were all analysed by specialists (taxon authorities) from different nations.

For example, in this group, together with British scientists such as William McIntosch from St Andrews who took the responsibility of studying annelids, Ernest Haeckel from the University of Jena (Germany) analysed radiolarians and jellyfish, Alexander E. Agassiz from the Museum of Comparative Zoology in the University of Harvard (USA) analysed echinoids, Albert Von Kolliker from the University of Würzburg (Germany) analysed animals of the Penatulacea group or Georg Ossian Sars from the University of Christiania (Oslo, Norway) studied the groups Schizopoda and Curnacea. Beforehand, there had not been too much room for international collaboration in research, and the analysis of the "Challenger samples" would lay the bases of a way of practice that is currently implanted in the foundations of scientific research. The search of truth for the resolution of global problems and the riddles of nature

[5] UNESCO 2017. Global Ocean Science Report. The current status of Ocean Science around the World. (Valdes, L. et al. edk.), *UNESCO Publishing*, Paris.



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should be an international undertaking. And this came from marine biological research. The scientific consequences of the Challenger expedition were very varied and abundant, published during years in different collections[1,4]. The Challenger Society was organized to manage these tasks and achievements, with its central offices in the number 32 of Queen Street, Edinburgh. This brought the focus on the need to establish the first marine station in Scotland, by the Scottish Association on Marine Science. Thus, in 1883, near Edinburgh, "The Ark", a ship stranded in the port of Granton was inaugurated as a marine laboratory. The Ark would be then moved to the west coast to Millport and it was a precursor to the SAMS Institution (Scottish Association for Marine Science), currently rooted in Oban, West coast of Scotland.

These and other expeditions collected and provided new marine species for museums and Universities. The same happened with the research and leisure visits of naturalists to the European coastal areas. A need emerged to compare species in collections, and a passion to establish relationships among species ordering nature based on the similarities and differences among creatures. Carl Linnaeus allowed establishing kinships between species with the beginning of taxonomy. However, there was shortage of marine biological species among the more than 4000 animals and about 7000 plant species that he classified in total. This classification fever grew with the creation of Natural History museums. Paris houses one the oldest and largest museums of Natural History in the world and in its "*Jardins des plantes*" a special building is devoted to "Comparative Anatomy" and to George Cuvier (1769-1832). Cuvier, moved to Normandy from Paris between 1793 and 1794, during the revolts in the French Revolution, where he saw the sea for the first time. That ignited the passion to study marine animals and he subsequently investigated molluscs, crustacean, fish and cetaceans. He broadened the taxonomic classification of Linnaeus grouping classes into phyla and introducing fossils together with living species into the classification[1]. His substitutes in the Natural History Museum of Paris were also keen on the investigation of marine animals, and the Laboratory of Zoology and Maritime Physiology of Concarneau opened its doors in 1859 with a connection to the Museum, which still exists for the provision of marine specimens. We recall that the protagonist of the novel "20,000 leagues under the sea" by Jules Verne was the naturalist of the "Natural History Museum of Paris", Pierre Aronnax. The novel can be read as a taxonomic list organisms in different seas.

The Professor of the University of Berlin, Johannes Müller (1801-1858) and mentor of some of the most important scientist in Prussian and world history, Theodor Schwan, Mathias Jacob Schleiden, Jacob Henle, Hermann von Helmholtz, Rudolph Virchow, Emil du Bois-Reymond, Robert Remak, Albert Von Kolliker, Carl Ludwig, Ernst Haeckle, Wilhelm Wund…, focused his interests in comparative microscopy and physiological research, always including the analysis of marine animals[1]. On his summer excursions to the island of Helgoland, or to the Italian coast, he collected samples with his students. Many of these samples were part of the heritage of the museum of natural history he directed in the University of Berlin, but his studies additionally established the pillars of Physiology. In this sense, the necessary methodological approach he defended was the microscopic analysis of organisms and biological tissues from a comparative perspective. Subsequently, his students would do the same incorporating chemical and biochemical approaches, at the beginning of such disciplines, extending the field of research to Comparative Embryology and Cytology. Indeed, Comparative Embryology



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would provide new resources and tools to classify some unclassifiable invertebrates[6]. These summer excursions to the coast can be considered as scientific tourism. This is the case for example, of the expedition of Ernst Haeckel and Nikolai Miklouho-Maclay to Lanzarote and Morocco, or those of Anton Dohrn, N. Miklouho-Maclay and Élie Metchnikoff to Italy[7]. In all cases the same problems emerged; the lack of sampling gear and material, the lack of tools and resources to analyse collected samples, the lack of knowledge about the life cycles of studied organisms and about the ecosystems that were sampled. In summary, a lack of working conditions for biological research.

The initiation of tourism for the general public and the start of weekend trips to the coast can also be traced back to the 19th century. In Great Britain the rapid expansion of the railway network contributed to make the coast reachable to the common public in the cities, and in a short time it became common in the Victorian society to collect shells and to create amateur collections. It is said that in the mid-19th century mussels, limpets, actinia and snails became domestic "pets." Then, the first aquarium stores opened in London and the first public aquaria were stablished also. The first one opened in London (1853), followed by those of Paris, Vienna, Berlin or Washington. Many marine stations would open their doors with public aquaria with a mission in outreach and to raise funds towards their sustainability.

There was a descriptive drive in this passion for the study of Natural History, and living close to the place where nature can be studies is better than traveling sporadically for a visit. Louis Agassiz (1807-1873), considered the father of American zoology coined the famous sentence "Study Nature not books"[8]. This provided a great boost to the creation of marine stations. He opened the first marine summer station on the East Coast of the United States (Penikese Laboratory, 1873), seed of what later would become the Woods Hole Marine Laboratory in Massachusetts[8]. Summer courses were taught to train Natural History teachers, in order to promote an understanding of nature in schools. Some to the greatest figures of the Marine Biology in America took these summer courses in the coast, even a Novel Prize winner (Thomas Hunt Morgan). There was also important participation of women in these classes and later the opening of the Woods Hole Marine Laboratory (1888) was possible thanks to an important participation of the Women's Educational Association of Boston. Afterwards more than 50 Nobel Prize winners have been working in this institution, stably or as visitors, in research and/or teaching. At the same time in Europe, T. A. Huxley laid the foundations of science education in Universities as we know it nowadays, centred on experimental work in the laboratory[9]. Basically, sciences transitioned from mere philosophical, theoretical and descriptive disciplines to become experimental and inductive, placing experimentation and laboratory based work in the centre of activities. This marked the birth of modern Biology through the spanning and branching of its different fields of knowledge and disciplines: Zoology, Botany, Physiology, Embryology, Cytology, and Biochemistry. The conclusion was

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[6] Fantini, B. 2000. The "Stazione Zoologica Anton Dohrn" and the history of embryology. Int. J. Dev. Biol. **44**: 523-535.
[7] Webster, E. M., 1984. The moon man. A biography of Nikolai Miklouho-Maclay. *The University of California Press*, pp. 421.
[8] Benson, K. R., 1988. Why American marine stations?: the teaching argument. Amer. Zool. **28**, 7-14.
[9] Paul, H. W., 1985. From knowledge to power. The rise of the science empire in France, 1860-1939. *Cambridge, Cambridge University Press*, **IX**-415 pp.



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clear, the sea being in the centre of biodiversity research, there was a need to bring the laboratories to the coast[9], and Huxley would become the first president of one of such laboratories, the Marine British Association in Plymouth in the year 1888.

From the point of view of Natural History, the main reasons for the implementation of marine stations were:

1 – **The analysis of coastal habitats of great biodiversity**.

2 - **The supply of marine organisms for museums and for research**.

3 – **The training of professionals for the study and teaching of Natural History and Biodiversity**.

4 - **The need to show the beauty and importance of nature to the public**.

## 4.1. The analysis of coastal habitats of great biodiversity

Marine stations allowed the in situ investigation of the life cycles of different organisms throughout the whole year[1,4,5,10]. On the other hand, they guaranteed the possibility to describe coastal ecosystems and to study local biodiversity analysing the relationships between the different organisms. Thus, scientific journals were created in marine biological stations: "Fauna und Flora des Golfes von Neapel und der angrenzenden Meeresabschnitte" in Naples or "Bulletin of the Station Biologique d 'Arcachon" in Arcachon to put some examples. This emphasized the need to open marine stations for the study of unique coastal ecosystems. In this context we could highlight examples such as the mega-tidal areas of Brittany studied in the Station Biologique de Roscoff (1872), the Baltic Sea observation that is carried out in the Tvärminne Zoological Station (1904) or the gateway to the study of the White Sea and Arctic allowed by the Solovetsky islands station of the Saint-Petersburg Naturalists Society (1881) and the Murman Marine Station at Alexandrovsk (1899)[3].

## 4.2. The supply of marine organisms for museums and for research

The collection of organisms has always been one of the main missions of marine stations for the provision of museums and universities in Europe. For example, the Marine Laboratory of Trieste where a young medical student, Sigmund Freud (1856-1939), conducted his first investigations (during his stay of several months in 1877 he investigated the gonads of the European eel), was born in 1875 to supply marine organisms to the Museum of Vienna. In Naples, at the Zoological Station methodologies were developed for the preparation of organisms and tissues (for example microscopic slides), with a public catalogue for the supply of samples already available in the 19th century. Another example is Santiago Ramón y Cajal (1852-1934), who obtained the Novel Prize in Physiology and Medicine in 1906 extending the cell theory to the nervous tissue. He accessed through different research stays to the marine

[10] Van Bennekom, A. J., 2013. Political factors in the establishment of biological stations before 1900. Groeben, C., (Ed.) Places, People, Tools: Oceanography in the Mediterranean and Beyond. Proceedings of the Eigth International Congress for the History of Oceanography. *Pubblicazioni della Stazione Zoologica Anton Dohrn*, **IV**: pp. 125-139.



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stations of Porto Pi (Mallorca, Spain) and Banyuls-sur-Mer (France), and visited also that of Santander (Spain). He published a paper on the retina and optical nerve centres of different species of cephalopods in 1917. Such microscopic investigations were carried out in Madrid utilizing samples supplied by the Marine Stations of Santander and Porto Pi (currently, Spanish Oceanographic Institute, IEO)[11].

## *4.3. The training of professionals for the study and teaching of Natural History and Biodiversity*

This was the main reason for the creation of the first maritime stations in the United States; training teachers for schools[8]. In Europe most of the marine stations emerged with a institutional connection with universities and their primary purpose was research[3], providing a great boost to predoctoral studies conducted in the field[9]. Thus, marine stations have been paramount in the birth of the different biological disciplines, from the creation of Physiology and Embryology, to that of the current Comparative Genomics. Another function has been lifelong education and training, with specialized courses (taxonomy, sampling and other laboratory techniques ...), or training workshops for professionals from different fields (fishermen, aquaculture professionals, environmentalists, public servants...)[1,3,8]. Education and training have always been activities that have contributed to the sustainability of marine stations, and today possesses great value in the socialization of science.

## *4.4. The need to show the beauty and importance of nature to the public*

For outreach, it is significant and it deserves highlighting the commitment of many marine stations in Europe to run public aquaria. This is the case of the Zoological Station Anton Dohrn in Naples, one of the oldest (1872) and most prominent. One of the reasons for the location of the station in Naples was the size of the city and its vitality attracting many visitors to the city throughout the year. For all these people the Aquarium would become another attractive spectacle. Monaco on the other hand, is known for its aquarium but not many people know that it was born (1910) as a biological marine station for research. The prince of Monaco was a passionate marine naturalist. Marine Stations such as those of Arcachon (1863), Plymouth (1888) or Helgoland (1892) to mention some also opened a public aquarium[1,3]. These aquaria were in many cases the first approach to Marine Biology for the public, and contributed funds for the maintenance of the stations. To visit the "The Ark", while it was anchored in Port Loy Millport, one penny was charged per visitor. This helped in the maintenance of the facility, until in 1900 it was swept away by a storm.

[11] Cajal, S. R., 1917. Contribución al conocimiento de la retina y centros ópticos de los cefalópodos. *Trabajos del Laboratorio de Investigaciones Biológicas.* XV, Madrid.



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# 5. The Evolution theory, a revolution for the understanding of life in marine stations.

In 1859, the Evolution Theory of Darwin changed not only Biology, but also our way of understanding living organisms and life in general. Since 1859 we know that there is nothing that can be explained in Biology outside Evolution. Although it has had little echo in the collective imaginary and understanding of how scientific reasoning is constructed, a special group of marine invertebrates "cirripeds" were important so Darwin could organise his ideas around Evolution on solid grounds. Darwin had a sketch of his theory since the arrival of the Beagle in Britain in 1836, and a draft of the book by 1844. What did he do until the book was published in 1859? He had to make a name for himself among the British scientific community and prove that he was a reliable scientist. He had to earn his stripes! To do this, he devoted his days to a monograph on cirripeds (barnacles) that would be published in four books between 1846 and 1854[12]. Long classified as molluscs they had already been classified among crustaceans thanks to Cuvier, but their character, biodiversity and biology were unknown. All species of this group were considered hermaphrodites. In his decision to dig into cirriped biology an organism he found in the perforated shell of a mollusc in the southern coast of Chile during the Beagle expedition plaid an important role. This organism remained taxonomically unclassified and without a name. Meanwhile, it received a nickname, "Mr Arthrobalanus", as apparently it had two penises and there was no female part to be seen[12]. Darwin´s monographic work was monumental and global from any perspective and it earned for him the Royal Medal of the Royal Society of Great Britain in 1853. In his work he used his microscope and an importance peace if infrastructure, the British Royal Mail. In this way he would receive at home specimens for classification from museums, collections, naturalists, researchers and scholars from around the world (another international collaborative effort).

But in the case of "Mr Arthrobalanus", *Cryptophialus minutus*, like with other members of the genera *Alcippe* and *Ibla,* we are facing a species in transition to gonochorism. Some of these species have dwarf males that survive on hermaphroditic individuals of the same species, while in some others both sexes are completely separated, with dwarf parasitic males living on giant females. Darwin faced with such transitional species, a phenomenal manifestation of evolution, possibly experienced an "Eureka" moment, important in the materialization of his "Origin of Species"[12]. Lamarck had already said, as Aristotle, Linnaeus, and Cuvier had also defended that invertebrates were important for understanding Natural History. From their simplicity you can better understand complex biological traits, and where to go better for the study of invertebrate animals than to the seashore¡¡

Researchers studying the diversity of marine invertebrates strongly aligned with the theory. A Prussian zoologist who was Haeckel's student, Anton Dohrn (1840-1909), was convinced that scientists needed research stations located on the coast to allow such investigations. He would create a marine station with a mission to find evidences of the Theory of Evolution in the Gulf

[12] Buchanan, R. D., 2017. Darwin's "Mr. Arthrobalanus": sexual differentiation, evolutionary destiny and the expert eye of the beholder. *J. Hist. Biol.* **50**, 315-355.



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of Naples. Dohrn and Darwin exchanged many letters. In one of them Darwin congratulated Dohrn on the achievement of the creation of his marine station and contributed financially and with books for its outstanding library. In the Vision of Anton Dohrn marine stations were institutions that had to be open to marine researchers and his dream was the creation of a network of marine observatories as a kind of hostels or train-station for scientists around the world. This was defended in the report he presented in the meeting of the Association for the Advancement of Science of Great Britain in 1871.

Finally, Anton Dohrn would invest his life in a single marine station constructed with his own money and with help from the Prussian government and friends in 1872. Naples offered the advantage of good weather conditions for investigation and the enormous marine biodiversity of its Bay. This would become some kind of a “Mecca” for scientists all around the oocidental world. Anton Dohrn, has been called the “Statesman of Darwin”[13], but he really was a catalyzer of scientific progress. In a totally privately managed institution he established a table access system. A research table in Naples offered a workplace, equipment/infrastructure, bioresources brought fresh from the Bay of Naples every morning if necessary and local knowledge on the nature of the Neapolitan flora and fauna. Each table was rented for the whole year or 6 months by institutions. In 1910, a fee of 500 $ was paid for an annual table and 50 tables were rented[3]. The clients of these tables were different European and American Universities (Heidelberg, Wurzburg, Berlin, Cambridge, Oxford, Columbia, Pennsylvania ...), scientific associations and institutions (The American Naples Table Association for Promoting Scientific Research by Women…), governments (Russia, Romania, Italy ...). The annual rent entitled the right to send scientists to Naples to conduct marine research. Dohrn did not supervise the research to be done, and the system resulted in an international climate similar to that of a never-ending congress[1,3,6,13]. Visiting researchers were invited to write monographies on different phyla, and their research was published in scientific journals specially created in house. These scientists upon return to their institutions would sent publications available to them in their Universities, helping in the continuous growth of the contents of the library in the station[1,3,6]. On the other hand, Dohrn was a close friend with Ernst Abbe (1840-1905) and Carl Zeiss (1816-1888) and this made Naples a hub where the microscopy and histological processing techniques that we know today were developed and tested. The new Zeiss microscopes, the first dissecting microscopes, the first achromatic lenses were used first in Naples for the study of marine organisms[6]. And this happened at a time when microscopy, physiology and comparative embryology, before comparative molecular biology or genomics, became the fore-front branches of biological research. In Stazione Zoologica Anton Dohrn 19 Nobel Prize winners in Medicine and Physiology or in Chemistry have conducted research stays, some of them with more than one stay during their career (Otto Meyerhoff, Otto Warburg, Thomas Hunt Morgan or Maurice Wilkins)[14]. We need to add also a Peace Nobel Prize winner (1922), the Norwegian zoologist, traveler and adventurer Fridtjof Nansen (1861-1930), who conducted a research stay in Naples at the

[13] Groeben, C., 1985. Anton Dohrn-the statesman of Darwinism. *Biol. Bull.* **168**, 4-25.
[14] Groeben, C., De Sio, F., 2006. Nobel laureates at the Stazione Zoologica Anton Dohrn: phenomenology and paths to discovery in neuroscience. *J. Hist. Neurosci*. **15**, 376-395.



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beginning of his career (1886) after a short stay with Camilo Golgi learning his staining techniques.

Of course, other marine stations were not managed in the same way. The antithesis of Anton Dohrn can be observed in Henri Lacaze-Duthiers who opened and directed the two main marine stations of France, the first one in Brittany (Station Biologique de Roscoff, 1872) and the second one in southern France (Observatorie Océanologique de Banyuls sur Mer, Laboratoire Arago, 1881) in the Mediterranean Sea. Lacaze-Duthiers (1821-1901) was the most important promoter of Marine Biology in France. He regarded management in Naples as elitist, and in his view marine stations should be open free to all scientists[15]. It was like that that in most of the marine stations and no payment was requested for the use of any infrastructure. But above that, his attitude was very aggressive against Dohrn. Anton Dohrn was Prussian, and in the war between France and Prussia (1870-1871) Prussia prevailed. Of strong nationalistic convictions and from his privileged position at the University of Sorbonne and his role in the Natural History Museum of Paris, he Lacaze-Duthiers totally stopped any French researcher from visiting the marine station in Naples. France had no table in rent. Kofoid in his book[3] in 1910 provides the numbers of visitors to Naples since 1872. 630 had been Germans, 163 Russians, 153 British, 111 North Americans, 72 Dutch or 18 Spanish, to mention some countries, while only four had been French[3]. This "prohibition" extended after the death of Lacaze-Duthiers in 1901 until the 1930s. To a large extent this justifies the surplus of the marine stations observed in France[3,9,15] (Figure 1).

# 6. Fish shortage, scientific research in fisheries and the beginning of national research programs

In the 19th century there was a vivid debate about the situation of fish and shellfish stocks. Signals were emerging everywhere in different places that fish and shelfish stocks could be in danger[1,16]. This concern was very noticeable in Britain, where the industrial revolution, and the increase in population, brought many changes. With the development of the railway system, fish became accessible to the general public in the cities and the technology to meet the new demand for fish was developed. The large steam trawlers did not choose species or sizes, and much more fish were captured and the debate arose[10,16]. Does trawling destroy fish stocks and their spawning areas? In this situation, the International Fisheries Exhibition took place in London in 1883[16]. Huxley had been in charge of analysing the concerns of traditional fishermen on the effects of trawlers on spawning grounds for the British Government (1865-1866). Cod eggs were demonstrated to be pelagic by the famous Norwegian ichthyologist G.O. Sars, and thus bottom trawling could not possibly affect fish spawning fields. Huxley's intervention in the reception of the exhibition would have an important negative impact on the investigation of fish stocks: "*I believe, then, that the cod fishery, the herring fishery, the pilchard fishery, the mackerel fishery, and probably all the great sea fisheries, are inexhaustible; that is to say, that nothing we do seriously affects the number of the fish. And any attempt to regulate these*

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[15] Dayrat, B., 2016. Henri de Lacaze-Duthiers and the creation of the Laboratoire de zoologie expérimentale. Roscoff, France. *Revue s´histoire des sceinces*, **69**, 335-368.
[16] Hubbard, J., 2014. In the wake of politics: the political and economic construction of fisheries biology, 1860-1870. *Isis*, **105**, 364-378.



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*fisheries seems consequently, from the nature of the case, to be useless*". Edwin Lankester (1847-1929) had an opposite view and defended the need to concentrate research efforts to study life in the sea, in particular the life cycles of fish and their habitats. He defended the need to create a scientific association that would be responsible to supervise such research, stressing the need for a coastal laboratory in UK. Thus, in 1884 the British Association of Marine Science was born at a meeting of the Royal Society with the aim of promoting scientific research in Marine Zoology and Fisheries[10]. Huxley was paradoxically chosen as the first President, although he was contrary to the project, and Lankester became the first secretary. Plymouth was chosen, due to its coastal biodiversity, for the building of a laboratory fit to the purpose opening its doors in 1888. This is one of the most prestigious marine research institutions, where 12 Nobel laureates have carried out research.

First quantitative studies of ichthyofauna were carried out by C.G. Johannes Petersen (1860-1929), first director of the Danish Marine Station[1]. Fisheries research at its origin, or "commercial research" as it was termed at the time of Huxley, focused on very basic biological aspects such as the study of the life cycles of fish and their reproduction, trophic chains, ecology, and oceanographic conditions (sea currents…) that impact stocks. In the investigation of the trophic chains relevant to these stocks scientists realised about the importance of plankton, especially in Kiel ("*Laboratorium für die Intenationale Meeresforschung*"), Germany, and such studies contributed to the birth of Ecology as a scientific discipline. The investigation of the dynamics of plankton acquired high relevance and the different marine stations began to carry out annual plankton samplings, which today constitute some of the most extensive historical series of biological research. For example, the studies of life cycles, reproduction, taxonomy and distribution of copepods, the main component of zooplankton, became common. When shortage of fish stocks revealed as an evidence, marine aquaculture was explored as a possible solution, with the initial objective to help in the recovery of marine stocks. Thus, flat fish farming techniques, such as those used today in turbot farming, were developed at the Port Erin Marine Station on the island of Mann, UK (1892-2005). Thus, at the beginning, fisheries research was not the economic, mathematical, engineer and management discipline aimed at exploitation in which it developed in the mid-twentieth century[16]. We can say that currently, biological marine stations continue to carry out basic ichthyologic and ecological research, but fisheries research for government advice has been subordinated to other specialized research institutions.

Through a convention, some European nations (Denmark, Finland, Germany, Holland, Norway, Sweden, Germany, Holland, Norway, Sweden, Germany, Holland, Norway, Sweden, Germany and Great Britain) decided to implement the International Council for the Exploration of the Seas, ICES, in 1902[3,10,16]. Marine issues and the analysis of certain fisheries stock dynamics are transnational, and they need to be tackled transnationally. Other countries would join later, such as France that joined in 1920 or Spain in 1924. ICES is a marine research association partnered by governments, and its initial mission was to boost fisheries research. The associated nations and non-associated nations that still contributed with fisheries, biological and oceanographic data to ICES promoted the opening of institutions for research in their coasts to guarantee these studies. For the first time an important flow of public funds arrived into the already existing marine stations. Consequently, marine stations experienced a growth, both in resources and in the possibilities of hiring new and stable personnel[10,16].



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At this historic moment, governments realized the importance of scientific research, because "*Scientia potentia est*" (Knowledge is power), largely catalysing the establishment of the national funding mechanisms we know nowadays to finance scientific activities[10,16]. Most of the research carried out in universities and research centres around the world is based on the use of public funding schemes, for which countries set their research priorities and programs. And of course, they publish and manage national/regional systems to award research projects. Marine biological research can be placed playing an important role in this naissance of public scientific funding.

# 7. Marine model organisms and transformative biological science

Biomedical research is constructed upon the use of biological model organisms. There are different animal species that are often utilized in laboratories due to the ease to handle them, their reproductive mechanisms, their response capacity under different conditions and the possibilities they offer to analyse diverse molecular, cellular, physiological and developmental processes within simplified anatomical structures[17]. The Theory of Evolution tells us that all animals are related. In addition, the Cell Theory (1839) of Schleiden and Schwann explains that if the structural unit of life is the cell, the biological responses studied in any species are models transposable to the rest. This conceptual revolution broke out in the 19th century and the marine biological stations were at its origin. Recall the importance of basic taxonomy, comparative physiology or comparative and experimental embryology. No embryological explanation can be given without presenting the studies carried out with cnidarians, molluscs and echinoderms by Thomas Huxley, Hans Driesch, Hans Spemann, Jacques Loeb, Theodor Boveri…, and in marine stations[6].

Asking any Biology or Medicine student, they will respond that biomedical research model organisms are the yeast *Saccharomices cerevisae*, the mouse, the rat, the fruit fly or the nematode *Caenorhabditis elegans*. Take the fruit fly (*Drosophila melanogaster*), a favorite species in Genetics. The species was brought to the spotlight by the Nobel Prize winner (1933) Thomas Hunt Morgan (1866-1945). He was a marine biologist, affiliated to the Woods Hole Marine Station where he carried out his work nearly every summer and visited Naples four times (1894, 1895, 1900 and 1902). He worked with a number of very different species, especially with sea urchins. In his research stays in Naples he studied the embryology of ctenophores. He proposed the “Chromosome Theory”, as did also Theodor Boveri who used sea-urchins as model species in his 8 visits to Naples[6].

Sea urchins are wonderful model organisms because they produce oocytes easy to obtain and manipulate that are fertilized externally. For example, Otto Warburg (1883-1970) visited Naples five times between 1908 and 1914, and working with sea urchin embryos he would discover a tremendous increase in oxygen consumption upon fertilization. As a result, his work centered around the study of cellular respiration was awarded the Nobel Prize in 1931. Warburg´s friend Otto F. Meyerhoff (1884-1951) described the oxidation of glucose and the

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[17] Ocean Studies Science Board 1999. From Monsoons to microbes:understanding the ocean’s role in human health. *Washington, DC: National Academy Press*. 132 pp.



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production of lactic acid in the muscle, obtaining the Nobel Prize in 1922. His metabolic studies carried out previously in frogs were contrasted in the sea urchin. Yes, in Naples in two visits in 1910 and in 1913[14], with his friend Warburg taking advantage of the Wurzburg table.

But sea urchin has been mainly a fundamental example in the investigation of fertilization. There is a debate about who discovered the process of fertilization. Herman Fol (1845-1892), the first director of the marine station in Villefranche sur Mer, observed in a marine star the entrance of a single sperm into an oocyte. Oscar Hertwig (1849-1922) witnessed the same process during a research stay in Naples in 1975. He additionally described the fusion of male and female pronuclei at the beginning of embryo development underlining the contribution of the nucleus, and the importance of the material it provides, in the development of the embryo. He first observed the genetic material in the process of meiosis, although meiosis would be described (1883) by another marine biologist Edouard Van Beneden, son of the promoter of the first marine station in the world, P. J. Van Beneden. At the beginning of research in Development Biology, August Weismann (1834-1914) discovered between 1881 and 1882 the tissues that produce gametes (germ plasma) develop separately from other pioneer tissues that will produce body tissues. Where? In Naples!

Another example is the discovery of cyclins in the beginnings of cellular Molecular Biology. The initial stages of cell division of the embryos of the urchin *Arbacia punctulata* were studied by Tim Hunt during his first visit to Woods Hole Marine Laboratory from in Cambridge (UK) in 1982. He would finding these essential proteins whose concentrations go through production and destruction cycles in the control of the cell cycle[18]. Molluscs were also relevant. The Atlantic surf clam, *Spissula solidisima,* had been the biological model of Joan Ruderman (president of Woods Hole Marine Laboratory between 2012 and 2014). Ruderman also observed cyclic patterns during the cell divisions of the embryo development in the clam. In his visit to Woods Hole from Israel, Avram Hershko analyzed such dividing embryo cells in 1991, and he observed the proteolytic cleavage of cyclins during the cell cycle. This was worth a Nobel Prize in Chemistry for him in 2004 and the discovery of ubiquitin, while Hunt would be awarded the Nobel Prize in Physiology and Medicine in 2001. Both discoveries can be presented as pioneering and at the origin of the molecular study of cancer[17,18].

However, the most shinning contribution of molluscs to biosciences has been made by cephalopods and gastropods in the field of neurophysiological research. The giant axon of the squid in the genus Loligo was discovered across Woods Hole, Plymouth and Naples by English zoologist and neurophysiologist J. Z. Young. As it can reach a diameter up to a 1,5 millimeters, it is very appropriate for experimental research. Alan Lloyd Hodgkin (1914-1998) and Andrew Huxely (1914-1998) utilized this structure in their studies on action potentials and neuronal signaling (Nobel Prize, 1963) in Plymouth while Bernard Katz did the same to study neurotransmission in Naples (Nobel Prize, 1970)[19]. Another more cutting-edge biological model has been the sea hare, gastropods of the family Aplysidae. These molluscs possess a reflective movement to hide their siphon, commanded by a total of 20,000 large neurons (soma of neurons 1 mm in diameter). After a learning process they have the ability to remember and

[18] Hunt, T., 2004. The discovery of cylcin. *Cell*, **S116**, S63-S64.
[19] Schwiening, C. J., 2012. A brief historical perspective: Hodgkin and Huxley. *J. Physiol*. **590**, 2571-2575.



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accelerate this contraction movement[17]. It is a simple and very useful model in the investigation of sinaptogenesis, synaptic transduction and memory, and thanks to research conducted in California, Eric R Kandel obtained the Nobel Prize in Medicine in 2000.

There are numerous examples of marine organisms that can be used in the molecular and cellular research to understand important processes. Let us think on aging, a challenge in our occidental societies. There is a jellyfish species that can be considered biologically immortal, *Turritopsis dohrnii*. These colonial organisms that live in the Mediterranean Sea, possess in their adult phase and under stressful situations or at aging the capacity to return to the immature polyp stage through cell transdifferentiation. Thus, they can resume their colonial life without end. Closer to us, marine vertebrates can live for hundreds of years. The Greenland shark holds a record, with a female identified to be 392 ± 120 years old[20]. But the whale (*Balaena mysticetus*), is a mammal and thus a species closest to us. In 2007, a Greenlandic whale was captured in Alaska, with a Victorian harpoon attached result of an unlucky encounter with whale hunters at the time. Her age was reported to be 211 years. The genome of this cetacean species has been sequenced and this information begins to provide clues of its longevity. For example, an important gene in DNA repair, PCNA, is duplicated in its genome[21]. Can these species help in disclosing clues to delay the aging process? How can we guarantee in any case that we could use that information to extend survival? There are marine model organisms that could allow us to respond such questions. Sea cucumbers for instance, secrete their digestive tract under stress or in the presence of a predator. In a few days they recover the lost organ completely. Another example are Acoela, a small group of worms in the phylum Xenacoelomorpha that live in the sand. *Symsagittifera roscoffensis* for instance, is a species that performs photosynthesis through strict symbiosis with a unicellular algae, *Tetraselmis convolutae*[22]. These worms possess a frontal accumulation of serotonergic and photo- and mechano-receptor neurons that form a primitive brain. By cutting these serotonergic heads, the worms loose their borrowing capacity, but through an amazing neuroregenerative process they can regrow their brain in 20 days. This may be a wonderful biological model to study neural regeneration in the future[22].

One of the first examples in history maybe that of Élie Metchnikoff, one of the fathers of Immunology. In Messina he had the opportunity to work with larvae of sea stars in the summer of 1882. Cellular movement is easy to observe in these larvae because of their transparency. Perforating the larvae with a rose thorn, he was able to observe the movement of the phagocytic cells to heal the wound. Phagocytosis sprouted as a concept and as a theory of cellular immune response from such observation, and Metchnikoff would be awarded the

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[20] Nielsen, J., Hedeholm, R. B., Heinemeier, J., Bushnell, P. G., Christiansen, J. S., Olsen, J., Ramsey, C. B., Brill, R. W., Simon, M., Steffensen, K. F., Steffensen, J. F., 2016. Eye lens radiocarbon reveals centuries of longevity in the Greenland shark (*Somniosus microcephalus*) . *Science*. **353**, 702–704.

[21] Keane, M., Semeiks, J., Webb, A. E., Li, Y. I., Quesada, V., Craig, T., Madsen, L. B., Van Dam, S., Brawand, D., Marques, P. I., Michalak, P., Kang, L., Bhak, J., Yim, H. S., Grishin, N. V., Nielsen, N. H., Heide-Jørgensen, M. P., Oziolor, E. M., Matson, C. W., Church, G. M., Stuart, G. W., Patton, J. C., George, J. C., Suydam, R., Larsen, K., López-Otín, C., O'connell, M. J., Bickham, J. W., Thomsen, B., De Magalhães, J. P., 2015. Insights into the evolution of longevity from the bowhead whale genome. *Cell Rep*. **10**, 112-122.

[22] Bailly X, Laguerre L, Correc G, Dupont S, Kurth T, Pfannkuchen A, Entzeroth R, Probert I, Vinogradov S, Lechauve C, Garet-Delmas MJ, Reichert H, Hartenstein V. (2014). The chimerical and multifaceted marine acoel Symsagittifera roscoffensis: from photosymbiosis to brain regeneration. *Front Microbiol.* **5**, 498.



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Nobel Prize in 1908. The father of Immunology was a marine biologist and worked with marine model organisms for his PhD, and in his visits to different marine stations of Europe, for example Naples or Sevastopol, before Pasteur incorporated him to his institute in Paris.

# 8. Marine biological resources and blue biotechnology

Where does the future lie for marine biological stations? The General Directorate for Maritime Affairs and Fisheries of the European Union (DG-MARE) has identified 5 emerging activities in its Blue Growth strategy. Among them, two have biology in their focus: Marine Aquaculture and Marine Biotechnology[23]. The OECD also refers to these two activities in their report “Oceans Economy in 2030”[24]. What is marine or blue biotechnology? The truth is that it is an area with very diffuse boundaries, but we are talking about biotechnology utilizing marine biological resources to obtain products or services beneficial to humans[22]. Biotechnology has always provided value-added products from marine organisms. Phoenicians, Greeks or Romans obtained "garum" or "liquamen" from fish and fish leftovers. Garum was a fermented fish broth that was used as condiment in dishes. On the other hand, think of the purple colour that has always been a symbol of power, kings and cardinals. The purple dye was obtained from marine gastropods of the Muricidae family and it was very expensive to obtain, as many snails were necessary to obtain the bromoindigo dye that the snails use in their immune protection. More recently, we could highlight the green fluorescent protein obtained from jellyfish. Osamu Shimomura managed to isolate this fluorescent protein at the University of Washington Friday Harbor Laboratory, during the 1960s and 70s. This protein is used as a "reporter" protein in most transgenic analyses. This protein, that allows to observe gene expression processes life, has brought a terrible revolution to the investigation of germline cells, to cloning processes, to the investigations necessary for the observation of cells in vivo, to organ transplants, to neurosciences...

Today, and above all, with the possibilities that parallel mass sequencing techniques allow, and the ability to perform multiple screening of biological functions, marine bioprospection has become the last frontier[22]. We look for food, nutraceutical or probiotic products. Think for instance on the benefits of omega-3 fatty acids. We have begun to look at algae as part of our diet. But screening projects look for different specificities in all kinds of molecules and metabolites that can only be found in marine creatures. Some act as immunosuppressants, immunostimulants, antibiotics or fungicides. Some other are cell growth suppressants and can be utilized in the development of anti-cancer drugs. We also look for moisturizing compounds, antioxidants or photo-protectors for the cosmetic industry and others[25]. There are marine fungi that could be the source of the next generation of antibiotics. The options are enormous, because life initiated in the sea 4 billion years ago and 34 of the 36 animal phyla are

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[23] Hurst, D., Børresen, T., Almesjö, L., De Raedemaecker, F., Bergseth, S., 2016. Marine biotechnology strategic research and innovation roadmap: Insights to the future direction of European marine biotechnology. *Marine Biotechnology ERA-NET: Oostende.* pp. 64.

[24] OECD 2016. The Ocean Economy in 2030> *OECD Publishing*, Paris. http://dx.doi.org/10.1787/9789264251724-en.

[25] Guillerme, J. B., Couteau, C., Coiffard, L. 2017. Applications for marine resources in cosmetics. *Cosmetics* **4**, 35.



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represented in the sea, while only 17 are present on land. Evolution has been playing for years in the sea and all kinds of molecules are there to be found.

There is a huge potential, but the biotechnology industry does not pay too much attention to the sea, in part because marine bioresources are not that easy to access and manipulate[22]. This will be, to a large extent, the new framework to be developed by marine biological stations, and this has been the goal of the European ESFRI roadmap of research infrastructures launching the pan-European research infrastructure "European Marine Biological Resource Centre" (EMBRC, www.embrc.eu). This is an infrastructure disseminated in nine countries, consisting of 29 maritime stations and research centres in Belgium, France, Greece, Israel, Italy, Norway, Portugal, Spain and UK. The goal is to make marine bioresources and marine biological research accessible to all researchers and industry, offering services for their molecular, cellular and biotechnological utilization, catalysing the Blue biotechnology to be developed in Europe. For many years!

# 9. Conclusions

Learning form the past of marine biological stations, many clues to understand their resilience over the year and learning lessons to underpin their future long-term sustainability can be gained. They are summarised in the following list of conclusions.

1 - Oldest marine biological stations were born mainly as a consequence of the personal drive of individual academics, researchers or wealthy naturalists (philanthropists or Maecenas). Sometimes they initiated activities as private institutions or most times linked to Universities or to naturalist, scientific or fisheries associations where those individual persons had some influence. Many of them, have changed governance and ownership over the years, many of them finally becoming integrating into larger Universities, where the educational mission (and tuition fees) has always contributed to ensure sustainability. Some of them have survived even after changing countries, with Rovinj as the most paradigmatic example: first Austro-Hungarian, then Italo-German (with and Italian and a German Director at the same time), then German, afterwards Yugoslavian and finally Croatian. Another example is the Marine Observatory of Villefranche sur Mer, first French, then Russian and finally French again.

2 - Few marine stations have closed definitively since the "Laboratory des Dunes" was opened in Ostend (Belgium) in 1843, the reasons for such closings being: political changes (e.g. Trieste, Fiume), bombing of the building during the second World War (Le Portel or Kiel), economic shortage and high costs (Millport, Port Erin) or have changed into becoming more centred in economic fisheries of physical oceanography (Santander and Mallorca, Lowestoft).

3 - Marine biological stations, that have shown capacity to reinvent themselves along the years and to survive in times of crisis, were opened in the second half of the 19$^{th}$ century in Europe with a mission to:

- Study and describe (taxonomy, ecology) coastal marine biodiversity close to the places where it is the richest.



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- Conduct experimental biological research with marine organisms the closest possible to their natural habitats and during the adequate developmental time windows.
- Obtain empirical proofs of the evolution theory.
- Allow research in polar areas, at the beginning in the subarctic and Arctic region, and after the Second World War in Antarctica.
- Supply museums, universities and schools around Europe with marine organisms and samples from bioresources.
- Train teachers in natural history, educate researchers in biology (undergraduates and postgraduates) and offer academic and training specialisation courses.
- Educate the public on marine natural history (public aquaria…).

Some of the marine stations have worked pursuing different aspects of such missions at the same time. In many circumstances a multidisciplinary approach, often exploiting the triad research/education/outreach has been basic to their sustainability.

4 - The last years of the 19th century, and specially the beginning of the 20th century with the depletion of fisheries stocks and the birth of the International Council for the Exploration of the Seas (ICES), biological fisheries research (commercial research) was incorporated as a main driver of the scientific activities of most marine stations, resulting in the growth of already existing institutions and the birth of new ones.

- Fisheries research marked the beginning of the national science funding programs as we know them today, nations becoming aware that research funding is not an expense but an investment.
- Fisheries research initiated marine aquaculture research in marine stations mainly with restocking purposes.

5 - Marine biology trying to answer global questions locally was one of the first fields of research in which international collaboration became desirable and even obligatory (Challenger expedition, 1st International Polar Year, ICES fisheries research activities… research in Climate change). This has many important implications in how research is conducted nowadays, and without doubt a practical example, politically very powerful, can be seen in the Antarctic treaty.

6 - The study of marine biological resources in the cradle of all comparative biological disciplines (comparative anatomy, comparative physiology, comparative embryology…) contributed to specialisation and branching into biological research departments.

- Marine organisms are fundamental laboratory model species for different research disciplines and for the investigation of multiple biomedical questions.
- Many techniques, not only sampling techniques specific to work with marine pelagic or benthic organisms, were developed to study marine organisms. The clearest example is microscopy and histological processing developed in Stazione Zoologica Anton Dohrn.

9 - Research in marine biological stations has responded to two main drivers necessary for the advancement of science:

- Experimental biological research in the frontiers of knowledge.
- Long term datasets and biological oceanography observatories.



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7 - Marine biological stations have lived closely linked to the (sometimes) small maritime communities where they were stablished, contributing to the socioeconomic development of peripheral maritime areas.

- The promise of the development of the emerging field of "marine biotechnology" it is an opportunity not only for the sustainability but also for the growth and socioeconomic impact potential of marine biological stations.

8 - Marine biological stations have suffered, and are suffering, from their peripheral location. For instance, in the case of institutions belonging to a University located more centrally, their unit costs are comparatively higher than those in Departments closer to the main campus. This has been counteracted by marine biological stations by their attractive training/educational capacity, and their capacity to conduct outstanding research. In these cases it has been important when their governing bodies have maintained locally rooted but with capacity to influence centrally.

9 - The marine environment is perceived as a treasure by the common citizen since the times of Jacques Cousteau, and now into the times of the BBC "Blue Planet" nature documentaries, and this citizen awareness is an important asset for the sustainability of marine biological stations, one they have always nurtured (public aquaria, citizen science, "we are open for visits"…). This message has been taken by the United Nations that has decided on a UN "Decade of Ocean Science for Sustainable Development (2021-2030)" that will start in one year time.

10 - In the last 20 years the marine biological stations have initiated a networking process through associations such as MARS and WAMS to work towards common objectives in marine observation, that finally, and for a subset of European Marine Biological Stations, has resulted in the creation of an ESFRI-roadmap pan-European research infrastructure ,EMBRC-ERIC (www.embrc.eu), to offer access to marine ecosystems and advanced biological research platforms and services for marine biologists, administrations and industry.



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# 10. Appendices

## *10.1. Appendix 1. Minimal bibliography*

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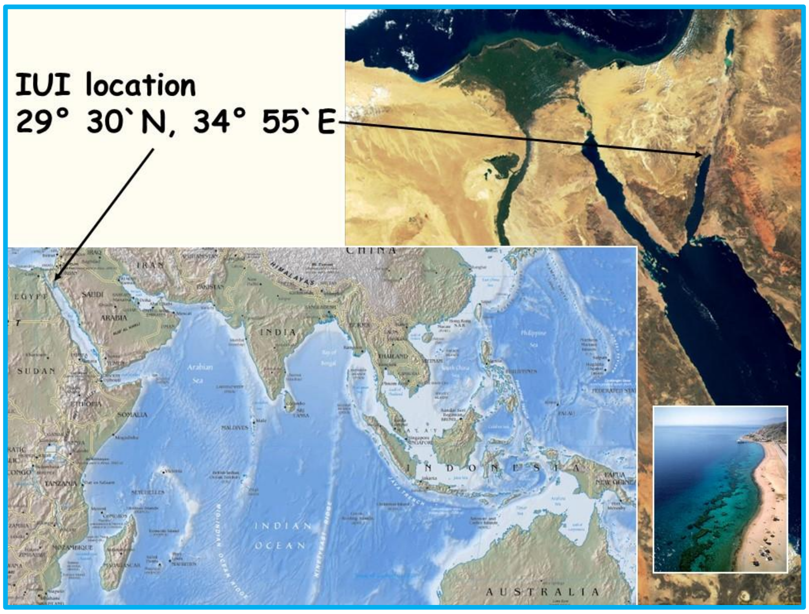
## *10.2. Appendix 2. Summarised example of one of the Marine Stations presented in the book*

# The Interuniversity Institute for Marine Sciences in Eilat (IUI): A unique marine science research consortium

**Simon Berkowitz, Amatzia Ganin**

The Interuniversity Institute for Marine Sciences in Eilat, Israel, is Israel's only academic hub for research and graduate studies in marine science. Located in Eilat on the Gulf of Aqaba, it was established in 1984 by the Israel Council of Higher Education to advance research and teaching in marine sciences across all universities in Israel. As such it serves as a national facility pooling together countrywide resources and expertise for the benefit of people and the sea. A Board of Directors has oversight of the IUI and consists of members from each university in Israel (Ben Gurion Universdity, Bar Ilan University, Hebrew University of Jerusalem, Haifa University, Tel Aviv University, Weizmann Institute of Science, and the Technion-Institute of Technology).




The IUI is located next to a flourishing coral reef and close to deep, 'blue' waters. The unique proximity to the reef and deep waters, the availability of state of the art facilities, and scientific excellence attracts numerous scientists and students from Israel and around the world to carry out their research in Eilat and to take part in the diverse teaching courses and special programs.



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## Brief History

It all started some 50 years ago with a vision of a pioneering zoologist from the Hebrew University of Jerusalem, Prof. Heinz Steinitz, who initiated and then established the university's first Marine Biology Laboratory (MBL). A decade of scientific proliferation turned MBL into a vivid, thriving institute, frequented by Israeli and international researchers. Identifying MBL's immense potential for research and teaching, in 1984 the director of the laboratory at that time, together with the heads of the Hebrew University and Israel Council of Higher Education, agreed to transform the MBL into an Interuniversity Institute to be shared by all universities in Israel. That ingenious move was made possible due to the farsighted vision of the people involved and the exceptional generosity of the Hebrew University to open and share its marine campus. Since then the IUI has become a unique international example for pooling of academic and physical resources to optimize limited resources and maximize the operational budget.


Today the IUI serves as a leading research center and an advanced institute for education and training of graduate students in all fields of marine sciences. Research and teaching activities are carried out by researchers, students and staff belonging to two categories: "Residents" – those who reside in Eilat, and "Non-residents" – those who frequently visit the IUI to carry out their research and/or to take part in the interuniversity teaching program. Because the IUI is not a university on its own, each resident researcher and resident student is




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affiliated with a “home university” from which the academic degree is awarded (students) or in which he/she is promoted (faculty). The total number of residents working at the IUI in 2020 is 68, consisting of 7 tenure-track researchers (4 from Hebrew University and one from each of Tel Aviv, Bar Ilan and Ben Gurion universities), 9 postdoctoral fellows (5 from abroad), 32 technical and administrative employees (11 of them research assistants), 13 MSc students, and 16 PhD students (3 from abroad). A total of 118 non-resident researchers from Israel are active in marine research and/or teaching at the IUI, of whom 96 are from Israeli higher-education institutes and 22 from governmental research institutes. The IUI is growing as a hub of international research in marine sciences (see below).

In addition, the institute considers outreach and contributions to the local community as undertakings of immense importance. Accordingly, IUI researchers, students and staff contribute substantially to the city’s educational activities, disseminate science to the public, and assume a leading role in protecting the Gulf of Eilat’s unique marine ecosystem. To that end, the IUI makes a valuable contribution to the economy of Eilat by helping to preserve the coral reef as an international and national touristic magnet, but also through its skilled and trained staff and their families who make Eilat their home.

### How does an interuniversity entity work?

International marine institutions and academics frequently ask “How can a shared institute function so well in Eilat whereas elsewhere in the world universities compete fiercely against one another for students and resources?” It works because each university of the IUI partners considers the IUI an extension of its own campus, where unique and costly infrastructure and instruments are available as shared resources. Furthermore, the unparalleled ease of access to the coral reef and deep waters together with the availability of state-of-the-art facilities and instruments attracts researchers and students from all universities and research institutes (including from abroad) to carry out research that in many cases cannot be done elsewhere. No institution on its own could provide and maintain such an infrastructure. Accordingly, the benefits to marine science in Israel, to researchers, to students, and to the region are immeasurable.

### Research at the IUI

Research at the IUI is carried out by researchers from all institutes in Israel and by numerous international visitors. The research is typically closely related to on site field work and sampling, utilizing the unique location, setting and facilities at the IUI, and focusing on three major topics : coral reefs, blue-water ecosystems, and global changes. Over 6000 scientific papers that were fully or partially based on work performed at the IUI have been published since its establishment, including key papers in leading journals.



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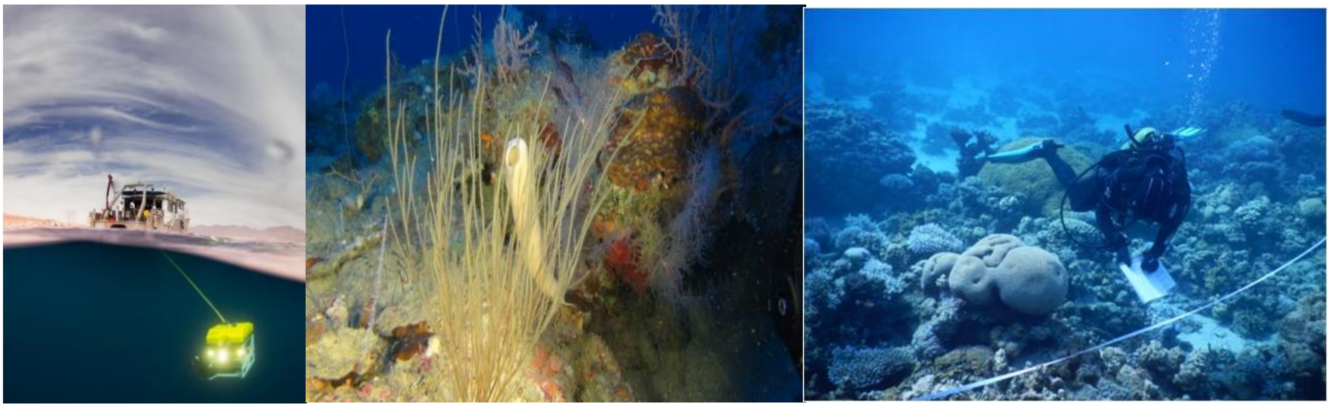

Key research targets at the IUI (from left to right: the IUI research vessel launches the Remotely Operated Vehicle (ROV) for studies of the deep water column, the deep, "mosophotic" reef and the flourishing coral reef.

### Teaching at the IUI

The IUI serves as an advanced education and training center for graduate students. The teaching program in 2020 consists of 22 courses, primarily at the graduate level and one undergraduate courses. The courses cover all major disciplines in marine sciences and are taught by leading experts in the respective fields in Israel. The courses are open to students from all universities in Israel, free of charge, and are given credit units accepted at their home universities. Over the past 5 years both the number of applications and the number of accepted students has increased such that there are far more applicants than available spaces. Training and courses at the IUI have been highly productive to the country. Over 90% of Israeli marine researchers and marine-related high-level professionals in governmental institutes gained part of their training and education at the IUI.

## 10.3. Appendix 3. Dissemination of the Task results and conclusions

Conferences and communications

- "Diving in marine minds" within the **annual symposium of the Erasmus Mundus Masters**, EMBC+ and IMBRsea, Lecture: "Marine Biological Stations "to be or… to be" in history", Cancio, I, Vayamundo, Ostend (Belgium). 8 June 2017

- **53th European Marine Biology Symposium-EMBS53**. Presentation of the oral communication: "Sustainability of Marine Biological Stations, lessons from a historical perspective". Cancio, I, Nardelo, I. Ostend, Belgium, 17-21 September 2018.

- **Science club**, within the **Science Week-2018 of the Univeristy of the Basque Country**, Scientific monologues "*Scientia Potentia Est*" Cancio, I, **Bizkaia Aretoa,** Bilbao, 10 November 2018.



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- **Biophysics Colloquium** organised by the Biophysics Research Centre, Euscampus, University of Bordeaux and University of Bath Conference "*Fruti di mare: from the sea to the laboratory bench*" Cancio, I, **Bizkaia Aretoa,** Bilbao, 15 November 2018.

- **Ceremony Saint Albert the Great**, BSc degrees awarding ceremony to promotion 46 of the School of Science and Technology of the Unversity of the Basque Country. **Invited last gradutaion lecture** "*Scientia potentia est; eta itsasoa zabala da*" Cancio, I. Main Auditorium of the University of the Basque Country, 16 November 2018.

- **3rd General Assembly of Assemble plus**, Conference entitled "Scientia potentia est and marine biological stations are here to proof it" Cancio, I. Stazione Zoologica Anton Dohrn, Naples, September 2019.

- **30th Annual Newth Lecture**, "*Scientia Portentia est* and marine biology is the proof", Cancio, I.Scottish Association of Marine Science, Oban, Scotland. 6 December 2019. Video streamed: https://youtu.be/H6w5Xm91VQY

**Publications**:

- Cancio, I. "Itsas estazio biologikoen historia eta kostaldeko bioaniztasunaren ikerketa". EKAIA Special issue UN Decade for Ocean Science for Sustainable development (2021-2030) ISSN: 0214-9001 (in press).

  Web publication: https://www.ehu.eus/ojs/index.php/ekaia/article/view/21074

**Organization of congresses**

Participation in the Organization Committee of the 53th EUROPEAN MARINE BIOLOGY SYMPOSIUM-EMBS53. http://www.vliz.be/events/embs53/. Ostend, Belgium, 17-21 September 2018.

*"EMBS53 aims at linking the history, the present and the future of (European) marine biology. This edition will be special, as 2018 is a celebration year in Ostend: the first marine station ever worldwide was inaugurated exactly 175 years ago, in Ostend, by professor Pierre-Joseph Van Beneden. Since then, the world of marine biology has changed dramatically - both in Belgium and Europe - especially in relation to used technologies and techniques."*

**Media**

- **Radio program** "Norteko Ferrokarrila", Euskadi Irratia (Basque public radio station), with the creation of a special monthly corner "Itsas Lamiaren txokoa" (**Mermaid´s corner**) to promote the "UN Decade of Ocean Science for Sustainable Development 2021-2030".

  https://www.eitb.eus/eu/irratia/euskadi-irratia/programak/norteko-ferrokarrila/audioak/osoa/6458618/itsasoaren-kimika/

  https://www.eitb.eus/eu/irratia/euskadi-irratia/programak/norteko-ferrokarrila/audioak/osoa/6346543/ionan-marigomez/



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https://www.eitb.eus/eu/irratia/euskadi-irratia/programak/norteko-ferrokarrila/audioak/osoa/6329765/itsas-estazioen-historia-eta-brexita/

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http://norteko.elhuyar.eus/entzun.asp?Kodea=1582



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