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OCEANOGRAPHY AND MARINE ECOLOGY

Oceans

Evolving Concepts

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Table of Contents

[Cover](#)

[Title Page](#)

[Copyright](#)

[Acknowledgments](#)

[Introduction](#)

[1 The Challenger Expedition: The Birth of Oceanography](#)

[1.1. The Challenger cruise \(1872-1876\)](#)

[1.2. From the Challenger to the “golden age” of oceanography](#)

[2 From Physical Oceanography to Ocean-Atmosphere Interactions](#)

[2.1. Technological advances revealing the complexity of the ocean](#)

[2.2. The international TOGA and WOCE programs](#)

[2.3. Observing for short-term forecasting and climate study](#)

[2.4. Major advances](#)

[2.5. An ocean of change](#)

[2.6. Conclusion](#)

[3 From Chemistry to Marine Biogeochemistry](#)

[3.1. The birth of chemical oceanography](#)

[3.2. From the chemical composition of seawater to that of plankton](#)

[3.3. Chemical tracers³ and water mass identification](#)

3.4. Advancement of concepts on the pelagic ecosystem

3.5. Vertical nutrient inputs and coastal upwellings

3.6. Nutrient upwelling and Southern Ocean

3.7. Rise of marine biogeochemistry

3.8. From local nutrient inputs to large-scale ocean-atmosphere interactions

3.9. Conclusion

4 From Marine Biology to Biological Oceanography

4.1. The key role of marine stations

4.2. The beginnings of marine ecology

4.3. A case study: a comparative approach to phyto- and zooplankton

4.4. The rise of marine genomics

4.5. Conclusion

5 Anoxia and Chemosynthesis

5.1. Hypoxia and anoxia in the ocean

5.2. Eutrophication and anoxia of coastal systems

5.3. Hydrothermal ecosystems

5.4. Conclusion

6 A Warmer, More Acidified and Less Oxygenated Ocean

6.1. Ocean “acidification”: process, evolution and impacts

6.2. A less productive ocean?

6.3. Impacts of climate change on the ocean

6.4. Conclusion

7 The Ocean at High Resolution

7.1. Reminder: the ocean on a large scale

[7.2. Tools for moving from large to small scale](#)

[7.3. A new vision of the ocean](#)

[7.4. Conclusion](#)

[8 Challenges for the Ocean](#)

[8.1. Context](#)

[8.2. Combining the exploitation of biological resources and sustainable development?](#)

[8.3. Combining the exploitation of deep sea mineral resources with biodiversity conservation?](#)

[8.4. Mitigating the anthropogenic greenhouse effect by manipulating the ocean?](#)

[8.5. Conclusion](#)

[Conclusion](#)

[Glossary of Terms](#)

[References](#)

[List of Authors](#)

[Index](#)

[End User License Agreement](#)

List of Illustrations

Chapter 1

[Figure 1.1. Sir John Murray \(©NOAA Ocean exploration and research\)](#)

[Figure 1.2. Dredging and sounding on board the HMS Challenger \(©NOAA Ocean explo...](#)

[Figure 1.3. "Around the world" trip of the Challenger between December 21, 1872 ...](#)

[Figure 1.4. Prince Albert I of Monaco aboard Princess Alice \(©Coll. Institut océ...](#)

Chapter 2

[Figure 2.1. Chassis equipped with 28 seawater sampling bottles, a CTDO2 probe an...](#)

[Figure 2.2. WOCE Section A03 in the North Atlantic. For a color version of this ...](#)

[Figure 2.3. The surface drift of wrecks listed in the pilot charts between 1883 ...](#)

[Figure 2.4. Trajectories of 26 Sofar floats \(Langrangian SOund Fixing And Rangin...](#)

[Figure 2.5. The Gulf Stream as seen by Seasat. \(a\) Ground traces of the satellit...](#)

[Figure 2.6. Henry Stommel in 1965 on board the Atlantis II \(Wunsch 1997\).](#)

[Figure 2.7. El Niño. For a color version of this figure, see \[www.iste.co.uk/jacq...\]\(http://www.iste.co.uk/jacq...\)](#)

[Figure 2.8. TOGA observation system \(©Eumetsat\)](#)

[Figure 2.9. TOGA observation system in 1994: it included opportunity vessels for...](#)

[Figure 2.10. Diagram of meridional overturning circulations \(MOCs\) in the three ...](#)

[Figure 2.11. Heat transport \(in petawatts, PW\) through the hydrographic sections...](#)

[Figure 2.12. Hydrography, biogeochemistry and currentometry sections of the inte...](#)

[Figure 2.13. Position of the 3,903 active profiling floats in the Argo program i...](#)

[Figure 2.14. Position of OceanSITES program moorings. In orange, recorded platfo...](#)

[Figure 2.15. Rapid program moorings that measure the variability of the meridian...](#)

[Figure 2.16. Walter Munk in Stockholm in 2010 to receive the Crafoord Award \(Hol...](#)

[Figure 2.17. Dynamic surface topography obtained by combining altimetry data, ge...](#)

[Figure 2.18. Position of Antarctic circumpolar current fronts with, from north t...](#)

[Figure 2.19. Pacific Ocean. Zonal component of the average current velocity dete...](#)

[Figure 2.20. Annual variability in surface salinity observed from space by the A...](#)

[Figure 2.21. Amplitude, in centimeters, of mesoscale eddies as evidenced by alti...](#)

[Figure 2.22. Characteristics of \(a\) mode waters and \(b\) the main pycnocline for ...](#)

[Figure 2.23. Diapycnal diffusivity represented as a function of longitude and de...](#)

[Figure 2.24. Change in the mean sea surface level measured by altimetry from spa...](#)

[Figure 2.25. Regional rising sea level trend calculated over 1993-2010 after rem...](#)

[Figure 2.26. Change in ocean temperature between the Challenger expedition \(1872...](#)

[Figure 2.27. Evolution of the integrated heat content of the oceans between 1993...](#)

Chapter 3

[Figure 3.1. Alfred C. Redfield in his laboratory in 1955 \(© Marine Biological La...](#)

[Figure 3.2. Relative changes in ocean nitrate and phosphate concentrations compa...](#)

[Figure 3.3. Map of Geosecs stations in the Atlantic](#)

[Figure 3.4. Relative changes in potential temperature and “\[NO\] = 9 \[NO3-\] + \[O2...](#)

[Figure 3.5. Potential temperature, salinity, dioxygen and nitrate profiles for t...](#)

[Figure 3.6. Vertical distributions of natural \$^{14}\text{C}/\text{C}\$ ratios \(expressed as \$\Delta^{14}\text{C}\$ \) a...](#)

[Figure 3.7. World thermohaline circulation in the form of a conveyor belt \(Broec...](#)

[Figure 3.8. Global thermohaline circulation \(Talley 2015\). For a color version o...](#)

[Figure 3.9. Wallace Smith Broecker \(with the kind permission of the LDEO\)](#)

[Figure 3.10. Penetration of solar radiation into the sea. In the ocean, phytopla...](#)

[Figure 3.11. Relationship between the depth of the euphotic layer \(1% of surface...](#)

[Figure 3.12. Sverdrup’s theory \(1937–1938\). Springtime change in critical depth ...](#)

[Figure 3.13. Vertical distribution of density off the Provençal coast in Februar...](#)

[Figure 3.14. Chlorophyll content \(\$\text{mg}\cdot\text{m}^{-3}\$ \) in surface waters in the NW Mediterran...](#)

[Figure 3.15. Eppley and Peterson’s \(1979\) concept. In line with the work of Dugd...](#)

[Figure 3.16. Coastal upwellings. From the beginning, oceanographic cruises benef...](#)

[Figure 3.17. Ekman's theory \(1905\) on the birth of the drift current; in the nor...](#)

[Figure 3.18. Water mass circulation pattern in the subtropical coastal upwelling...](#)

[Figure 3.19. Transatlantic section showing the circulation of water masses](#)

[Figure 3.20. Biomass program; study areas \(rich in krill\) during the first seaso...](#)

[Figure 3.21. Change in atmospheric CO₂ concentration in Mauna Loa \(Hawaii\); init...](#)

[Figure 3.22. Hydrographic sections of the WOCE-JGOFS-NOAA programs for the deter...](#)

[Figure 3.23. Studies of the carbon cycle during JGOFS with time scales of the bi...](#)

[Figure 3.24. JGOFS time series. The observation stations \(black dots\) are locate...](#)

[Figure 3.25. Annual ocean-atmosphere CO₂ fluxes. CO₂ sinks \(net absorption by th...](#)

[Figure 3.26. Column inventory of anthropogenic CO₂ in the ocean \(mol·m⁻²\). High ...](#)

[Figure 3.27. Annual fluxes of organic carbon exported to the global ocean at a d...](#)

[Figure 3.28. The El Niño/La Niña ocean index from 1865 to 2018 based on surface ...](#)

[Figure 3.29. Bjerknes' theory on ocean-atmosphere interactions in the equatorial...](#)

[Figure 3.30. The major equatorial currents in the Pacific \(Wyrтки 1979\)](#)

[Figure 3.31. The seven most intense El Niño \(a\) and La Niña \(b\) since 1950; the ...](#)

[Figure 3.32. Network of buoys \(moorings\) of the international TOGA program in th...](#)

Chapter 4

[Figure 4.1. Henri de Lacaze-Duthiers at the Arago laboratory in June 1893, photo...](#)

[Figure 4.2. The two marine stations developed by Lacaze-Duthiers: \(a\) the Roscof...](#)

[Figure 4.3. Images of two marine stations at the Faculty of Sciences of Paris: \(...\)](#)

[Figure 4.4. The Citadell Hill Marine Laboratory in Plymouth around 1925. Opened ...](#)

[Figure 4.5. WHOI central building built in 1930 and Atlantis I in service from 1...](#)

[Figure 4.6. Current view of some of the buildings and ships of the Woods Hole oc...](#)

[Figure 4.7. The Mediproduct group during its inaugural cruise, Mediproduct 1 in the Gu...](#)

[Figure 4.8. The Jean Charcot, France's first public research oceanographic vesse...](#)

[Figure 4.9. Surface chromatograms \(a\) at the deep chlorophyll maximum \(b\) at the...](#)

[Figure 4.10. André Morel, with the kind permission of Xiaogang Xing](#)

[Figure 4.11. Flowering of the coccolithophorid Emiliana huxleyi in the English C...](#)

[Figure 4.12. Mean distribution \(1998-2006\) of chlorophyll a based on SeaWiFS dat...](#)

[Figure 4.13. Sargasso Sea cytogram; red fluorescence separates small prokaryotes...](#)

[Figure 4.14. Plankton nets](#)

[Figure 4.15. The continuous plankton recorder in service on board the Australian...](#)

[Figure 4.16. Sir Alister Hardy with the original CPR model during the Discovery ...](#)

[Figure 4.17. Vertical migrations of zooplankton in the western equatorial Pacifi...](#)

[Figure 4.18. A “classical” network such as phytoplankton zooplankton → nekton → ...](#)

Chapter 5

[Figure 5.1. Evolution of the dioxygen content in the atmosphere of planet Earth ...](#)

[Figure 5.2. Extension of the dioxygen-minimum zone \(mLL-1\) of the world’s ocean ...](#)

[Figure 5.3. Redox scale in aquatic environments and electron transport in aerobi...](#)

[Figure 5.4. Typical concentration profiles of dioxygen, hydrogen sulfide and dis...](#)

[Figure 5.5. In a subarctic environment, the Baltic is a semi-enclosed sea with a...](#)

[Figure 5.6. Physical and biogeochemical processes leading to hypoxia and even an...](#)

[Figure 5.7. The intermittent inflows \(1-15\), mainly in winter, of saltier and de...](#)

[Figure 5.8. Extension of hypoxia, even anoxia, in the deep waters of the Baltic ...](#)

[Figure 5.9. Change in characteristics of the Baltic Sea since the beginning of t...](#)

[Figure 5.10. Growth in continental or atmospheric inputs of phosphorus \(P\) and n...](#)

[Figure 5.11. Coastal dead zones \(red dots\) where severe hypoxia \(\$O_2 < 1.4\$ mL...](#)

[Figure 5.12. 65,000 km of ridges separate the lithospheric plates; the arrows in...](#)

[Figure 5.13. Section of a fast oceanic ridge located 13°N in the eastern Pacific...](#)

[Figure 5.14. The American submersible Alvin launched by the WHOI Atlantis. Havin...](#)

[Figure 5.15. Lucien Laubier and Myriam Sibuet](#)

[Figure 5.16. Launching of the Cyana submersible \(former diving saucer SP2000 of ...](#)

[Figure 5.17. Submersibles in service in 2019 reaching or exceeding 6,000 m: \(a\) ...](#)

[Figure 5.18. Remotely operated underwater vehicles: \(a\) HROV Ariane \(France\) \(© ...](#)

[Figure 5.19. Neptune-Canada cabled seabed observatory installed in 2014. Located...](#)

[Figure 5.20. Tempo ecological observation module on the Lucky Strike site in 201...](#)

[Figure 5.21. Some remarkable organisms of hydrothermal springs showing the origi...](#)

[Figure 5.22. Thermococcus fumicolans, a hyperthermophilic archaea isolated from ...](#)

Chapter 6

[Figure 6.1. Changes in pHT and total CO₂ concentration \(sum of the concentration...](#)

[Figure 6.2. Basics of carbonate chemistry in the marine environment. Calcareous ...](#)

[Figure 6.3. Processes contributing to the regulation of seawater pH \(Hönisch et ...](#)

[Figure 6.4. Changes in pCO₂, total pH and carbonate ion concentration at the obs...](#)

[Figure 6.5. Simulation of the change in the equilibrium of the carbonate system ...](#)

[Figure 6.6. Calcareous shell planktonic organisms: \(a\) the coccolithophore Emili...](#)

[Figure 6.7. Proposed trajectories of calcareous and organic fossil lineages over...](#)

[Figure 6.8. Impact of a change in ocean pH associated with CO₂ emission scenario...](#)

[Figure 6.9. Coral bleaching in New Caledonia \(© IRD – Jean-Michel Boré\). For a c...](#)

[Figure 6.10. A drastic increase in atmospheric CO₂ content will lead to a reduct...](#)

[Figure 6.11. Cold water coral ecosystem with redfish \(white arrow\) dominating a ...](#)

[Figure 6.12. Margalef's model \(1977\); dominance of phytoplankton groups in a tur...](#)

[Figure 6.13. Ramón Margalef \(© Institut de Ciències del Mar, Barcelona\)](#)

[Figure 6.14. Change in primary production and exported production from the prese...](#)

[Figure 6.15. Distribution of spectral size slope in a global model of planktonic...](#)

[Figure 6.16. Rising sea level forecasts during the 21st Century compared to 1986...](#)

[Figure 6.17. Sea level changes in millimeters from October 1992 to July 2009 rec...](#)

[Figure 6.18. Impact of CO2 emissions on the ocean in 2100 \(Gattuso and Magnan 20...](#)

Chapter 7

[Figure 7.1. The Gulf Stream according to Benjamin Franklin \(1785\). In London, in...](#)

[Figure 7.2. General surface circulation of the planetary ocean \(© L'océan planét...](#)

[Figure 7.3. The large-scale global ocean biogeochemical provinces; from monthly ...](#)

[Figure 7.4. Operating diagram of the Jason oceanography satellite \(© Eumetsat\). ...](#)

[Figure 7.5. Modis operational diagram for measuring the optical properties of th...](#)

[Figure 7.6. Operation of an underwater glider; other time cycles and routes are ...](#)

[Figure 7.7. Oceanographic animals in the Southern Ocean \(Della Pena et al. 2015\)...](#)

[Figure 7.8. High-resolution global ocean: surface currents from the global simul...](#)

[Figure 7.9. The Agulhas Current along the east coast of South Africa at high res...](#)

[Figure 7.10. Steps of energy dissipation in the ocean, from global forcing to mi...](#)

[Figure 7.11. Example of a surface front separating two water bodies of different...](#)

[Figure 7.12. Simulation of phytoplankton in the global ocean at high resolution ...](#)

[Figure 7.13. Mesoscale eddies are oases; comparison of acoustic, satellite and b...](#)

[Figure 7.14. Impacts of mesoscale circulation on phytoplankton and, beyond, inte...](#)

[Figure 7.15. The alpha diversity of phytoplankton is higher at the fronts \(solid...](#)

[Figure 7.16. Ocean general circulation model: downscaling example: \(a\) surface t...](#)

Chapter 8

[Figure 8.1. Global fisheries and aquaculture developments since the mid-20th Cen...](#)

[Figure 8.2. Geographical and in-depth expansion of fisheries; in dotted lines, t...](#)

[Figure 8.3. Daniel Pauly](#)

[Figure 8.4. Ecosystem components and interactions involved in the ecosystem appr...](#)

[Figure 8.5. Maritime areas defined by UNCLOS](#)

[Figure 8.6. Benguela Current fishing areas concerned by an EAFM project currentl...](#)

[Figure 8.7. Upwelling ecosystem in Peru. This 3D structure defines the upwelling...](#)

[Figure 8.8. Location of the main nodule fields and encrusted areas as well as th...](#)

[Figure 8.9. Major element composition \(percentage by weight\) in deep sea mineral...](#)

[Figure 8.10. Ore extractor robot of the international consortium Nautilus capabl...](#)

[Figure 8.11. Diagram showing potential impacts of an idealized underwater mining...](#)

[Figure 8.12. The ocean floor is home to a mosaic of habitats \(© Ifremer, except ...](#)

[Figure 8.13. Mining on the ocean floor involving the lift of minerals without di...](#)

[Figure 8.14. Zones of massive metal sulfide deposits at the mid-Atlantic ridge i...](#)

[Figure 8.15. Variations in atmospheric temperature and CO₂ content from glacial ...](#)

[Figure 8.16. Distribution of the average annual chlorophyll a content at the oce...](#)

[Figure 8.17. Schematic representation of John Martin's iron hypothesis \(© Carrin...](#)

[Figure 8.18. Deposits of lithogenic dust \(g·m⁻²·y⁻¹\) into the oceans, originatin...](#)

[Figure 8.19. John Martin, sketch by Philippe Pondaven](#)

[Figure 8.20. Iron fertilization of the Southern Ocean \(south of Australia\) durin...](#)

[Figure 8.21. Large blooms \(annual average chlorophyll content\) in meso- and subm...](#)

List of Tables

Chapter 4

[Table 4.1. Historical “sea color” sensors](#)

[Table 4.2. “Sea color” sensors in use](#)

[Table 4.3. Phytoplankton size classes](#)

Chapter 5

Table 5.1. Microbial metabolism detected or possible in deep hydrothermal sites

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Introduction

Published in the new *Sciences* encyclopedia launched in 2020 by ISTE Ltd, this book aims to introduce readers to key themes in oceanography and marine ecology by focusing on how concepts are evolving. First, we briefly recall (see [Chapter 1](#)) some elements of the history of oceanography, the birth of which is conventionally dated by the expedition of the British ship *Challenger* (1872-1876). The main concern of ocean physicists at that time was to understand ocean circulation and characterize ocean water masses at the basin scale and then, through major international programs, at the scale of the global ocean. With the creation of new tools, physical oceanography has gradually evolved toward describing and modeling ocean variability at different scales and studying its interactions with the atmosphere within a context of climate change (see [Chapter 2](#)). Chemical oceanography, also born with the voyage of the *Challenger*, after a phase dominated by analytical chemistry for the determination of seawater elements and their stoichiometry, has evolved toward biogeochemistry through the development of concepts at the interface between physics, chemistry, biology and geology to understand the relationships between nutrients and major ocean cycles in relation to the atmosphere (see [Chapter 3](#)). Biological oceanography, which originated in the 19th Century in marine stations in the coastal environment, has spread to the wider ocean, developing concepts in marine ecology, in particular to explain how pelagic biomes work. The impact of the genomic approach is overturning traditional concepts in marine biology, particularly with regard to biodiversity and functions often expressed at the cellular level (see [Chapter 4](#)). About 2.4 billion years ago, the composition of the two fluid envelopes

of planet Earth underwent a drastic change, with the “great oxidation event”, leading to significant changes in ocean chemistry that had previously been displaced toward lower oxidation/reduction “redox” potentials, typical of anoxic environments. The *Challenger* expedition had dealt a final blow to the idea of an abiotic ocean beyond the first 500 m. In the 20th Century, one of the major discoveries was that of hydrothermal oases in ocean ridges, showing that anoxia could go hand in hand with the production of organic matter by chemosynthesis (see [Chapter 5](#)).

While the *Challenger* expedition marked the birth of oceanography, this discipline has experienced, since the 1960s, a real “golden age” on a global scale with the massive recruitment of researchers, the launch of dedicated vessels and underwater vehicles, the emergence of international programs, technical revolutions (bathythermograph, automatic nutrient salt analyzers, instrumented buoys, chromatography for pigment analysis, etc.), the satellite revolution concerning a growing number of parameters and an increasingly interdisciplinary approach. The time is therefore right to combine these advances.

The last three chapters of this book go beyond the traditional routes of oceanography works. First, they attempt, through an interdisciplinary approach, to anticipate the future of a warmer, more acidified and less oxygenated ocean in the context of climate change. This is due to anthropogenic emissions of greenhouse gases, in particular carbon dioxide, more than a quarter of which is captured in the ocean, but at the cost of changing the chemical balance of carbonates (see [Chapter 6](#)). They then show how our ability to observe the ocean, not only on a large scale but also on a small scale, changes our understanding of the processes that control its functioning, physically, chemically and biologically (see [Chapter 7](#)).

Finally, we present (see [Chapter 8](#)) three challenges the oceans face in the 21st Century:

- Can we exploit biological resources within the framework of sustainable development?
- Is the exploitation of its deep mining resources compatible with respect for the biodiversity of the seabed?
- Should the ocean be manipulated to better regulate climate change?

1

The *Challenger* Expedition: The Birth of Oceanography

1.1. The *Challenger* cruise (1872-1876)

It is to Great Britain's credit that the first major oceanographic expeditions were organized, thus confirming its undeniable supremacy over the oceans (*Rule, Britannia!*).

One name came to be highly recognized at the end of the 19th Century, the English naturalist Charles Wyville Thomson (see [Box 1.1](#)). For many (Deacon 2001), the circumnavigation of the HMS *Challenger* he commanded between 1872 and 1876 marked "Year 1" of offshore oceanography. This multidisciplinary expedition sponsored by the Royal Society of London is the most expensive ever undertaken, at a cost of about 10 million pounds today.

It is true that Great Britain was at the height of its maritime domination and could not bear the idea of the United States, Germany or Sweden taking the lead. Let us examine the contributions of this circumnavigation of 68,916 miles across all oceans to the far reaches of the Southern Ocean using sails for transit and the steam engine at stations, especially for dredging.

This expedition with precise objectives (Corfield 2003) was out of the ordinary due to the meticulous preparation of the ship. Eighteen months were needed to select the old, 70-m, three-masted warship, set up laboratories and housing, winches and oceanographic equipment to study the

distribution of pelagic fauna, collect organisms living at depth, multiply bathymetric measurements and take water samples at all depths.

Box 1.1. Charles Wyville Thomson and John Murray

The two major players in the *Challenger* cruise

The English naturalist Charles Wyville Thomson (1830–1882, Linlithgow), fascinated by crinoids, true living fossils, confirmed that life is abundant and diversified up to a depth of at least 4,500 m and that there is a deep ocean circulation. He published his results in *The Depths of the Sea* (1873), the first book dealing with the great depths, which made him the true founder of modern oceanography. He was entrusted by the British navy with the direction of the *Challenger* cruise and was knighted upon his return in 1876.



Figure 1.1. *Sir John Murray* (©NOAA Ocean exploration and research)

John Murray (1841, Cobourg-1914, Kirkliston) (see [Figure 1.1](#)), a man capable of all during this cruise, was responsible for the publication, at the British government's expense, of the 50 volumes published between 1880 and 1895. With quite a bit of humor, Murray wrote in the introduction: "Our knowledge of the ocean was, in the strict sense, superficial." In 1912, he published with the Norwegian Johan Hjort *The Depths of the Ocean* (1912), whose first chapter summarizes the history of oceanography from its origins. He was also knighted in 1898.

This mission was considered exceptional due to its significant number of staff. When the *Challenger* left Portsmouth on December 21, 1872, it had 243 officers, crew and scientists on board.

The head of the mission, Scotsman Wyville Thomson, was not in good health and returned exhausted from this journey. John Murray, another Scot, in charge of studying deep sediments, was a skillful and vigorous man. The Scot John Buchanan, a chemist, irascible and pretentious, was the genius of DIY and invention. Henry Moseley, a true naturalist, also an astronomer, was assisted by the German Rudolph von Willemoes-Suhm, who died during one of the first stops. John Wild was the expedition's secretary and artist.

The monotony of the soundings and dredgings (see [Figure 1.2](#)) during the *Challenger's* journey (see [Figure 1.3](#)) led to a number of defections by the crew: about 60 abandoned the voyage and about 10 died.

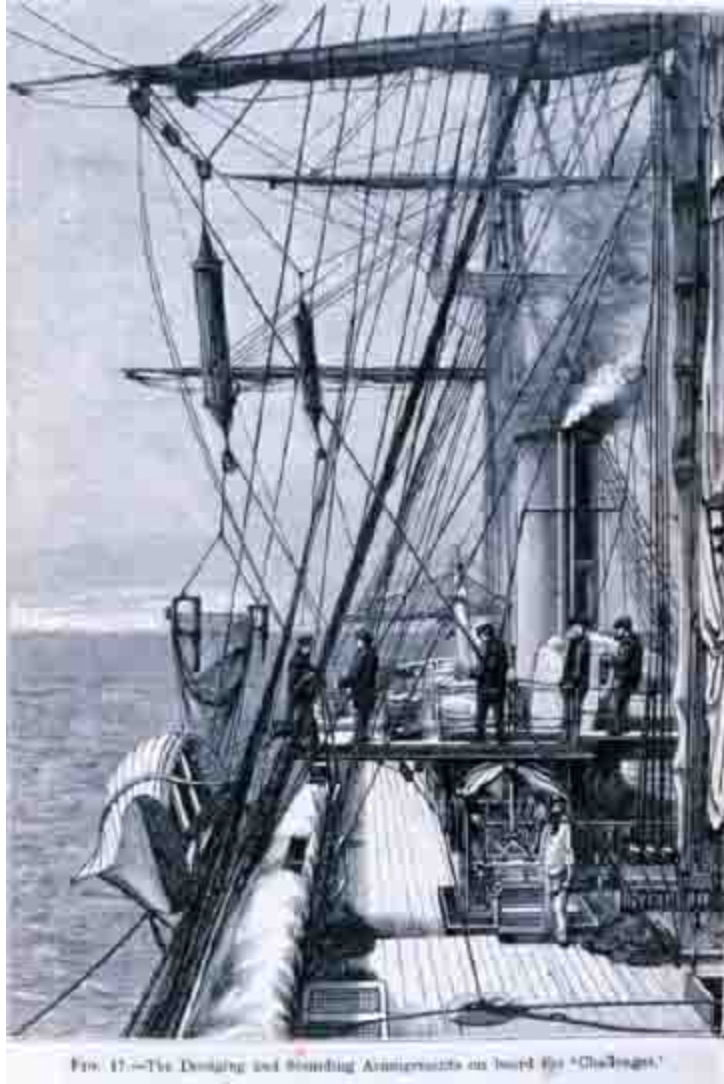


FIG. 17.—The Dredging and Sounding Arrangements on board the "Challenger."

Figure 1.2. *Dredging and sounding on board the HMS Challenger (©NOAA Ocean exploration and research)*

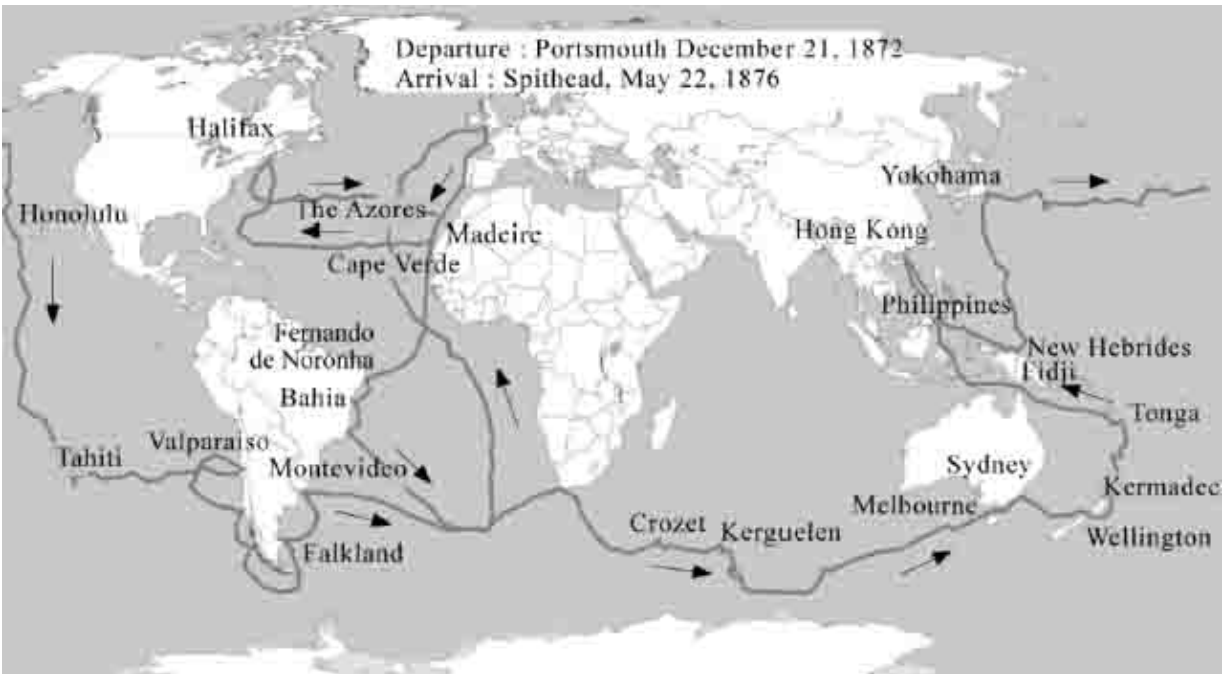


Figure 1.3. *“Around the world” trip of the Challenger between December 21, 1872 and May 24, 1876*

Still out of the ordinary, the 713 days at sea allowed 362 “stations”: determination of depth, meteorological conditions, direction and speed of the surface current, sampling of the surface layer of the sediment, sampling of bottom water and measurement of its temperature. In addition to most stations, plankton sampling by hauls of net and bottom dredging and trawling with beam trawls were carried out.

This expedition marked the beginning of oceanography because of its major contributions to ocean knowledge:

- 1) It definitively put an end to the theory of the British naturalist Edward Forbes (1843) who had stated that there could be no life beyond 400 m. Certainly, as early as 1861, the rise of a telegraph cable immersed 1,800 m at the bottom of the Mediterranean on which solitary corals had settled had already eroded this hypothesis (not to mention the forgotten work of the pharmacist

and naturalist from Nice Antoine Risso in *Histoire naturelle des crustacés des environs de Nice*, published in 1816);

2) Of the 7,000 species harvested, about 1,500 were new; showing the richness and diversity of the deep environment, which Thomson (1873) translated into these terms:

It is inhabited by a fauna more rich and varied on account of the enormous extent of the area, and with organisms in many cases apparently even more elaborately and delicately formed and more exquisitely beautiful, in their soft shades of coloring and the rainbow tints of their wonderful phosphorescence, than the fauna of the well-known belt of shallow water.

3) It specified the topography of the seabed showing a depth of more than 8,183 m in the Mariana trench (the *Challenger* did not have a longer cable!) and highlighted the mid-Atlantic ridge, thus preparing the way for Alfred Wegener's (1912) continental drift theory;

4) It showed that sediments were formed from pelagic organisms: globigerin, diatomaceous earth, pteropod and red mud from the deep sea;

5) It brilliantly confirmed the constancy of the relative proportions of the various salts contained in seawater, having been previously observed in 1819 by the Swiss Alexandre Marcet and, in 1855, by the American Matthew Fontaine Maury. We will elaborate on this at the beginning of [Chapter 3](#).

Carpenter's hope to discover the mechanisms of ocean circulation was not materializing, despite valuable information gathered on vertical profiles of temperature, salinity and density, including confirmation that cold waters