SCIENCES

OCEANOGRAPHY AND MARINE ECOLOGY

Oceans

Evolving Concepts

Guy Jacques
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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.

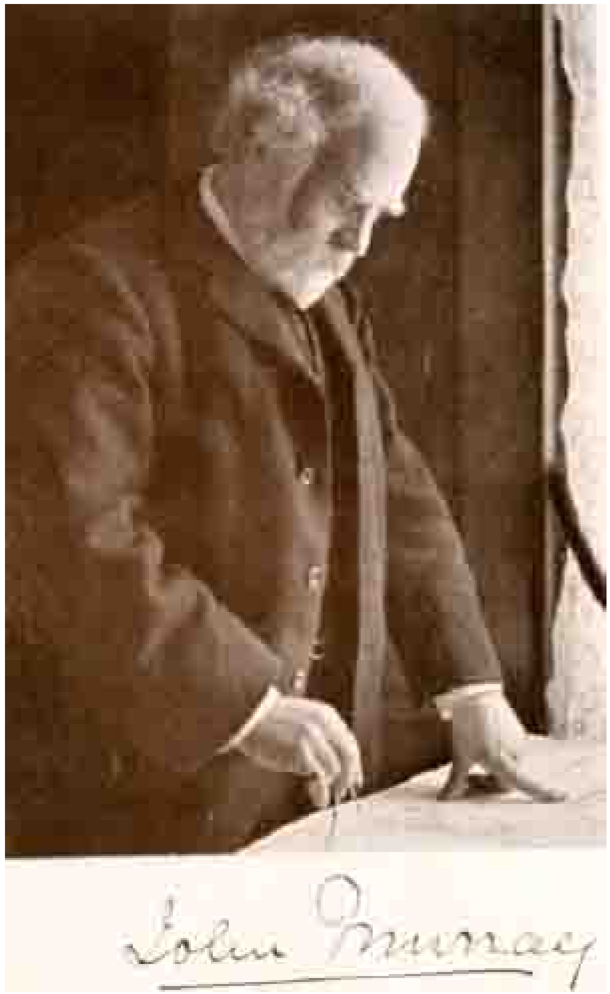

Figure 1.1. *Sir John Murray (©NOAA Ocean exploration and research)*

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.

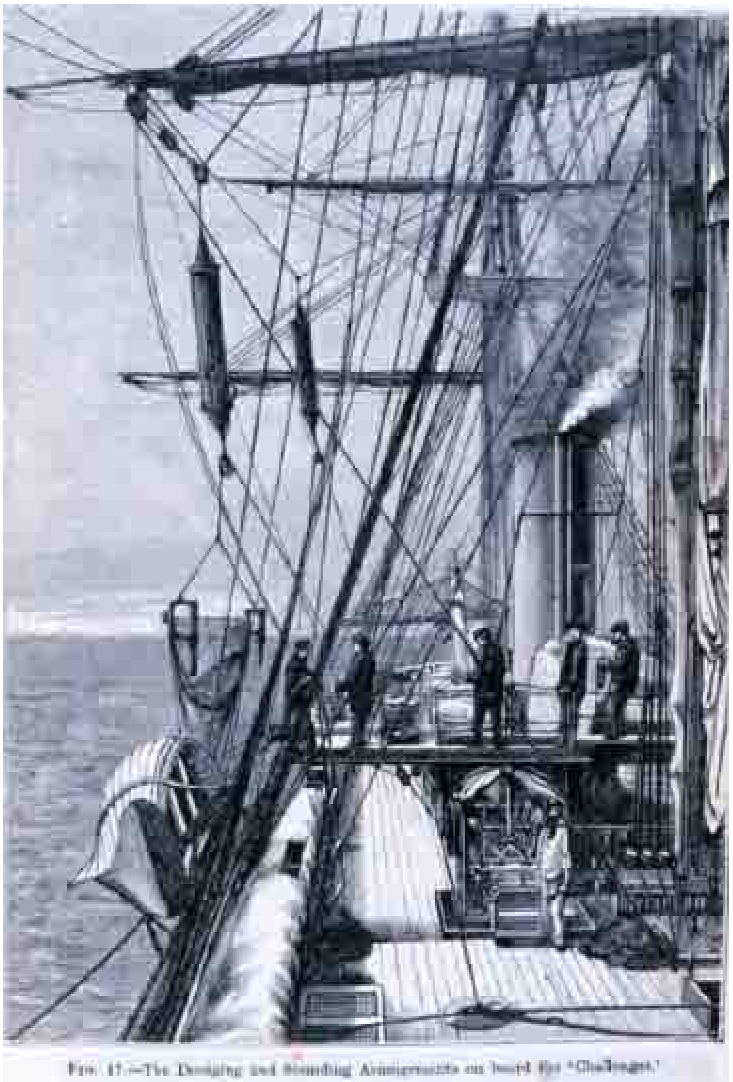

Figure 1.2. *Dredging and sounding on board the HMS* Challenger *(©NOAA Ocean exploration and research)*

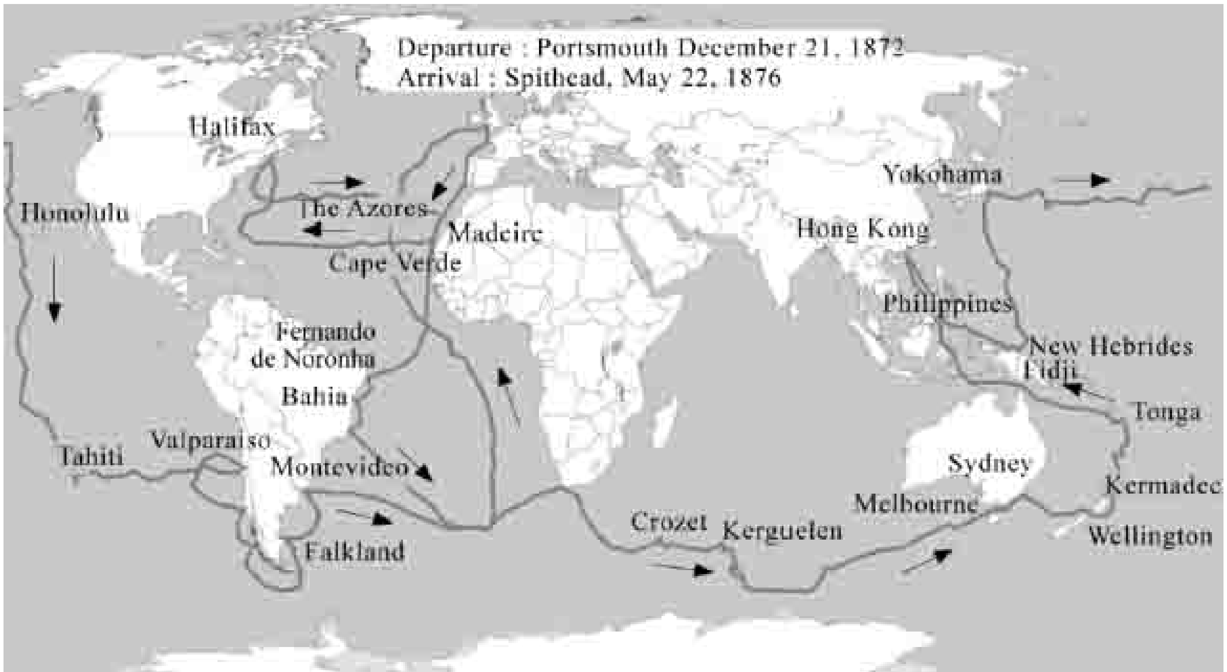

Figure 1.3. *"Around the world" trip of the* Challenger *between December 21, 1872 and May 24, 1876*

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