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The Sea

Melvyn Bragg : Hello.. In 1870, when Jules Verne described the deep ocean in 2000 *leagues sunder the sea* he wrote "The sea is an immense desert, where man is never alone, for he feels life quivering around him on every side". This fiction was actually rather closer to the truth than the science of the time, when the Azoic theory held sway and it was believed that nothing could exist below 600m. Now we estimate, there are more species in the deep ocean than in the rest of the planet put together. Somewhere between 2 million and a 100 million species of organism are living on the ocean floor. Science has dispelled the old idea that huge underground tunnels join our oceans together, and the even older notion that giant Krakens lurk in the deep, but our seas still retain much of their mystery, and there's been more men on the surface of the moon, than at the bottom of the ocean, so how should be understand the sea?"The lonely sea and the sky".

With me to discuss the science that's attempted to plummet, is the historian of oceanography, Margaret Deakin, until recently visiting research fellow at Southampton Oceanography Centre, and author of "Scientists and the Sea". Also with us is Tony Rice, Biological Oceanographer, and Simon Scheffer, Reader in History and Philosophy of Science at the University of Cambridge and a fellow of Darwin College.

Simon Scheffer the Royal Society was set up to investigate questions of science under Charles II patronage in 1620. How important a part of that society's business was it to understand the sea?

Simon Scheffer : I think the sea plays an enormously significant role in the work of the early Royal Society right through from its foundation in the middle of the 17th century to the end of the 17th century, and one obvious reason for that is just how important maritime affairs were for the welfare of the kingdom. So that if you look at what fellows of the Royal Society were doing, their interests ranged right across military, commercial and what we might now more properly call scientific interests. The movements of fish, of tides, of how to improve navigation, how to design ships better. One fellow of the Royal Society even proposed building catamarans, because they sailed better even in the English Channel and he named one of these catamarans "HMS Experiment" in honour of the link between the navy and science.
What's interesting too, is the way in which the work of the early fellows of the Royal Society played such an important role in what I suppose we could call their advertising campaign. Fellows could point to improvements in navigation and mapping as palpable examples of how the cultivation of natural knowledge could actual aid commerce and war.

Melvyn Bragg : So there's a very early example, or quite an early example, and a very effective one at the start or or so it seemed to be, of the establishment getting in, and for practical reasons which are based on commerce and military reasons, actually finding that science was a handmaiden and an enabler, that conjunction, because James I, sorry James II was deeply interested in matters of the sea...

Simon Scheffer : ....wasn't immediately obvious in the 17th century whether or not all these schemes would actually pay off . There was already an enormous amount of practical experience and law in how better to sail ships, how better to navigate, how the tides move. There's also a sense then of natural philosophers and astronomers catching up with what practical folk already knew, and I think also that's an important theme in the history of marine science. Sailor's and fisherman know more and better than self styled experts and one of the keys to the history of marine science is how better to ally different kinds of expertise together.

Melvyn Bragg : But it's still interesting -just to pursue this point - that for commercial and military reasons, science was driven, and in a sense one can say using the 1066, it was a "good end" really wasn't it?

Simon Scheffer : Yes, I..that's surely right. I mean it's been argued by some historians of Oceanography that Oceanography almost of all sciences has been most closely allied to the interests and patronage of the state, and I think that's a very interesting point.

Melvyn Bragg : Margaret Deakin, what kind of assumptions about the sea was the Royal Society trying to challenge or supplement, or what gap did it discover?

Margaret Deakin : Well there was very little in scientific literature, when they began their experiments and observations. Simon said, they learnt from seafarers, and some of their early research programmes are based on suggestions made by navigators. For example, the very interesting question of was there a current in the strait of Gibraltar?
It has been known for a very long time that there is a perpetual current from the Atlantic into the Mediterranean and also a lot of rivers flow into the Mediterranean through the Black Sea and the Nile, and there was no visible outflow, so where did all this water go?I mean this was a very interesting philosophical question which had been described and attacked for a long time but not in a particularly scientific way.

A lot of speculations about - a lot of these debates go back to the middle ages and quite possibly beyond, and another thing that they learnt was that sailors - and this was the practical people - had discovered, or thought they had discovered - and had evidence for the existence of an undercurrent which was actually carrying water out of the Mediterranean, but the scientists didn't like this idea, they thought "no we can't explain an undercurrent - it's against nature" - there must be other explanations, you know, perhaps it's evaporation by the sun - it's in a hot part of the world, so that perhaps the excess water disappears that way, or perhaps it disappears through one of these tunnels in the floor that you were referring to earlier.

Melvyn Bragg : Simon suggested and so did you and as I've read for this programme that there was that there was - as we all would all say - from Ulysses onwards, or even before Ulysses, local law intensely known by people whose lives as well as livelihoods depended on knowing what the currents were around the coasts where they fished or where they set off for war, and that sort of thing, that must have been intense local knowledge, one must imagine very accurate indeed. Now was there a sense in which the Royal Society acknowledged that and collected that?

Margaret Deakin : Well how they went about it, was not so much in this particular area to collect existing law, they also went back to ideas that they could find in the classical texts and people like Aristotle, there are...were assumptions about for example, what causes the sea to be salt, and so they were looking at these ideas, they were trying to collect information but how they did this was to actually prepare questionnaires, and they did this for travellers generally going to different countries, so that they could get information about the countries, about their politics, their natural resources and customs, and they also did it for the sea and they issued these to travellers who were going to different places by ship, people who were leading naval expeditions, they were particularly interested as Simon said, in tides, so they would encourage individual members or the wider scientific community, people who weren't necessarily FRS's, but who were interested in this new movement.

Melvyn Bragg : I've got to bring in Tony Rice or people won't think he's here at all! (laughter) We'll come back to that if I may. Why do you think the sea seems to be very important- as Simon Scheffer said at the top of the programme, for the enlightenment mindset if we can use that word? What...can we just rummage around that a little bit more?

Tony Rice : Yeah, well, not being an expert on the 17th century, I have to be pretty careful here, but on the other hand, I think one of the things that Simon said, this business of the sort of juxtaposition of commercial interests with scientific interests, is an interesting one.
My impression was that one of the things which prompted some of the early fellows of the Royal Society to be particularly interested in the sea was that the study of such phenomena as tides would actually help them to understand cosmology, understand the system as a whole, not just our system, so that was another reason that was very valid. Coming back to your point about the use of amateurs if you like, that's not past, that's still going on today, and certainly was very important in the middle years of last century, in understanding - certainly shallow water, I'm not talking about the deep sea now - but understanding for example, aspects of fisheries which are extremely important and always have been. So the knowledge people who earn of people who earn their living in that medium but not as scientists, is still - and I suspect always will be - extremely important.

Melvyn Bragg : Can we just talk Simon, about the importance of tides...

Simon Scheffer : Yes.

Melvyn Bragg : ...which were obviously ...why do you think they were so important? And one of the things that was so amusing is that when Newton's great book came out *Principia Mathematica*, probably the thing they were

most excited about, is that it might give them the solution to tides - it didn't give them the solution they wanted - but it might do that, but why was...can you say why *they* thought it was so important in the Royal Society?

Simon Scheffer : Yes, I think it's absolutely true, tides matter to the cosmos. It wasn't obvious to everybody in the 17th century that that was true. So that for example, when Galileo in the start of the 17th century, that some people already had that the moon might be causing the tides, Galileo thought that was old fashioned astrology and completely rejected the idea, because it looked like magic.

So the cosmic significance of the motion of all the seas on the Earth was absolutely obvious already in the 17th century, and what Newton proposes as a research project to himself, is can one show how the behaviour of the globe would be if it was entirely covered in water, Newton understood pretty well that it was rather unfortunate that not all the Earth was covered with water, and therefore it was much more difficult to do the calculations, or at least to match his theory of universal gravitation to the **actual** behaviour of the tides, themselves.

Newton, of course never saw the sea, he was from Lincolnshire, he went to college in Cambridge, he lived in London, he was never on an ocean going vessel, and he was probably never on the beach, despite the famous remark about picking up pebbles. And it's a demonstration in that sense of the power of analytical mechanics and mathematics, to say useful and important things. But the most important thing about Newton's theory of the tides is that it shows so well the problems of trusting other folks data. There are some phenomena that Newton's tidal theory seeks to explain which aren't actually phenomena at all, but which were widely reported stories in London taverns, presumably that Newton incorporated into his theory.

Melvyn Bragg : That would be - such as?

Simon Scheffer : Well, for example the extraordinary behaviour of the sea around the straits Magellan, which was widely exaggerated, that's the straits at the Southern end of South America, which was widely exaggerated - travellers tales? So that Newton quite often was forced to derive numbers where the numbers were being given to him by folk that maybe he shouldn't have trusted.

Melvyn Bragg : In this development Margaret Deakin, the idea of *longitude* has been well discussed in this country over the last 2-3 years, because of the very successful book on the subject and Harrison's invention. But that..we can't not refer to it, so briefly how did that invention of that sea going chronometer affect oceanography?

Margaret Deakin : Well there were two methods of measuring longitude, there was the lunar distance one, which really sort of came pretty well at the same time, and then chronometers were more successful and easier, and these methods were first used widely by Captain Cook, who is the name most associated with the development. There was a whole range of circumstances, it's wasn't just longitude. Put in crude terms, before the middle of the 18th century, Cook's voyages, which came in the latter part of that century, any voyage encountered an enormous range of hazards, and part of them were to do with navigation that you - literally, once you were out of sight of land, didn't know where you were, because you couldn't measure time accurately on a ship, and the astronomical methods were fine so long as you were sailing along latitudes, going west-east, or east-west, but north-south, sorry - other way round, north-south it was okay, you could measure the altitude of stars, some things like that. East-west it was very difficult. Terrible things happened in the Indian Ocean and the Atlantic, you know sort of ships..whole fleets were wrecked. In the Pacific, which is a huge ocean with very little in the way of natural features, tiny islands, which if your navigation isn't spot on you may sail right past without seeing, because they're low in the water.

So you get these early 18th century expeditions both naval and exploratory, suffering terrible hazards of starvation, illnesses caused by nutritional deficiencies of which scurvy was only one, though possibly the worst. So going to sea was a very hazardous enterprise and people were really I think sort of concentrating on getting to where they wanted to go and staying alive, and they didn't really have much sort of aptitude or wish to do science, but the latter part of the century it's become what I think's been referred to as you know, the whole thing changed, you could see where you where you were going, you could plan where you were going, they began to solve, in a pragmatic rather than an understanding way, the problems related to nutrition so that Cook lost men on his first voyage in the East Indies, but had virtually no problem with scurvy at all. He didn't understand as we do today, what the real causes were, but he just took every eventuality to protect his men, it worked. So you had people now, with the leisure and the energy to collect scientific information, and of course on his first voyage he took Sir Joseph Banks who's an

enormously important figure in this respect, it's been called possibly the beginning of the grand tour of the Pacific, rather as the grand tour of the countries of Europe that the noble and wealthy youngsters would take during the 18th century.

Melvyn Bragg : But this brings biology in after geography doesn't it really? We're bringing specimens back and we're looking at plant life of not only the sea, but other places in the world, in this case the south seas and the search for breadfruit, and all that sort of thing and all that sort of thing, so it brings about....in the 19th century Tony Rice, with this unrivalled navy we had after the Napoleonic wars, in a sense almost partly to do with giving them something to do....

Tony Rice : Absolutely.

Melvyn Bragg : ...away they went on various expeditions, and the polar explorations were very important and as Margaret indicated we begin to switch from commerce and geography to biology as well. Can you just tell us what -before we come to challenge it - what was happening in the 19th century- what the navy was finding out?

Tony Rice : Well, first of all go back to the last half of the 18th century, as Margaret pointed out - the problems of navigation, by the time you get to Cook, are now more or less solved and as a result by the end of that century the broad outline of the Earth was pretty well known.
Remember that one of Cook's objectives for example was to search for what was called *Terra Incognita*, there was thought to be an enormous land mass at the southern half of the Earth to balance the enormous land mass that we all lived on in the north. Of course it wasn't there - there was this other rather sterile or difficult land mass Antarctica. Anyway by the end of the century, and by the end of the Napoleonic wars that was pretty well worked out. what wasn't known was a good deal about the interior of some of the continents, consequently the first intention was to use the unemployed navy, would you believe, to investigate Africa. An attempt was made sailing up the Congo or the river Zaire, to find out what the situation with the great rivers like the Niger and the Nile in the interior of Africa were, that was 1815, actually just before the war ended. It was a total and utter disaster, almost everybody died. So Sir John Barrow, the secretary to the Admiralty, whose responsibility basically was to convince the government not to sack all his officers thought of another rouse, and the rouse was "Let's go to the poles" and "Let's look..." introducing commerce again "Let's first look for the old Northwest passage", which of course had been an objective 200 years before with Hudson and Baffin and people like that. Never found it. Of course we still haven't got one, but that was what was the first expedition in 1818 after.

Melvyn Bragg : Simon Scheffer what happened in the 1870s was this great voyage of the Challenger. Now it's been compared to the space probes, it lasted 5 years, 68, 000 nautical miles, goodness knows how many station stops and so on. It was massive and unprecedented and the consequences I believe are still with us. It was a magnificent enterprise.
Can you just give some...give people the size of that and the scope of that and why it's important?

Simon Scheffer : I think it's quite difficult for us to think back to just how much this mattered, this great clearly scientific voyage - that's the first point.

Melvyn Bragg : 1870....2 to 7 yeah?

Simon Scheffer : 1872 to....

Tony Rice : 6.

Simon Scheffer : 6. It's... one of the things that I think really does need emphasis is that it's a dedicated voyage, that is to say naval resources are being used not mainly, but almost solely for putatively scientific ends, and that speaks to the rapidly emerging power of what can only be called the science lobby in high Victorian England, men like Thomas Henry Huxley, Darwin's bulldog, professor in London, brilliant physiologist, himself the veteran of a naval voyage into the south seas on HMS Rattlesnake back in the 1840s. He and his allies understood extremely well that the navy was likely to be interested in many of the data that marine science could produce. It would help with navigation and oceanographic mapping, but at the same time, they also understood extremely well as great scientists do, that one has to think up very good reasons for spending so much money over such a long period. The

point about science being that it's not just the finding, but the publishing that always matters, and the Challenger voyage and all the samples that it collected and all the maps that it made occupy more than 4 dozen large volumes. It took another 30-40 years of work after the voyage fully to compile analyse and catalogue all the results on marine organisms, tides and winds, and currents that they found and perhaps the most important thing is that it helped forge a genuinely international community of experts interested in marine science. It's really a whole project that begins to see the internationalisation of a genuine community of real science.

Tony Rice : And remember that was ...the idea of giving the data...the specimens to foreigners at the time, went down like a lead balloon with the British scientific establishment, they didn't want to, this was British material, collected by a British naval ship and belonged to us. It was Sir John Murray who would've ultimately supervised the publication of the results, who took this stand. But going back also to the origins of the voyage, the voyage cost altogether about £200, 000 at the time, that's big money, something like £20 million now, certainly compared with space research - small - but it's reckoned to be the first example of big science, it would not have taken place if science had been the only excuse for it. It was also because the navy - the hydrographic office, was being asked for more and more about the nature of the bottom of the sea, particularly in relation to the new technology of submarine telegraph cable laying, that's what drove it in the end. Cables were being laid across the Atlantic at great expense, and the last thing they wanted to do was for them all to break because we didn't know what the bottom was like.

Melvyn Bragg : Is it too panglossian to say this was..the Challenger was a very good example of something which brought prestige to this country, brought it great scientific knowledge and empowered it in straightforward ways, like we knew better how to lay cables, we knew more about oceans currents so our ships could.....is that...do those three things come together, d'you think Tony?

Tony Rice : Absolutely, but do remember one of the things that Simon said was that Challenger was also at the beginning of really international science, in fact one of the scientists on the Challenger was a man called Rudolf Von Willamasoon (?) a German. He actually died during the voyage would you believe of Erasiphilus - which is now a sort of disease restricted to pigs I understand - but anyway - he was brought aboard as one of the scientists and this was the first time that an international complexion to big scientific project had taken place. So yes, the Challenger did bring back a great deal of information and prestige to the UK, but it also brought that knowledge to the international community, because remember that....

Melvyn Bragg : Why didn't we keep it for ourselves, and sort of get ahead..would be the churlish, churlish...I mean I don't know who would say that sort of thing....

Tony Rice : Perish the thought! I can't imagine either.

Melvyn Bragg : ...but why didn't we?

Tony Rice : Well we didn't because the people involved, some of the big names involved were thinking bigger than that. There were a lot of small minds who wanted...

Melvyn Bragg : (mumbles)

Tony Rice : Sorry?

Melvyn Bragg : Nevermind!

Tony Rice : (laughs) So we didn't, and thank the lord we didn't because within 20 years of the end of the Challenger expedition things were happening on a much broader international scale with the International Council of the Seas which became a very important element in the understanding of things like fisheries and so on.

Melvyn Bragg : In the last few minutes I want to talk about the very....the bottom of the ocean, there's some 11, 000 metres below the surface of the Atlantic ocean, that's supposed to be the deepest, a couple of people have only been there once. But there is a bottom of the ocean, a bit more if it's....less of it's 11, 000 metres. Nevertheless the interesting thing about the bottom of the ocean is that so much is going on, when it seems from what we had

known until we discovered that so much was going on that nothing should be going on at all! (Tony laughs). Now can you unravel that in a sensible way, Simon Scheffer please?

Simon Scheffer : I think there's, as you've said, and as we've said right through the conversation, there are two different prejudices going on here, I mean one is the thought is that everyone must have that deep in the ocean it's cold and dark and therefore lifeless and uninteresting and inert. One might call that the telegrapher's dream, because if that's true then laying deep sea cables on the ocean floor should be nice and safe.

But there's also I think very widely distributed in our culture, and it becomes extremely important precisely in the period of the Challenger, the idea of the ocean as warm soup. So that the coming of Darwinism in the middle of the 19th century, with spokesmen for Darwinism like Huxley, and his German allies, begins to describe the ocean not as cold and inert and lifeless, but as where life comes from. So that for example for Huxley himself he had a very powerfully worked out theory that the slime that could be found right across the ocean floor which he named in honour of his German colleague Ernst Heckle, not entirely politely, is the substance from which all life has evolved. So that at the biological level - one sees this in Jules Verne's stories, one sees this in stories of the Kraken - the ocean floor is a place of unknowable and overwhelming organic activity is perhaps at least as important as the idea of the ocean as inert. And I think what is interesting about current oceanographic models of the ocean floor is the way in which it tends to confirm and celebrate this idea of a vital ocean floor - not only that - but for me with sort of more expertise it has to be said in astronomy than oceanography - the idea that the very extreme conditions one sees on the ocean floor in vents for example, where the water is at extraordinary pressure and one gets volcanic eruptions under sea which produce very high temperatures and very high pressures, that those environments might well sustain a host of organic life forms, and that one could use them to make an interesting analogy with life on other planets. So that one can think precisely of life in extreme conditions on the ocean floor as something like a sign of the fantastic range of environments in which life itself can survive.

Melvyn Bragg : Tony Rice.

Tony Rice : Well I think in a way this brings up...completes the circle in a sense. Simon was just touching on these volcanic eruptions at the bottom of the sea and extreme conditions. How do thermal events - the ones that lots of us have seen pictures on the television of - of these fantastic communities of animals living round water which is gushing out from beneath the surface of the sea floor, at the ridges at 400 degrees centigrade, it doesn't boil at that temperature because of the enormous pressure**.**
Bringing with it a complex of chemicals, it supports communities which don't depend upon the energy from sea light, but depend upon the energy from chemicals, these fantastic areas are thought possibly to be those where life originated. Now these are waters gushing out from tunnels in the bottom of the sea, what did we start talking about, an idea in the 17th century that there might be tunnels in the bottom of the sea. Boy, we know there are.

Melvyn Bragg : Thank you all very much and thanks for listening.