SIR JOHN MURRAY OF THE CHALLENGER EXPEDITION: FOUNDER OF OCEANOGRAPHY
People of the Forth (16)

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Introduction

In 1986 Stirling officials were lobbied to support a campaign to have Sir John Murray commemorated on a Canadian stamp. Few recognized him as the father of oceanography nor were aware of any local connection. Sir John had been born in Canada in 1841 but came to the Bridge of Allan to complete his education at the home of his maternal grandfather, John Macfarlane. It was the grounding he received at The High School of Stirling and as curator of his grandfather's museum that set him on the path to becoming one of the early twentieth century's most distinguished explorer-scientists. In later life he stated "It is always with emotion that I look down the valley of the Forth from Abbey Craig or the terrace at Coney Hill and see stretched before me the scene of my first explorations, my first scientific observations and my first collections".

Murray (Figure 1) together with Sir Wyville Thomson of Linlithgow guided the destiny of the Challenger expedition (1873-76), the greatest oceanographic exploration of all time. By unlocking the secrets hidden beneath two-thirds of the earth's surface the expedition could justifiably claim to have rivalled the great voyages of da Gama, Magellan and Cook in its contribution to our knowledge of the planet. Murray gave us the term oceanography and established Scotland as the international centre of this new science. He also placed the country at the forefront of world limnology (study of lakes). In this he received invaluable help from his life-long friend Laurence Pullar, the owner of the Bridge of Allan and Ashfield dye works. Their bathymetric study of the Scottish lochs would warrant the authors a place in Scottish history in its own right (Duck, 1990).

Although in 1986 there was an embarrassing lack of local recognition of Murray's contribution to science there was no shortage of international acclaim. Indeed his head had already appeared on a Christmas Island stamp (Figure 2). He was awarded knighthoods in Britain, Prussia and Norway. In Britain he won the prestigious gold medal of the Royal Society and the Founder's medal of the Royal Geographical Society, in France the Cuvier Medal, in Germany the Humboldt medal, in America the Cullum medal and in Australia the Clark medal. He was also awarded honorary degrees by the Universities of Edinburgh, Oxford, Harvard, Jena, Geneva, Christiania (Oslo), Toronto and Liverpool. He had named after him: an expedition, a research vessel, a deep sea trench, a bird, a bat, several fish, a spider crab, an octopus and several protozoa. Murray's acquaintances also claimed to recognize him in Conan Doyle's character Professor Challenger of *The Lost World* and much more recently the *Challenger* spacecraft was named after the expedition.

Belatedly in 1987 Stirling Council acknowledged its famous son naming a road in his honour, yet unfortunately there are still few who have heard of him. The purpose of this article is to enhance local recognition. There has been no comprehensive biography of Murray and this general account has been constructed from secondary sources which have specialized in different aspects of his eventful life.

John Murray's Life in Bridge of Allan

Born in Cobourg, Ontario in March 1841, John was the second son of Robert Murray, an accountant and his wife Elizabeth nee Macfarlane, who had emigrated there in 1834. He was probably named after his grandfather John Macfarlane who was born in Stirling in 1785 and who was to play a pivotal role in his later life. John Macfarlane left to work in Glasgow aged 14 and developed a talent for textile design. Between 1817-1845 he lived in Manchester and made his fortune as a major developer in the commercial heart of the city. He retired to Bridge of Allan in 1848 and while living in what is now the Old Manor established a new settlement in the area around Coneyhill at the eastern end of the village. His plans included twelve villas, a terrace of workers' houses, shops and an impressive museum (Allan, 2006). Macfarlane became a local philanthropist giving money towards the building of the High School of Stirling and providing Stirling's first Free Library. According to his obituaries he was also the first to suggest the erection of a monument to Wallace on Abbey Craig.

John Macfarlane was used to getting his way and family accounts suggest that Robert and Elizabeth Murray emigrated because he disapproved of their marriage. We know little of John Murray's early life except that he received schooling in London, Ontario and at Victoria School in Cobourg. It seems that his father died and his grandfather offered to complete his education in Stirling. In 1858 at the age of 17 he crossed the Atlantic to live in Bridge of Allan, joining many other members of his mother's family including two great aunts and Major John Henderson of the Westerton Estate.

It was the reputation of the High School of Stirling for navigation that determined John Murray's presence there. He learned about the principles of the sextant from an inspirational physics teacher Duncan Macdougall. In an address to the High School in 1899 he related how his courses in physics and geology were to be very influential in his subsequent career. Similarly during an interview with Bridge of Allan's *Spa Magazine* (AWD, 1899) he stated "I commenced my geological studies at the 'Bridge' and became enthusiastically interested in the subject through the exhuming of a whale at Cornton and an Irish Elk at Stirling Bridge. I took great delight in washing the clays of the carse for minute organisms and examining the shell beds in the banks of the Allan". He related how he traced the marks of glaciers over the slopes of the Ochils and from all these observations endeavoured to form a mental picture of conditions in the Forth Valley in bygone ages.

It seems that John Macfarlane always had plans for a museum or art gallery

at Coneyhill both to attract new residents to his development and to act as a tourist attraction for the Spa. As his grandson's interest in natural history developed he saw it could provide a curatorial career for him. The recent discovery of John Macfarlane's 1860-3 letter book at the Natural History Museum in London has provided much new information about the establishment of the Macfarlane's Museum of Natural History as it was called. This it turn resulted in a re-evaluation of the importance it played in Murray's path to a distinguished career (Deacon, 1999).

The construction of a three storey museum was started about 1860 on high ground above Coneyhill terrace. Macfarlane had moved with his grandson from the *Old Manor* into *Edgehill House*, one of his new villas just across the road from the Museum. Murray became the curator with responsibility for purchasing, arranging and cataloguing the exhibits. He also provided some of the shells and birds' eggs from his own local collections. Macfarlane was very much the controlling hand being in weekly correspondence with an old Scots friend Thomas Brown a taxidermist and the curator of the Manchester Natural History Museum. To help provide the background in taxonomy and organisation of exhibits Murray was sent to the British Museum (Natural History) in London and the Jardin des Plantes in Paris. Macfarlane was determined that the museum was to be second only to the British Museum in its collections of quadrupeds, shells and birds. To this end examples of stuffed lions, tigers, leopards, giraffes, elephants, kangaroos, hippos, llamas, flying squirrels, alligators, crocodiles, armadillos etc. were collected. Malcolm Allan's recent entertaining account gives much more detail of the project (Allan, 2006).

At the age of nineteen Murray established a lifelong friendship with Laurence Pullar who eventually lived round the corner at *The Lea*, Kenilworth Road. Pullar had moved to Bridge of Allan from the family company's base in Perth in 1858. As a mechanic he arrived to help his brother John rescue the Bridge of Allan and Ashfield dyeing works which were threatened with closure. After twelve years "unremitting toil" the business proved very successful and Laurence became a wealthy co-owner. Pullar (1910) relates that "during the whole of the sixties there was hardly an evening when he and Murray did not meet for reading and the study of science". It was not all study though and Pullar was the president of Airthrey Spa Bowling Club from 1860-66 and Murray a champion bowler.

At the age of 77 Macfarlane's health began to fail and he found difficulty coping with his youthful grandson. As a consequence John moved to stay with Elizabeth Macfarlane his great aunt who lived next door at *Upperhill House*. Pullar (1910) relates that Murray was "tired of his want of a definite occupation and enrolled at Edinburgh University in 1863 where he studied medicine amongst other things." This only lasted a few terms because "his grandfather objected to his proceeding further with these studies". In his will of 1865 John Macfarlane set out a settlement for his grandson which he thought would provide him with a career and ensure the prosperity of the Macfarlane Museum. Firstly it required John to adopt the surname Murray-Macfarlane.

Then the will's trustees were *Directed to appoint John Murray to be curator of my Museum of Natural History declaring that the said John Murray shall be under their control and be obliged to perform any instructions given by them.* The trustees were charged with visiting the museum to check *that he has been in attendance every lawful day from ten o'clock until six o'clock in the evening*. For this John was to be paid £100 per annum and *Centrehill House*, Coneyhill was to be made over to him together with £150 to furnish it.

Most of Macfarlane's estate was left in trust to run and improve the museum. There is no reference in the will to his daughter Elizabeth Murray though his other Canadian grandson James Murray was included together with many other relatives. The will was subject to twelve changes which has made interpretation difficult for the modern Macfarlane Trust administrators. There was clearly disagreement between John and his grandfather and in 1867 codicil 8 cancelled the requirement to adopt the Macfarlane name. Then in a tenth codicil dated 4th September 1867 Macfarlane annulled the entire clause dealing with John Murray, essentially disinheriting him. This was apparently *in consequence of his having intimated to me that the considerable allowances with house etc. etc. as being too inconsiderable and that he could (do) much better in various other ways and that he intends to leave my service in October.* This left his grandfather's plans for the museum in ruins but as events unravelled Murray's prediction was to prove more correct than he probably imagined.

Freed from the constraints of his grandfather's regime the following February Murray shipped as the surgeon on the whaler *Jan Mayen* presumably on the basis of the medical lectures he had attended. They visited Spitzbergen and Jan Mayen Island eventually reaching 81°N. During the seven month trip he kept a log of the meteorology and made one deep-sea sounding at 160 fathoms (293 metres) measuring temperatures and retrieving mud from the sea floor. These were the first of many such measurements he was to make in his future career. Murray's grandfather's health deteriorated and when John returned to Scotland on 30th August 1868 he found his grandfather had died two days previously. He is buried in the Holy Rude cemetery with his father James Macfarlane, a Stirling merchant.

John Murray was later to become one of the Trustees of the Macfarlane's Trust who built the more elegant replacement Museum Hall on Henderson Street (formerly Macfarlane Street) in 1886. Later the old museum was demolished. Murray also mediated the transfer of books from the free library, firstly to the Smith Institute in 1882 and then subsequently to the Macfarlane Room in the Central Public Library in 1905. It was during the first of these transfers that he negotiated for the Stirling *Field Club* to be renamed *Stirling Natural History and Archaeological Society*.

According to Pullar (1910) "All his grandfather's trustees could promise John was a minute annual allowance for a short number of years". However together with his earnings from the whaler this seems to have allowed him to enrol again as a student at Edinburgh University and resume his informal studies. In his own words "I was sometimes known as a chronic student at

Edinburgh. I attended classes in nearly all the faculties but did not go in for exams and never took a degree. Robert Louis Stevenson … with whom I worked in Professor Tait's laboratory used to say I was a wandering star for whom was reserved the blackness of darkness". At this time *RLS* was training to follow in the footsteps of his father and grandfather as an engineer.

During the next three years he lodged as a *student of science* in Edinburgh and experimented with the development of a deep sea electrical resistance thermometer in Professor Tait's laboratory. Weekends in Bridge of Allan were spent either with his great aunt or with Laurence Pullar. Whenever possible Murray and Pullar used to arrange dredging excursions on the Forth to study its marine biology. In 1870 they hired a 14 ton sailing yacht and sailed from Leith through the Caledonian Canal to Eigg and Skye to investigate the region's geology. During the trip they were invited for dinner aboard the yacht of the famous physicist Lord Kelvin who was obviously impressed by Murray's knowledge and later recommended him for the Challenger expedition.

During the fifteen years he was based in Bridge of Allan Murray fortuitously accumulated the skills that were to make him an ideal member of the forthcoming Challenger expedition. He was a proven seaman with practical experience of oceanography and a background in taxonomy and taxidermy. His experience of preserving, packing and transporting biological samples for his grandfather's Museum must also have been invaluable since wherever *Challenger* docked thousands of precious finds had to be sent back safely to London.

Sir Wyville Thomson and the Challenger Expedition

It was Sir Charles Wyville Thomson from Linlithgow who was to have an immense impact on John Murray's life. As a student at Edinburgh University Thomson became interested in marine biology whilst accompanying Prof Edward Forbes on dredging expeditions in the Firth of Forth. Forbes was one of the first oceanographers and is still remembered for propounding the theory that life could not exist in the *Azoic zone* at depths below 300 fathoms. Despite failing to graduate, Thomson progressed to become Professor of Natural History at Belfast where he took up dredging off the coast of Ireland. In 1866 he decided to visit Professor Michael Sars whose son had brought up a remarkable collection of unknown animals from depths of over 300 fathoms in the Lofoten fjords. One of these, *Rhizocrinus lofotensis,* was a stalked crinoid, a group previously known only as fossils. Thomson was impressed and his suggestion that we could be "still living in the Cretaceous epoch" unsettled the geologists.

As a result of his visit to Norway Thomson and the biologist Dr W. Carpenter persuaded the Royal Society to mount an expedition to explore the ocean deeps around the British Isles. The Navy offered their oldest paddle steamer which was rather inappropriately named *HMS Lightning*. They set sail from Oban in August 1868 and dredged down to 600 fathoms near the Faroes finding considerable life there. The next year a more appropriate survey ship

HMS Porcupine was provided and from it living organisms were retrieved from 2435 fathoms, nearly three miles beneath the surface. The presence of sponges, echinoderms, crustaceans and molluscs below 1000 fathoms should have sounded the death knell of the azoic theory though the topic remained controversial for some years. Many of these organisms were unknown and great excitement was generated amongst creationists by Thomson's prediction that deep sea animals identical to tertiary fossils would probably be discovered. As a result of the success of these expeditions Wyville Thomson was made an FRS and appointed Regius Professor of Natural History at Edinburgh.

This was the age of transoceanic telegraph cable-laying a science which in the UK was pioneered by Lord Kelvin in Glasgow. Much to Carpenter's consternation news had come that the United States, Germany and Sweden were all planning oceanographic surveys to aid cable laying. During a lecture at the Royal Institution in 1871 he called on H.M. Government not to let Britain's lead in marine science to go by default and appealed for them to undertake a thorough scientific study of all the oceans. Consent was given and in April 1872 preparations for the three-year circumnavigation of the globe began in earnest. A three masted, square rigged, steam corvette *HMS Challenger* which had been selected for the voyage (Figure 3) was placed under the command of Capt. George Nares from Aberdeen. Most of *Challenger's* guns were removed and she was refitted with laboratories and steam powered winding gear for deep sea trawls. Amongst the equipment stowed on board were 144 miles of rope for making bottom soundings, thermometers constructed to withstand the massive pressures in the ocean deeps, dredges for sampling bottom-living organisms and equipment for analyzing water chemistry. Wyville Thomson was to head the team of six scientists and he employed John Murray as a naturalist.

After an inspection by the Lords of the Admiralty and the Committee of the Royal Society, *Challenger* set sail on 21st December 1872. During the three and a half years she was away *Challenger* covered 68,890 miles surveying and recording depth, bottom deposits, chemistry, temperature etc. of all the world's oceans with the exception of the Arctic. The expedition revealed the ocean floor was far from flat and had trenches nearly as deep as Everest was high. In addition 4417 new species of marine organisms were discovered of which 715 were representatives of genera new to science.

The Nature of the Ocean Floor

Challenger started to investigate the nature of the deep ocean floor as she travelled from Tenerife across the Atlantic towards the West Indies. The initial bottom samples contained fawn *Globigerina* ooze which had earlier been shown to be principally composed of the remains of foraminifera. These are small (<1 mm) unicellular organisms which have an elaborate perforated shell made of calcium carbonate. Chalk rock was known to be composed of these shells and their discovery led to the proposal that chalk was still being formed on the sea bed. Wyville Thompson held the view that the ooze was composed of bottom-dwelling organisms but just before the expedition left it was claimed by

Major Owen that similar organisms were living in the surface layers of the ocean, suggesting the ooze was composed of their sunken dead remains.

To resolve this debate Murray deployed finely woven silk plankton nets at various depths in the water column. He discovered that the foraminifera in the upper 100 fathoms contained exactly the same species as those found in the ooze at the bottom. Initially Murray's data seemed to confirm Owen's theory but as the ocean got deeper a problem emerged. Sample by sample the ooze became progressively darker and eventually on 26th February 1873 at 3150 fathoms (3.5 miles) it was replaced by red clay with very little evidence of shells or calcium carbonate. Murray was still finding live *Globigerina* on the surface raising the question of why were there no remains on the bottom. As *Challenger* moved further west the ocean floor in the region of the Mid-Atlantic ridge came nearer to the surface and the *Globigerina* ooze reappeared only to be lost on March 7th as the water deepened again. Clearly some chemical process was occurring in water deeper than 3000 fathoms which was removing the shells. Buchanan the chemist pointed out that the concentration of carbonic acid increased with increasing depth which in turn would speed the rate of calcium carbonate dissolution. The depth at which calcium carbonate shells are completely dissolved is now known as the *Carbonate Compensation Depth*. Later Murray and Professor Renard of Ghent University were to demonstrate that the red clays which covered vast areas of the deep ocean floor were principally composed of the hydrated silicates of alumina and iron. They suggested these were derived from the decomposition of the pumice and volcanic ash deposited in the oceans and fine dust blown from the continents. The red clay was mixed with varying amounts of the remains of silicaceous organisms (diatoms and radiolarians) and microscopic particles composed of peroxides of iron and manganese.

The first deep ocean trawl for sea bed organisms at 3150 fathoms was accompanied by great anxiety since the extra hemp line needed to reach this great depth added another half a ton to what had already been strained lifting gear. When trawling at this depth the nets are dragged along the bottom at the end of a rope 8 miles astern. Although the operation was successful it was disappointing that nothing living was found. In March after passing over the mid-Atlantic ridge a second trawl at similar depth brought up sea worms and by the end of the voyage 161 species of animals had been recorded at depths greater 2500 fathoms. This proved a bit of an anticlimax since it had been suggested that organisms like trilobites, belemnites and gastropods which were only known as fossils might still exist in the deep ocean. After the trip had ended Murray concluded that there was no compelling evidence of a relic living fossil fauna, a great disappointment to the creationists. He proposed the less romantic notion that the deep sea had been colonized by migrations of organisms from shallower waters. By contrast with the low numbers of organisms at great depths huge numbers of organisms were recovered from the ocean floor when it was less than 1000 fathoms. For instance a trawl of 600 fathoms off Argentina recovered 500 types of invertebrates and fishes including 103 species new to science.

In the 10 months of her voyage *Challenge*r made her way back and forth across both the North and South Atlantic before rounding the Cape of Good Hope and making for Antarctica. The first deep sea sounding in these cold waters was taken on leaving Heard Island (60°S) amidst much speculation amongst officers and naturalists about the likely nature of the deposit. Murray ventured that it would not be *Globigerina* ooze since he had not caught any in his tow nets for several days. Initially when a white coloured deposit was brought on board which resembled the globigerina ooze of the Atlantic it seemed he was wrong. Subsequent microscopic analysis revealed it to be primarily composed of the silicaeous skeletons of diatoms and had very few globigerina shells. It transpired that such deposits were a feature of cold circumpolar waters.

After the completion of the voyage, Murray, with the assistance of Renard divided these deep ocean floor deposits into either red clay or various oozes depending on whether the predominant organismal remains were foraminifera, pteropods (pelagic molluscs), diatoms or radiolarians. This classification has been adopted ever since. They were also able to map the distribution of these deposits since their own data was supplemented by the large numbers of samples (12,000) gathered over the next decade by vessels from United States, Germany, Monaco, Norway, France, Italy, Russia and Britain.

Challenger was the first steam vessel to cross the Antarctic Circle and in doing so she collided with an iceberg which could so easily have brought the trip to a premature end. Fortunately damage was light and the expedition sailed on to Australia, New Zealand and the Pacific Islands before visiting Japan and China.

Although the primary purpose of the expedition was to research the world's great oceans, *Challenger* spent more than half the time at anchor either in port or adjacent to the many remote islands she encountered. Terrestrial expeditions were mounted which also yielded a huge amount of information not only about the geology, fauna and flora but also the ethnology of the native peoples. Besides meeting kings, queens, and emperors they studied the native peoples including some who had only recently given up cannibalism. Both Captain Spry's (1876) and Eric Linklater's (1972) books deal in detail with these aspects of the voyage.

On March 23rd 1875 during the leg of the voyage between New Guinea and Japan *Challenger* made her deepest sounding of 4484 fathoms (5 miles) off the Marianas islands. It took 2.5 hours for the weight to reach the bottom and then to retrieve the line. The expedition was showing the ocean floor was no featureless plain and these trenches were nearly as deep as Everest was high. After leaving Japan *Challenge*r zigzagged across the Pacific stopping at both the Hawaiian islands and Tahiti. The red clay deep ocean deposits found between Tahiti and Juan Fernandez were particularly interesting. One trawl on October 14th from 2385 fathoms brought up two bushels of manganese nodules together with 1500 shark's teeth and 42 cetacean ear bones. These had presumably settled there over countless millennia.

Eventually (much to the relief of the crew) *Challenger* left the Pacific and after navigating through the Magellan Straits during January 1876 made for Port Stanley in the Falklands. After a brief stop she sailed north to Montevideo, then to Ascension Island and St Vincent. The deep water temperature profiles mapped E-W across the southern Atlantic during the early part of the voyage had shown the eastern side was slightly warmer than the west. This led Captain Nares to suggest a ridge down the centre of the Atlantic keeping the two bodies of water separate. As *Challenger* sailed north the soundings showed the mid-Atlantic area was shallower than expected and the daring idea emerged that a continuous submerged mountain range might run down the centre of the Atlantic parallel to the continental outlines.

Challenger finally arrived home at Spithead on May 24th 1876. Queen Victoria conferred a knighthood on Wyville Thomson and by early July he and Murray were back in Edinburgh where their return was celebrated by a civic banquet. They brought with them 563 cases containing greatly in excess of 100,000 specimens which were distributed to 76 international specialists to describe. During the voyage Murray sent all his journals back to Pullar in the Bridge of Allan for safekeeping.

Murrray and the Edinburgh Challenger Commission

Before Thomson had sailed in *Challenger* he had negotiated a five year Treasury grant so that on their return the thousands of samples could be analyzed and reports written. It was agreed that the terrestrial items should be dealt with in London by the British Museum and Kew and the marine collections should be sent to the Challenger Commission Office in Edinburgh. Thomson employed Murray as his assistant for this mammoth task. There was a violent reaction amongst British scientists when it became known that Thomson intended to ship many of the samples to "the best men available irrespective of nationality". Duncan the President of the Geological Society was *howling mad* and an unpleasant public quarrel developed in which Darwin, Huxley and Hooker supported Thomson's position.

Initially everything went well and Edinburgh became the international centre for Marine Sciences visited by large numbers of leading biologists. The first of the expected Challenger Reports was published in 1880 but already serious difficulties were emerging with finance. The wealth of finds meant the authors were reluctant to constrain their publications and the costs of producing charts and illustrations got out of hand. Not all the press coverage was complementary and one newspaper commented that *we had got a lumbering volume of statistics for the monies spent feeding a mob of Germans and other aliens*.

Thomson had been very stressed during this period and suffered an attack of paralysis. It was clear that the work would not be finished in the five years and the Treasury gave no hope of renewal of the grant. Murray gradually began to take over affairs and Thomson died in March 1882. His role as leader of the Challenger expedition was commemorated by a magnificent stained

glass window over the altar in St Michael's Church, next to Linlithgow Palace. It shows *Challenger* amidst a range of whales, sharks, corals and other sea creatures.

Following Thomson's death Murray was appointed to take over the *Challenger* Office and being a much more forceful personality he soon had five more years funding and relentlessly set about completing the task. The volumes of the Challenger Report started appearing more regularly and by the end of the decade all 31 zoological volumes were finished. The 31st volume was shipwrecked on its way from the printers to London prompting the Stationery office to pun hopefully that owners of the recovered volumes would forgive any imperfections *compensated by the knowledge that the polyzoa so beautifully figured in them, have been "drawn" from the bottom of the sea*.

Murray himself worked on with the Belgian geologist Abbe Renard, completing the volume dealing with the deep sea deposits in 1891. It largely confirmed the conclusions reached on the voyage. The hypothesis that the 50 million square miles of red clay on the ocean floor resulted from wind blown volcanic dust and denatured pumice was given additional credibility by the eruption of Krakatoa in 1883. Work on the Challenger Report was completed in 1895 with the final publication and world wide distribution of the 750 sets of the 50 thick quarto volumes (29,552 pages). Murray was responsible for several of them: the general narrative of the expedition, the volumes on deep sea deposits and those summarizing the results. The second five year Treasury grant ran out before this. In the end Murray himself financed the last volumes being reimbursed for their publication only when the final volume appeared. A *Challenger* medal (Figure 4) was struck which was presented to all the authors depicting a knight casting down his gauntlet as a challenge to the waters to give up their secrets.

Charles Darwin and the Great Atoll Controversy.

Seamen and scientists had long been fascinated by the beautiful circular coral reefs or atolls which seemed to spring miraculously from the deepest ocean floors. In the eighteenth century it had shown that the coral rock was principally composed of the accumulated limey remains of colonial sea polyps. These coral forming organisms were known to grow only in relatively warm, shallow (25 fathoms) water, posing the dilemma of how reefs formed where the ocean was thousands of fathoms deep.

Based on observations made during the voyage of the *Beagle* Charles Darwin proposed that fringing reefs initially developed around the shores of the exposed tips of extinct submarine volcanoes. He suggested the greater availability of the coral polyp's planktonic food on the reef's oceanic edge would cause the fringing reef to grow outwards creating a barrier reef with a large internal navigable lagoon. Then in regions where the ocean floor was subsiding the island would slowly disappear beneath the waves while the corals in the barrier reef would be able to grow upwards keeping pace with the

changing sea level. In time a circular atoll would be formed enclosing an internal lagoon.

Although Darwin's theory was widely accepted there were over 400 known atolls and a few sceptics expressed surprise that the subsidence of oceanic floors was so widespread. In 1880 in a lecture to the Royal Society of Edinburgh Murray offered an alternative explanation (Murray 1880). Challenger surveys had revealed numerous extinct volcanic cones rising from the ocean bed some of which reached to within a few hundred fathoms of the surface. These were covered in *Globigerina* ooze and Murray argued that further deposition of foraminifera would slowly raise the submarine elevation to a point where it could be colonized by the reef forming corals. In common with Darwin's theory he proposed that once established the coral would extend seawards increasing the diameter of the reef. He envisaged that the atoll's lagoon would form not by subsidence but by the death of the central corals due to a lack of food, together with the dissolution of their limey remains by the carbonic acid in sea water.

Murray's theory generated little interest until the Duke of Argyll championed it in papers entitled *A Conspiracy of Silence* and *A Great Lesson* (Argyll, 1888). He pointed out that there was a reluctance to discuss the possibility that the great idol of the scientific world might be in error and argued that revered prophets could establish a sort of unconscious *reign of terror* suppressing derogatory opinions. He revealed that Murray had been induced to delay publishing his views for fear it might prejudice *Challenger* Office funding.

In 1896-8 an expedition financed by the Royal Society and the British Association set out to resolve the controversy by drilling a borehole into the reef at Funafuti atoll. The results superficially supported Darwin but were ambiguous. When interviewed for Bridge of Allan's *Spa Magazine* in March 1899 (AWD, 1899) Murray was obviously comfortable that the data verified his theory, as were many other oceanographers.

Britain's First Marine Research Station

While editing the *Challenger* Reports Murray felt the need of a marine station with access to sea water and aquaria etc.. He was helped by the Scottish Meteorological Society which in spite of its name had long been interested in Scottish fisheries. Murray offered to provide and equip the station if the society would donate £300 annually, to which they consented. Murray's friends and supporters raised £3000 in cash as well as apparatus and equipment. A notable donation was the steam yacht *Medusa* which was fitted out for oceanographic work. The boat was purchased with financial help from Murray's Bridge of Allan friend Laurence Pullar with design assistance from D. and W. Henderson's Clydeside boat-yard.

The site chosen was a flooded quarry at Granton on the Forth estuary which had originally been excavated well below sea level to provide stone for the

harbour installations. The narrow wall of rock which kept the sea out was breached during a storm in 1855 flooding the quarry with sea water to a depth of 60 feet. In 1883 Murray took the lease with his friend Robert Irvine a chemist and director of a Granton printing ink company. An old lighter he named the *Ark* was moored in the quarry and converted into a laboratory with pumped sea water. He also took over a tannery, installing aquaria on the ground floor and a museum and laboratory above. Additional rooms in the ruined abbey on Inchcolm were furnished to accomodate any eminent visitors to Britain's first marine station. A staff of young scientists started work in 1884 under Murray's direction, their remit being to survey the fauna and hydrography of the Forth and the life history of food fishes. Murray and Irvine themselves investigated the secretion of calcium carbonate by marine organisms.

In the first summer *Medusa* was employed to investigate the herring shoals off the east coast but she was not sturdy enough for open water and in the autumn she was taken through the Forth and Clyde canal to work on the more sheltered west coast sea lochs (Marshall, 1987). Murray was looking to found a branch station on the west coast. He was persuaded by David Robertson, an eminent amateur naturalist and self made man, that Millport on the Isle of Great Cumbrae was the ideal spot. This proved the case and the *Ark* was soon to join *Medusa* drawn up into a sheltered inlet on the island where she remained for 15 years. As it was realised that the west coast was more fertile scientifically the main focus of station's work shifted to Cumbrae and Granton was closed in 1903. The quarry was filled and is now the site of a public park.

The idea of a permanent Millport Marine Station was pursued by Robertson who managed to raise enough money from Glasgow businessmen to build it. Murray opened the handsome building in 1897 presenting the *Ark* and her contents to the managing committee. The title Scottish Marine Biological Association was adopted in 1914 when a non profit making company was formed to promote research and education in marine biology.

It was also through his association with the Scottish Meteorological Society that Murray became secretary of a committee concerned with the establishment of a manned extreme weather station on the summit of Ben Nevis. The funds to build it were raised by public subscription and the station built to Thomas Stevenson's design was opened in 1883. Provisioned with enough coal and food to survive 9 months isolation the staff kept hourly records for 21 years. The stations' eventual closure, which caused considerable public disquiet, was ultimately delayed by a donation of £500 by Mr Mackay Bernard of Kippenross House, Dunblane.

Plotting the Depths of Scottish Lochs

Anybody who has used a Scottish Ordinance Survey map will be familiar with another of Murray's undertakings. His bathymetric surveys made between 1900-1909 still provide the information upon which the depth contours of most freshwater lochs are based. Apparently he became aware that little was known about the inland bodies of water when sailing through Loch

Ness in *Medusa*. His interest in the subject was further stimulated by Buchanan's finding (which he repeated) that Loch Morar was deeper (175 fathoms) than the ocean over the continental shelf. There had been much debate about the responsibility for surveying inland waters. In answer to a question posed in the House of Lords it was stated that it did not fall within the remits of either the Ordnance Survey nor the Admiralty. Murray wanted to organize systematic charting of all the Scottish lochs arguing that the information was important to water engineers and for the utilization of water power. In spite of support from the Royal Society the Government would not finance the undertaking. Never daunted Murray set about surveying the local lochs in the Teith catchments as a hobby. He had the practical and financial support of Frederick Pullar his old Bridge of Allan friend's son. Frederick designed the depth sounding equipment with which they charted 15 lochs including Katrine, Venachar, Voil and Lubnaig (Murray and Pullar, 1900).

On 15th February 1901 tragedy struck when Frederick Pullar (aged 25) died heroically trying to rescue skaters who had fallen through the ice on Airthrey Loch, now in the grounds of Stirling University (Gracie, 1994). Wishing to see his son's work finished Laurence Pullar offered £10,000 to complete the task and became a co-director of the enterprise. Three salaried officials worked from the Challenger Office supported by over 50 volunteers in the field. By the end of 1909 all 562 Scottish lochs had been surveyed and bathymetric charts produced. The reports which were dedicated to Frederick Pullar were published in six volumes from the Challenger Office. Those lochs that have been resurveyed using sonar show the information was remarkably accurate.

Science pays off. Wealth and the Annexation of Christmas Island

After failing to obtain government funding for so many of his projects it was with considerable satisfaction that Murray was able to announce in 1913 that "His Majesty's Treasury had received in hard cash … a sum greater than the cost to the country of the whole *Challenger* expedition" (Burstyn,1975). He was referring to the rents, royalties and taxes paid by the Christmas Island Phosphate Company which was set up as a direct result of his oceanographic investigations.

This venture arose out of Murray's interest in coral reefs. He wanted to know more about Christmas Island which was situated 190 miles SW of Java in water three miles deep. He had asked ex-Challenger officers Maclear and Aldrich whose vessels were deployed in the area, to gather rock for him. Chemical analysis suggested the island harboured valuable high grade phosphate deposits, which were in great demand as fertiliser to drive the agricultural revolution.

In 1888 Murray asked the government to annex this uninhabited island with the view to securing the exploitation rights for himself. After checking treaty obligations with the Dutch the Foreign Office dispatched Captain May of *HMS Imperieuse* to secure the island as a British possession. While the news of the annexation was awaited Murray had formed a syndicate of friends to defray

the expense of further exploration. Dr Guppy a naval surgeon who had studied the geology the Solomon Islands was persuaded to lead the expedition accompanied by an experienced miner. They left in June 1888 two weeks after the annexation was announced.

The only way to get to Christmas Island was to persuade the owners of the schooner that sailed between Jakarta (Batavia) and the Cocos and Keeling islands to detour as it passed. The shipping company was owned by the Clunies Ross family who were descended from John a one time Shetland sea captain. He and his descendants had settled on the Keeling islands running coconut plantations with the aid of indentured coolies. Having agreed to land Guppy's party the boat sailed from Java to Cocos Keeling and back without dropping them off. While the very frustrated Guppy was on his way back to London, the Ross' attempted to establish a plantation on Christmas Island to reinforce their family's rival claim of ownership. During the next two years the claims on the lease were the subject of intense lobbying of the Colonial Office by both the Ross' agents and Murray. Harold Burstyn's (1975) account of this whole affair provides a fascinating read. Eventually in 1896 a joint company was formed.

Murray's first step before launching this massive mining effort was to commission a study of the island's wildlife by Charles Andrews of the Natural History Museum. To this he later added his own observations made during visits in 1900 and 1908. It transpired that there were several endemic species including a bat later named after Murray. They were also the first to observe the spectacular red crab migrations which are now considered one of the wonders of the natural world.

In 1899 mining began in earnest and eventually the Christmas Island settlement was populated by up to a thousand Chinese labourers. The size of the high grade phosphate deposit was estimated to be 12 million tons with each ton yielding £2 profit after shipment to London. A significant proportion of the rewards of this venture were used by Murray to support marine science. His chemist friend Robert Irvine also left his shares in the company to found the Edinburgh University Chair of Bacteriology.

Fame and a Tragic Death

In 1889 Murray abandoned bachelor life at the Caledonian United Service Club and married Isabel Henderson only daughter of Thomas Henderson owner of the Anchor shipping line. They may well have met when Murray was staying with her uncle John Henderson (1881 census) who helped design *Medusa*. After the *Challenger* office closed in 1895 the couple bought a large villa in Granton near the marine station which was renamed *Challenger Lodge*. Murray's collections were housed on the other side of the road in *Villa Medusa*. They had many important visitors including another enthusiastic oceanographer Prince Albert of Monaco who was able to berth his yacht there. Although his roots were now firmly in Granton Sir John did keep some contact with Stirling. For instance he addressed his old school (Graham, 1900), was

interviewed for Bridge of Allan's *Spa Magazine* (AWD, 1899) and was honorary president of the *Stirling Natural History and Archeological Society* from 1903-14.

Murray was now a man of fame and influence and travelled all over the world taking his wife and young family (two boys and three girls) with him. In 1910 The New York Times carried a full page illustrated article entitled *John Murray seeks the secrets of the deepest seas. This noted English oceanographer now here tells of the curious and interesting animal and plant life in the ocean depths.* He seems to have been much in demand to deliver lectures, chair meetings and receive the many honours listed in the introduction. Snippets of letters to Sir William Herdman (Herdman, 1923), once a Challenger Office assistant, give an insight: "Tomorrow I deliver the Agassiz address at Harvard, but have been let in for the Lowell lectures (eight) and addresses here at Princeton … there was a dinner in our honour here (Washington) last night the British Ambassador was present … we go to Philadelphia Academy tomorrow then to New York … Osborn is to have 14 millionaires to hear me at the Museum as to what they should do for the study of the Ocean".

As early as 1885 Murray had been promoting a renewal of polar exploration. He judged that there was no great appetite for pure marine investigations but the public interest in the polar regions could be harnessed to provide useful oceanographic information. He was involved in the preparations of the *Scotia* or Scottish National Antarctic Expedition 1902-1904 which made a considerable contribution to marine research. William Bruce who led the expedition had spent time as a volunteer with Murray in the Challenger Office. In 1897 Murray also presented Fridtjof Nansen with a *Challenger* Medal in recognition of the oceanographic work carried out during his famous *Fram* expedition of 1893.

At the age of 69 Sir John's last major contribution to oceanography was an expedition with Johan Hjort round the north Atlantic in the Norwegian Fisheries research vessel the *Michael Sars*. Murray offered to pay all the expenses incurred on the 11,000 mile voyage. The expedition discovered a hundred new species including a massive 2 metre wide moonfish *Saccopharynx hjorti*. It is still the only specimen to have been caught and is preserved in Bergen museum. On their return the pair wrote the highly acclaimed text book *The Depths of the Ocean* (Murray and Hjort, 1912). Murray followed this with his last publication a little book in the Home University Library series *The Ocean; A General Account of the Science of the Sea* (Murray, 1913).

A few days after his 73rd birthday on March 16th 1914 Sir John was killed during the course of an afternoon spin in his new open tourer. The wheel at the time had been taken by his twenty year old daughter Rhoda, the chauffeur being next to her in the passenger seat. While changing gear on a clear straight road near Kirkliston the car skidded, mounted the embankment and rolled over twice. Sir John was killed instantly and Rhoda was knocked unconscious. To add to the tragedy Lady Murray was away at the time visiting their youngest son who was seriously ill at Eton. The funeral at Dean, Edinburgh was attended by representatives of all the scientific societies and public bodies with which he had been associated. Besides the family, the pall bearers

included his lifelong friend Laurence Pullar and Admiral Aldrich from the *Challenger*.

In his will Murray left 1270 phosphate shares for oceanographic research. Initially this kept *Villa Medusa* running but after twenty years it was wound up and the books and records were sent to the British Museum of Natural History. The income was then used to fund the John Murray Expedition to the Indian ocean and after 1948 they financed the John Murray Travelling Studentships which benefited many young marine and freshwater biologists.

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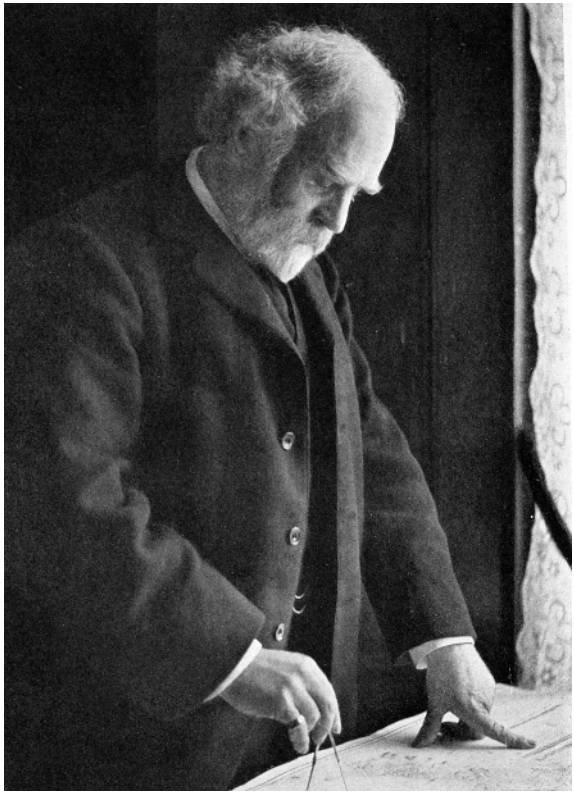

Figure 1. Sir John Murray 1900. *(Courtesy of National Oceanographic and Atmospheric Administration Photo Library.)*

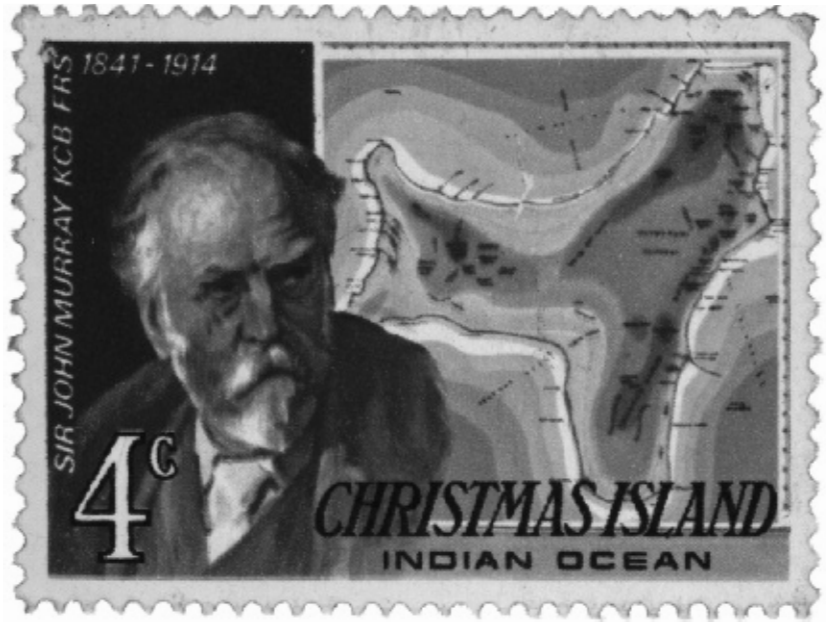

Figure 2. Sir John Murray commemorated on a Christmas Island stamp. *(Reproduced with permission of the Australian Postal Corporation. The original work is held in the National Philatelic Collection.)*

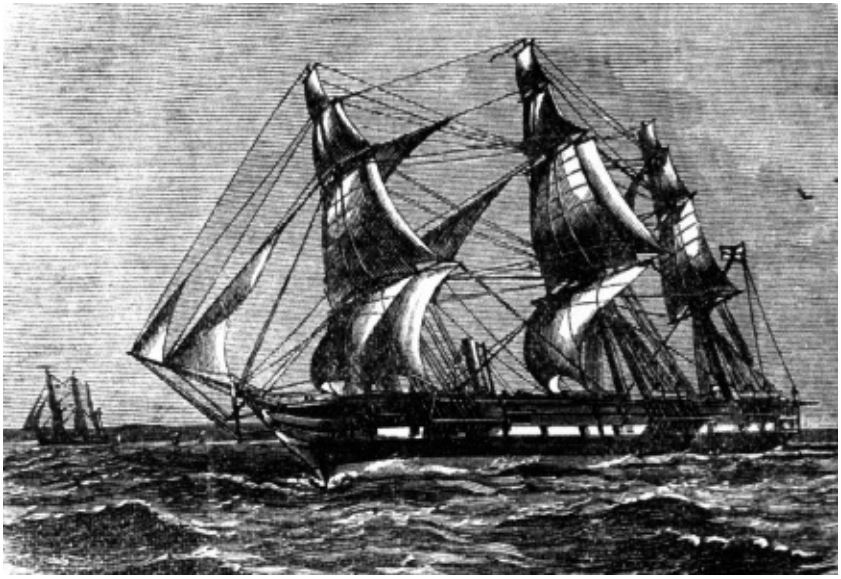

Figure 3. HMS Challenger under sail. *(Courtesy of National Oceanographic and Atmospheric Administration Photo Library.)*

Figure 4. The Challenger Medal designed by John Murray portraying a knight throwing down his gauntlet as a challenge to the ocean to give up its secrets. *(© National Maritime Museum, Greenwich, London.)*