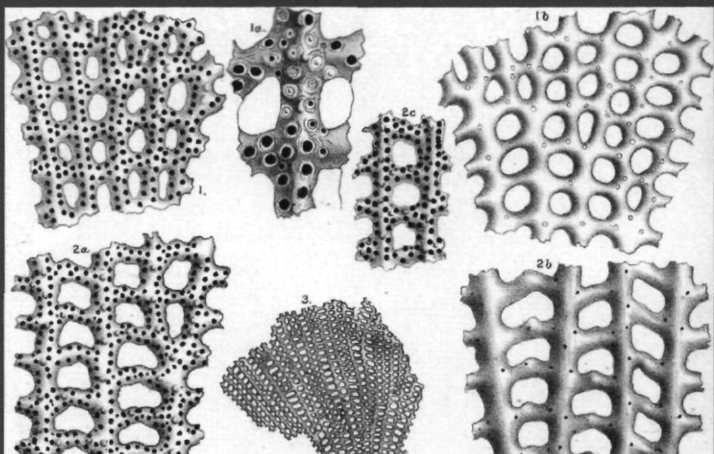
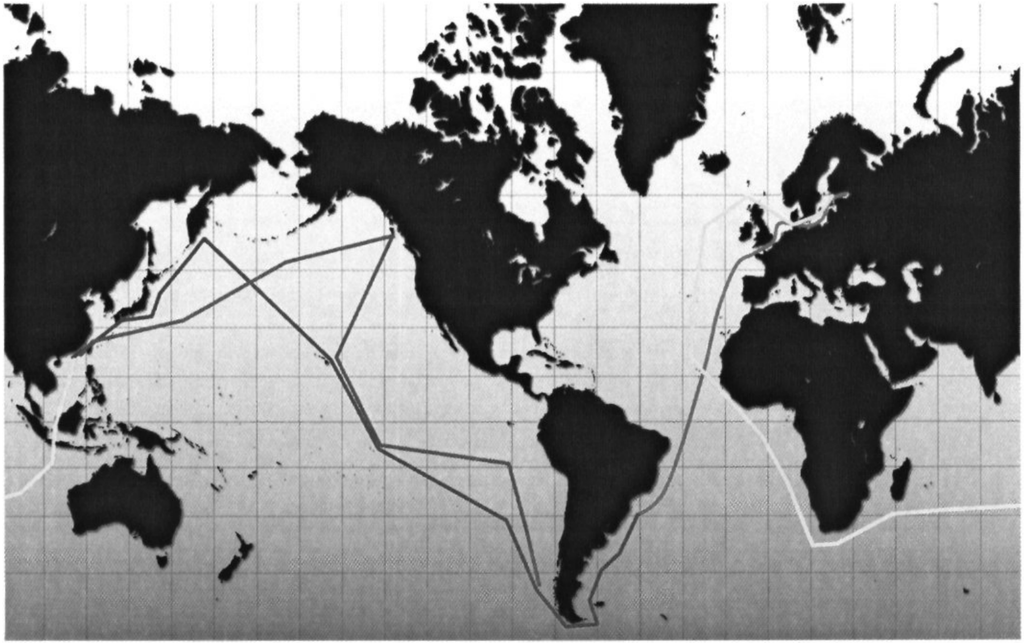
ANNALS OF BRYOZOOLOGY 4



EDITED BY
PATRICK N. WYSE JACKSON &
MARY E. SPENCER JONES

In the paper by Smith *et al.*, the caption to figure 4 (page 187) refers to the routes of the Krusenstern expedition marked in different colours. In the print volume this map is reproduced in greyscale, but is available in colour in the authors' pdf. A colour version is supplied here.



Annals of Bryozoology 4

Annals of Bryozoology 4: aspects of the history of research on bryozoans

Edited by
Patrick N. Wyse Jackson
&
Mary E. Spencer Jones

International Bryozoology Association
2014

This volume is dedicated with affection to Tim Wood,
a recent long-term Secretary of the International Bryozoology Association

ISBN 978-0-9543644-4-1

First published 2014 by the International Bryozoology Association,
c/o Department of Geology, Trinity College, Dublin 2, Ireland.

Printed in Ireland.

Previous volumes in the series:

Annals of Bryozoology [2002], pp. viii+382.
Annals of Bryozoology 2 [2008], pp. viii+442.
Annals of Bryozoology 3 [2011], pp. viii+226.

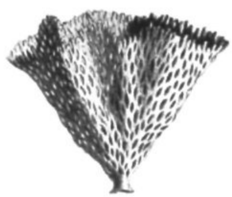
Cover illustrations

Front: Septoporids (Order Fenestrata) from the Mississippian and Pennsylvanian (Carboniferous) of Illinois, USA. Plate 64 from E.O. Ulrich (1890) Palaeozoic Bryozoa. *Illinois Geological Survey* 8: 283–688.

Back: Portion of a plate from Alicide d'Orbigny's *Paléontologie française* (1850–1852) showing the Cretaceous bryozoan *Retepora royana*.

Background: Structure of *Flustra* from Robert Hooke's *Micrographia* (1665).

CONTENTS



PREFACE

Bryozoans are complex colonial invertebrates, that have a long geological range of nearly 500 million years, and which are today still found in most marine and freshwater ecosystems.

This volume contains a collection of twelve papers that reflect the diversity of topics in the study of living and fossil Bryozoa, as well as the different backgrounds and interests of bryozoologists themselves. It is the fourth in a series that began publication in 2002, and with this current volume the total length extends to just over 1,300 pages.

A number of papers published here were presented at the conference of the International Bryozoology Association held in Catania in 2013. The editors gratefully acknowledge the support of the conference-host Antonietta Rosso, and all her colleagues in allowing these papers to appear here. The *Annals of Bryozoology* series depends on the scholarship of its contributors and they did not disappoint in delivering a cache of high quality papers for this volume.

The papers in this volume cover a diversity of topics from biography and assessments of research contributions; curation, museum collections and conservation methods; cruises and collecting; utilization of collections for research on climate change; and bryozoological illustration.

Collecting and documentation has been a long-time passion for many naturalists, and their findings have continued to fascinate both scientists and members of the general public for centuries. The paintings by the Vienna-based artist Giorgio Liberale, executed in the 1560s as part of a commission for Ferdinand II, Archduke of Austria, show two modern cyclostome bryozoans. The background to this commission and the work itself is described by Xenia Ostrovskaya and her father Andrew Ostrovsky.

Much research material has been collected since the rise in oceanographic research in the mid-nineteenth century. Nearly every European power, whether they had a marine coastline or not, promoted marine research expeditions. The Krusenstern Expedition sailed from 1803 to 1806 and was sponsored by authorities in Russia. The significance of the several bryozoan genera named that are based on material collected on this cruise is documented by Abigail Smith and her co-authors. Bryozoology in South Africa has been advanced by numerous such marine expeditions and these are discussed by Melissa Boonzaaier and her co-authors. They note that while a large number of taxa are known, the influence of Eurocentric taxonomic determinations mean that much research is required to adequately document the true bryozoan diversity from these southern oceans.

Many museum collections have suffered calamitous loss or complete destruction during times of war: a suite of important fossil marine reptiles was lost during World War II when Bristol was bombed. At much the same time the Geologische Staatsinstitut in Hamburg was consumed by fire after intensive bombing raids over Berlin, and the large bryozoan collection assembled by Ehrhard Voigt was destroyed, or at least thought to have been. Thanks to the painstaking work of Silviu Martha and colleagues in the Senckenberg

Institute a number of Voigt's early type specimens have been identified and the story of their dispersal unraveled. On occasion the location of a specific collection is unknown and only comes to light thanks to chance or following a systematic search through a museum holding. The celebrated Russian bryozoologist German Kluge is remembered for his considerable output, and thanks to the diligence of Andrei Grischenko, an important collection of Kluge's bryozoans has been identified in Perm.

The collections of the Natural History Museum, London are perhaps globally unrivalled, and reexamination by Helena Fortunato and Mary Spencer Jones of collections of the rather common bryozoan *Flustra* made over the last 200 years, have shown that these specimens afford the opportunity to document changes in climate during that time. Consuelo Sendino has documented the methodologies utilized by William Dickson Lang when he prepared some of his bryozoans mounted in wooden cavity slides. His use of a blue pigment, presumably to get an even surface tone prior to photographing the material, has resulted in some important surface features becoming obscured, and this reduces the ability of a modern taxonomist to reevaluate the material adequately. Modern cleaning methods have been applied to specimens with encouraging results.

The life and work of a number of naturalists are closely documented in this volume. Two English-born zoologists from very different educational backgrounds both found employment in Ireland for a time, and while there conducted surveys of the modern marine bryozoans. James Edwin Duerden was a mill-worker in Burnley who was awarded a scholarship in London and ultimately became a professor of Zoology in South Africa. His research interests changed as his career progressed: he was an expert on fossil and living corals, ostriches, and ultimately wool. His contemporary Albert Russell Nichols was a Mathematics student in Cambridge who spent his whole career in the National Museum of Ireland where he was primarily responsible for the development and curation of the collections of molluscs, echinoderms and bryozoans. In the US Benjamin Harrison Grave carved out a successful academic career. He was a dedicated teacher, and published on a diverse range of zoological topics including in bryozoology and ornithology. During the mid-twentieth century the pioneering freshwater and later marine bryozoologist Mary Dora Rogick overcame social and family difficulties to follow a similar academic path by dint of very hard work, allied to a sound scientific intellect.

The contributions of Jeremy Jackson to marine science are legendary, and in a short paper his colleague Alan Cheetham discusses his contributions to the testing of the evolutionary mechanism Punctuated Equilibrium.

We dedicate this volume to Tim Wood, a long-time Secretary of the International Bryozoology Association and currently President-elect, and the leading expert on freshwater bryozoans.

Patrick Wyse Jackson (Trinity College, Dublin)
& Mary Spencer Jones (Natural History Museum, London)

28th November 2014

Historical review of South African bryozoology: a legacy of European endeavour

M.K. Boonzaaier,[1,2] W.K. Florence[1] and M.E. Spencer Jones[3]

[1]*Natural History Department, Iziko South African Museum, Cape Town, 8000, South Africa*

[2]*Biodiversity and Conservation Biology Department, University of the Western Cape, Bellville 7535, South Africa*

[3]*Department of Life Sciences, Natural History Museum, London SW7 5BD, United Kingdom*

1. Introduction

1.1 Oceanography

The coastline of South Africa, extending from about 21°S, 14°E to 28°S, 33°E, is influenced by two major current systems, namely the Benguela Current along the west coast and the Agulhas Current along the south and east coast. The Benguela Current passes three countries, namely Angola, Namibia and South Africa (Shillington *et al.* 2006), and is associated with coastal, seasonally variable, wind-driven upwelling (Shannon 1985,

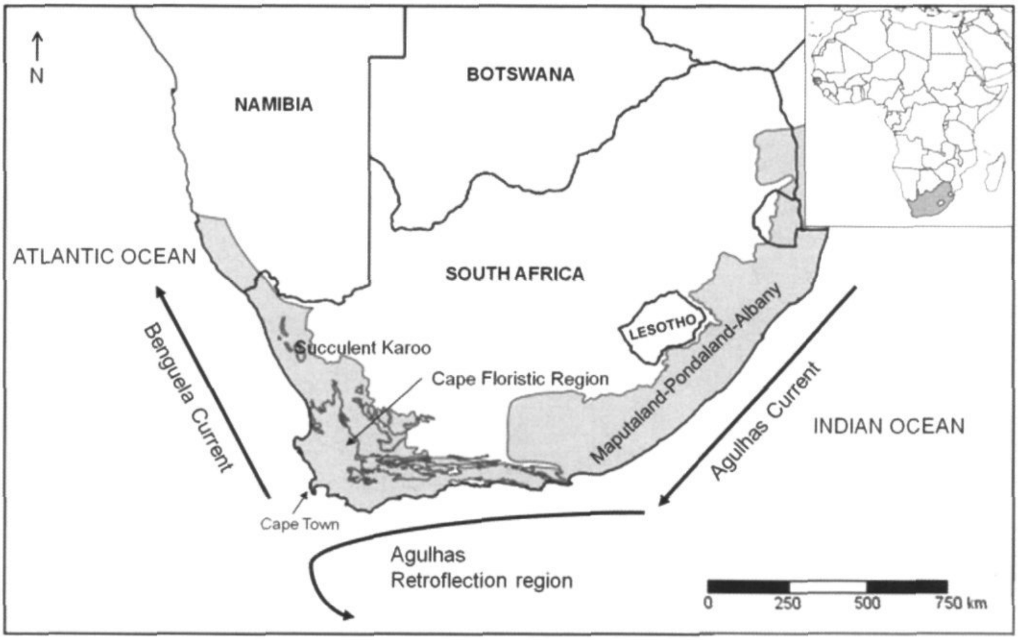


Figure 1. A schematic of the two major ocean currents around South Africa, the Benguela Current and Agulhas Current, also showing the retroflection of the Agulhas Current. The Angola Current (not shown) flows southward along West Africa. Three biodiversity hotspots (grey) are indicated, which includes the South African coast, according to Sloan et al. (2014).

Hill *et al*. 1998), while the Agulhas Current moves southward from the equatorial Indian Ocean (Lutjeharms 2006).

The intense upwelling of the Benguela Current carries cool (ranging between 10°C-20°C), nutrient-rich waters towards the equator (Shillington *et al*. 2006, Griffiths *et al*. 2010). Furthermore, the Benguela Current upwelling system is unique since it is restricted at the boundaries by two warm current systems, namely the tropical Angola Current in the north Atlantic and Agulhas Current System on the western boundary of the Indian Ocean in the south (Duda and Sherman 2002) (Figure 1). The nutrient-rich character of the Benguela Current supports high densities of pilchards, hake and rock lobster, but species richness is low (Griffiths *et al*. 2006). These include abundant fish populations (e.g. hake, *Merluccius capensis*; pilchard, *Sardinops ocellatus*), marine mammals (including the Cape fur seal, *Artocephalus pusillus*; southern right whale, *Eubalaena australis*; and the rare Heaviside's dolphin, *Cephalorhynchus heavisidei*), seabirds (such as the endangered African penguin, *Spheniscus demersus*) as well as important coastal lagoons and estuaries for migratory bird populations (Olson and Dinerstein 1998).

On the eastern coast of South Africa, the edge of the Agulhas Bank is the widest part of the shelf and stretches 250 km from shore to shelf edge (Lutjeharms 2006). A series of eddies move downstream with the current creating a sequence of currents in opposite directions (Walker 1989, Lutjeharms 2006). In contrast to the Benguela Current system, the Agulhas Current brings warmer (20°C-28°C), nutrient-poor tropical waters that result in high species richness, but low abundance (Lutjeharms 2006, Griffiths *et al.* 2010). Here, fish species include the shallow-water Cape hake (*Merluccius capensis*), blackhand sole (*Solea bleekeri*), and yellowfin tuna (*Thunnus albacares*), and several dolphin species (Family Delphinidae) inhabit the region (Olson and Dinerstein 1998). Furthermore, two species of sea turtles, including the critically endangered leatherback (*Dermochelys coriacea*) and endangered loggerhead (*Caretta caretta*) turtle have nesting grounds in South Africa on the north-eastern coast, while green turtles (*Chelonia mydas*) forage along the east coast (Hughes 1974, Olson and Dinerstein 1998).

1.2 South African marine biodiversity

South Africa is one of the most biologically diverse regions in the world, being amongst the 17 megadiverse countries recognized by Conservation International, and ranking third for terrestrial species richness after Brazil and Indonesia (Mittermeier *et al.* 1997). Probably, the most important reason for this ranking is that South Africa, but more specifically the Cape Province, is recognized as one of the botanical kingdoms of the world (Olson and Dinerstein 1998). The Cape Floristic Region has the highest floral species richness in Africa, comparing to its size, with approximately 9,000 species of vascular plants of which 70% are endemic to South Africa (Goldblatt and Manning 2002). Along with the Cape Floristic Region, the Succulent Karoo and Maputaland-Pondaland-Albany regions in South Africa have been identified as three of the 35 biodiversity hotspots in the world (Sloan *et al.* 2014) (Figure 1). Owing to the high levels of endemic taxa and vulnerability to processes that threaten these regions, biodiversity hotspots have been identified as a global conservation priority (Mittermeier *et al.* 1998, Myers *et al.* 2000, Sloan *et al.* 2014).

In contrast, South Africa's marine biodiversity has rarely been assessed on a global scale. In 2010, South Africa's marine species richness per area (km^2) of 15.3 was higher than most countries, for example Australia (4.8 species per area km^2), but much lower than South Korea (32.3 species per area km^2) and China (26.9 species per area km^2) (Costello *et al.* 2010). Marine biota along the South African coastline is characterized by high levels of diversity with species that exhibit large environmental tolerance ranges and remarkable endemism for several taxa (Tittensor *et al.* 2010, Scott *et al.* 2012). Biodiversity assessments of the past decade use limited available biodiversity data (including endemic and introduced species) for systematic conservation planning (Lombard *et al.* 2004, Sink *et al.* 2011, Sink *et al.* 2012).

An estimated 12,915 described marine species are found within South African waters, of which 33% (4,233 species) are considered endemic; these figures are probably lower than in reality if one takes into account that the listing is far from complete (Griffiths *et al.* 2010) (Table 1). Molluscs, arthropods and fish (not less than 2,000 species for each group) were the most speciose taxa and already account for 59% of marine biodiversity. It is important to note that the aforementioned taxa may also be used in aquaculture (e.g.

Table 1. Summary of known marine biodiversity in South Africa, adapted from Griffiths et al. *(2010) ordered from highest to lowest diversity within each group or domain.*

Taxonomic group	No. species[1]	State of knowledge[2]	No. of introduced species[3]	No. experts	No. ID guides[4]
Domain Archaea	n/a	1	n/a	0	0
Domain Bacteria (incl. Cyanobacteria)	n/a	1	n/a	0	0
Fungi	1	1	0	0	0
Domain Eukarya					
Kingdom Chromista					
Other Chromista	225	2	n/a	2	3
Phaeophyta	111	5	0	2	2
Kingdom Plantae					
Rhodophyta	505	5	3	4	2
Chlorophyta	197	5	1	4	2
Angiospermae	7	5	2	0	4
Kingdom Protoctista (Protozoa)					
Dinomastigota (Dinoflagellata)	220	3	3	1	0
Foraminifera	15	2	0	1	0
Kingdom Animalia					
Mollusca	3,154	4	11	1	10
Crustacea	2,331	3	21	4	9
Vertebrata (Pisces)	2,000	5	1	5	6
Cnidaria	853	3	13	4	9
Annelida	787	3	7	1	1
Echinodermata	410	4	2	2	5
Platyhelminthes	354	2	0	1	0
Porifera	346	3	1	1	1
Bryozoa	270	3	6	1	1
Urochordata (Tunicata etc.)	227	3	9	1	3
Other invertebrates	630	3	3	2	8
Other vertebrates	272	5	0	1	7
TOTAL REGIONAL DIVERSITY[5]		12,915			

Notes:

[1] Sources of the reports: databases, scientific literature, books, field guides, technical reports.

[2] State of knowledge is ranked on a scale of 1-5, where 1 = very poor or unknown and 5 = well-known, n/a = no data available.

[3] Number of introduced species follows Mead *et al*. (2011) and excludes cryptogenic species.

[4] Identification guides lists major works only.

[5] Total regional diversity including all taxonomic groups.

fish, abalone, oysters, shrimps, lobsters), therefore sampling and research effort is strongly biased towards these groups. Despite some comprehensive, but sporadic, systematic research efforts on a few marine invertebrate taxa (e.g. Porifera, Bryozoa, Cnidaria), these groups are suggested to be more diverse, especially deep-sea benthic communities. Sampling in deep-sea regions, however, is hampered due to inaccessibility and shortage of taxonomic expertise.

Marine invertebrates are amongst the smallest and taxonomic challenging groups and account for more than half of the total regional diversity in South Africa (Griffiths *et al.* 2010). Of the 9,362 marine invertebrate species, mollusc (3,154 species) and arthropod (2,451 species) diversity largely contribute to this figure, but an estimated 7,590 species need to be described for South Africa's marine invertebrate taxonomic knowledge for it to be comparable to other regions like Europe (Griffiths *et al.* 2010).

In total, 86 introduced species and 39 cryptogenic (i.e. neither clearly native nor exotic) marine and estuarine species have been identified in South Africa (Mead *et al.* 2011). The majority of introduced species (55 species) were found in the cool-temperate region (west coast), with the least number of introduced species (15 species) found in the warm-tropical region (north-east coast). Furthermore, the majority of introduced species (65%) were native to the northern hemisphere, therefore, northern hemisphere species have established themselves on the cool-temperate west coast and the warm-temperate south-east coast. In this study, ship fouling (48%) since the 1600s, and the carrying of ballast water (38%) since 1880s were found to be the most common vectors of marine introduced species to South Africa. This is not surprising, since South Africa has a long history of shipping activities associated with European colonization and the beginning of the slave trade.

2. A European start to trade and biodiversity research in South Africa

2.1 An era of exploration in South Africa, 15th and 16th century

Exploration in South Africa started in the late 15th century when Portuguese explorers navigated along the South African coastline to establish trade connections to East India (Pletcher 2010) (Figure 2). Bartholomeu Dias, along with his crew, came to the Cape of Good Hope in February 1488, but originally called it *Cabo das Tormentas* ("Cape of Storms"), and sailed around the tip of southern Africa eastwards. They arrived at *Angra da Roca* (now Algoa Bay in Port Elizabeth), but after a few days of sailing along the east coast up to *Rio do Infante* (now the Great Fish River) in the Eastern Cape, his crew was unwilling to continue; therefore he decided to return to Portugal. For almost a decade, no known voyages to India were attempted and in 1500, Dias died after his ship was lost at sea near the Cape of Good Hope. In July 1497, another Portuguese captain, Vasco da Gama, commenced a long voyage from Lisbon to India, through the South Atlantic and around the Cape. The fleet arrived in Santa Helena Bay (St Helena Bay) in November 1497, continued along the south coast and anchored in Mossel Bay a few days later where they stayed until December 8. They reached the coast of Natal on Christmas Day and in

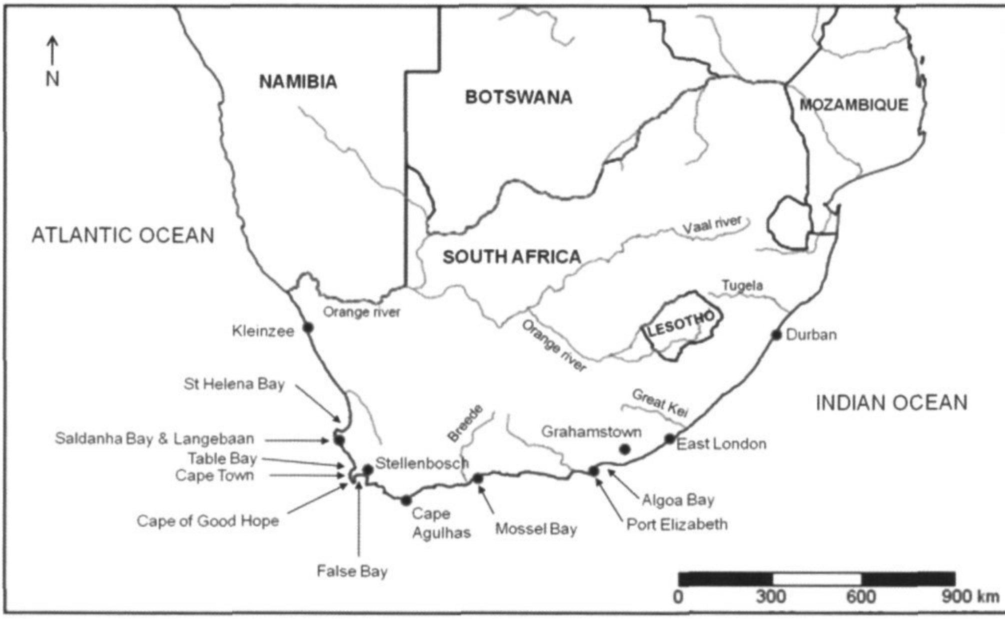


Figure 2. Map of South Africa indicating some places and rivers (grey lines) mentioned in the text.

January 1498 anchored for a few days near the mouth of *Rio do Cobre* (now the Copper River), a small river between Natal and Mozambique. Here, the route continued along East Africa to Mombasa (in Kenya) and finally, India. This route, and various other sea routes were established and exploited during the 16th century.

2.2 Colonialism in the Cape and the slave trade in 17th and 18th century

By the end of the 16th century, Portugal only held ports in Goa and Diu (India) and in Macau (China), while the English dominated the trade in India, and the Dutch in the East Indies (Indonesia) (Pletcher 2010). The Dutch East India Company was founded in 1602 by merchants from several Dutch cities (Thom 1952). The Dutch often repaired their ships in the Cape of Good Hope (Pletcher 2010), therefore a supply station was established in Table Bay by Jan van Riebeeck, a Dutch colonial administrator, who arrived in April 1652 (Thom 1952) (Figure 2). This led to South Africa's first European settlements and also, slavery at the Cape from the earliest days of settlement in 1652 (Worden and Groenewald 2005). Slaves provided the labour force on settler wine and grain farms, as well as domestic labour in private houses and on public works in and around the small European settlement in Cape Town.

The expansion of the Dutch colony in Cape and the importation of slaves, the majority from Madagascar since the Dutch East India Company's region of operation was in and around the Indian Ocean, continued until late 17th century. The Dutch East India

Company's slave trade practice was well-established in 1717 and near the end of the Company rule in 1795, about 16,789 slaves were reported in the Cape, although this was an under-reported total. In the early 18th century, half of the slaves in the Cape were from southern Asia (India and Sri Lanka), with roughly 20% from southeast Asia (including Jakarta, Bali and Makassar), and by the end of the century the majority of the slaves were imported from Mozambique, due to trading in Maputo. The indigenous people from the Cape, the Khoikhoi and San people, had been dispossessed from their land and enslaved by the Dutch East India Company, along with the Cape slaves (Worden and Groenewald 2005).

2.3 Arrival of the British settlers and institutional development in the Cape early 19th century[1]

By the end of the 18th century, the Dutch East India Company was taken over by the British through a military invasion. The British occupied the Cape in 1806, which also marked the abolition of the slave trade, and officially became a British colony in 1814. But, after the Napoleonic wars, Britain experienced a serious unemployment problem, consequently the British government sent migrants to the Cape Colony. The first group of British settlers arrived in Table Bay, 17 March 1820. Between April and June 1820, approximately 4,000 settlers arrived in the Cape. From the Cape Colony, the settlers were sent to Port Elizabeth, while Lord Charles Henry Somerset, the British governor in South Africa from 1814-1826, encouraged some settlers to migrate further into the Eastern Cape to places such as Grahamstown.

European colonization paved the way for migrant scholars such as doctors, zoologists, botanists, geologists and astronomers to conduct research in South Africa. The British naturalist Charles Darwin was amongst the scholars that briefly visited South Africa (Kennedy 2004), while others like the Scottish-born zoologist, John Dow Fisher Gilchrist (Brown 1997) and Dr Baron Von Ludwig, a German doctor and an avid collector (Summers 1975), both lived and studied in South Africa for many decades. It also became possible for scientific institutions to be established, the first of their kind in sub-Saharan Africa, as a result of increased research and taxonomic efforts by the visiting and migrant scientists (Cowling *et al*. 1996).

In 1818, the Cape Governor at the time, Lord Somerset, erected the South African Public Library in Cape Town (now Cape Town Campus) (Coates 2012). Less than two years later, on 20 October 1820, the British astronomer Fearon Fallows, erected the Royal Observatory in Cape Town, South Africa's first permanent modern observatory and research institution in Cape Town, and soon afterwards in 1825 the South African Museum was established by Somerset (Brown 1977). Though the South African Museum was founded in the early 1800s, the history of its collections originate from the mid-17th century in the early settlement years (Brown 1977).

2.4 The South African Museum in Cape Town, mid-17th century to present[2]

The oldest collections in the South African Museum, that would later form part of the museum displays, provide links to the earliest years of settlement from 1656 and zoological exploration of southern Africa (Summers 1975). Skins of lions and other wild animals killed, were preserved and often stuffed and mounted for display in the *Fort de Goede Hoop* ("Fort of Good Hope") built by Van Riebeeck upon his arrival in Cape Town. This was later replaced by the Castle of Good Hope built by the Dutch East India Company between 1666-1679. These collections continued to grow, and during the early 18th century, Willem Adriaan van der Stel, son of the former Dutch Governor of the Cape Colony, Simon van der Stel (after whom the town "Stellenbosch" and "Simon's Town" is named), established a small zoological museum as an appendage of the Governor's Menagerie and collection of live wild animals and birds near to the *Tuynhuys*, or "Garden House". The old Menagerie building which probably included the museum erected by (Willem) van der Stel, who succeeded his father as governor until 1707, is today occupied by the Michaelis School of Art of the University of Cape Town. Overseas demand for skins, skeletons or mounted specimens increased in the 18th century, but records of where these specimens were stored is not precisely known, although some specimens were used to decorate the *Tuynhuys* that was originally used as a toolshed for the Company's Garden established in 1653 by Van Riebeeck. After numerous renovations it later became the Governor's House after British occupation.

Figure 3. The first director of the South African Museum, Sir Andrew Smith (1797-1872). [Image taken from Summers (1975)]

Van der Stel's successor and the first British governor, Lord Somerset, founded the South African Museum on 11 June 1825 in Cape Town and it was situated at the bottom of Government Avenue in the Old Supreme Court. Lord Somerset appointed Dr Andrew Smith (Figure 3) as the director of Natural History at the museum (Kennedy 2004, Day 2000). Smith was a Scottish army medical doctor and naturalist who obtained his medical degree in 1816 at Edinburgh University and who then joined the British Army Medical Services. He was sent to the Cape Colony and Grahamstown in 1820 to supervise the medical care of European soldiers and soldiers of the Cape Corps (Kennedy 2004). Soon after his appointment to the Museum he conducted a few expeditions around the Cape to collect specimens for its collections.

During his tenure, Smith published several reports on zoology and anthropology, including *On the origin and history of the Bushmen* in 1831 and the *Report of the expedition for exploring Central Africa* published in 1836 (Kennedy 2004). The Museum was moved to Looyer's Plein (today on the corner of Roeland and Hope Streets) in 1832, exhibiting interesting specimens Smith collected during the Cape of Good Hope Association's Expedition to the Interior. The Museum was at Looyer's Plein from 1832-1838 and seems to have influenced the cultural life of Cape Town.

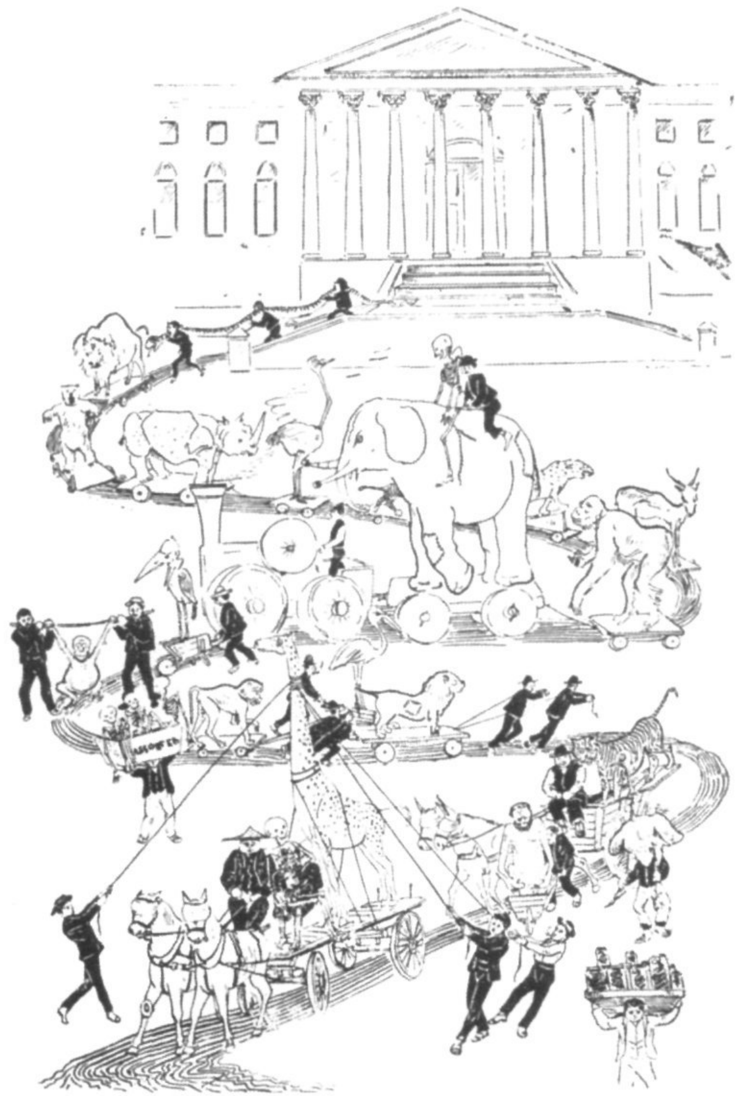
In May 1836, while on its second voyage, the HMS *Beagle* came to the Cape as it returned to England. Smith met Charles Darwin (Kennedy 2004, Day 2000), and together they spent a few days in and around the Cape, and Darwin made good use of Smith's valuable observations on large animals recorded during the excursions.

Shortly after Darwin's visit to the Cape, Smith returned to England in 1837 and took most of his collections with him (Day 2000). Baron von Ludwig, a doctor from Würtemburg, Germany, who settled in the Cape in 1805 and died in 1847, was an avid collector, and his collections of birds, insects and herbarium were sent to Europe. For more than a decade, after the greater part of the museum material was unavailable when Smith and von Ludwig removed their collections, the existing museum material decayed. Therefore, the interest in the museum collections decreased and there were no available funds to maintain the collections.

From 1838-1855, the collections were "lent" to the South African College (today, the *Weeshuis* or "Orphan House" on Long Street) on the condition that they be maintained. The Museum collection still contained important specimens, some were type specimens of great historical interest and unique zoological importance, which became teaching aids.

Fortunately, Sir George Grey, governor of the Cape Colony from 1854-1861, took an active interest in museum matters and on 25 June 1855 formed the Board of Trustees to govern the Museum. This meant that the Board of Trustees, initially consisted of three members, were to appoint staff, purchase equipment to maintain specimens and house the collections. The collection was moved from the South African College to a building on St Georges Street (today Barclay's Bank on Shortmarket Street), but it did not remain there for long. Edgar Leopold Layard was appointed as the curator at the Museum by the Trustees in 1855, and a few other men were appointed during those formative years. In the first report compiled by Layard to the Trustees of the South African Museum in August 1855, a small collection of insects, reptiles, birds, mammals and fish, of nearly 500 specimens were listed. Unfortunately the majority were in poor condition and had to be discarded.

Accommodating the specimens became increasingly difficult, and consequently the Government agreed to erect a building to house both the Museum and the Public Library at the lower end of the Botanical Gardens. During the summer of 1859/60, the Museum collection moved from St Georges Street to the new Museum and Public Library building.



Cartoon in the *Cape Argus*, August 1897, when the Museum was moved from the S.A. Library building to its present quarters.

Figure 4. In 1860 the Museum was part of the South African Public Library building. The museum's holdings were moved to its present day location in the Company's Gardens in 1897. [Image taken from Summers (1975)]

By 1886, the Museum was too small to cope with its rapidly increasing collection; as the Public Library faced the same problem, the Government decided to move the Museum to a new site and built a museum building in the upper part of the Botanical Gardens. The Museum, today known as the Iziko South African Museum (SAMC), moved to its present day location in 1897 on the site of the historic Company's Garden begun by Van Riebeeck in 1653.

Table 2. Summary of current collection objects in the specimen collections lodged at the SAMC. Adapted from a report compiled by Dr Hamish Robertson (Director of the Natural History Department, SAMC).

	Total no. coll objects		**Est. no. uncatalogued. coll. objects**		
Collection	**Catalogued[1]**	**ID'ed**	**ID'ed**	**Unidentified**	**Total coll. objects**
Terrestrial vertebrates	44,535	45,586	1,000	0	46,586
Marine Invertebrates	61,602	67,602	6,000	60,000	133,602
Ichthyology (fishes)	20,526	20,273	0	600	20,873
Marine mammals	1,437	1,437	0	7,598	9,035
Entomology	270,839	287,339	16,500	1,000,000	1,303,839
Cenozoic Palaeontology*	221,031	267,451	46,420	20,000	333,871
Karoo Palaeontology	7,670	7,770	100	0	7,870
Invertebrate Palaeontology and Geology	59,955	48,211	8,000	2,000	58,211
Total	**687,595**	**745,669**	**78,020**	**1,090,198**	**1,913,887**

Abbreviations: No. – Number; coll. – collection; Est. – Estimated; ID'ed – Identified.
[1]Total number of collection objects catalogued in the *Specify* database and hard copy catalogues. *Other databases were used, not *Specify*.

Today, this museum holds some of the largest collections in southern Africa which include fossils, insects, mammals, birds, fish, marine invertebrates as well as several archaeological artefacts. A recent inventory of SAMC's natural history collections were estimated at 1.9 million collection objects, of which 22.09% are catalogued on the *Specify version 6.5.02* database (Table 2). The current number of accessions dwarfs the figure of about 500 specimens reported by Layard in 1855 just over 150 years ago, and gives an indication of the scale of research and collecting during that time.

Figure 5. The South African Museum in the Company's Gardens in the 1940s. It has been at this location since 1897. [Image taken from Summers (1975)]

3. A brief history of scientific voyages around South Africa, 19th and 20th century

Early naturalists that visited the Cape were generally more interested in terrestrial organisms than marine life (Talbot 1977). Kolb (1726) published a book that included 24 pages on marine fish, whales, seals, molluscs and crustaceans; Thunberg assembled a fine marine collection between 1772-1775 (Day 1977), while Rennell (1778, 1832) investigated the Agulhas Bank and ocean currents around southern Africa. These all contributed to the understanding at that time of South African biodiversity during the late 18th century. Apart from these early studies, extensive marine fauna collections were made in the first half of the 19th century by visiting biologists, including Ferdinand Krauss, J.H. Wahlberg and Wilhelm Peters (Brown 1997). Opportunistic collections were made by passing ships such as the HMS *Beagle* (see above) (Day 2000). Yet, nearly five decades after the South African Museum was established in 1825, local marine collections and biologists were few and sporadic (Day 2000). Therefore, marine specimens were sent to Europe to be described by experts such as Carl Linnaeus (Brown 1997).

The late 19th century was dedicated to marine exploratory expeditions of which the first global marine research expedition was conducted during the years 1873-1876 by the British Royal Navy vessel, HMS *Challenger* (Figure 6) that had been launched in 1858 at Woolwich (Morris 1986). The main objectives of the expedition were to examine benthic (deep-sea floor) diversity and physical conditions of the ocean floor (Perry and Fautin 2003). The *Challenger Expedition* (named after the vessel) commenced on 7 December 1872 from Portsmouth (England), and its findings were considered the baseline of oceanography (Morris 1986, Perry and Fautin 2003).

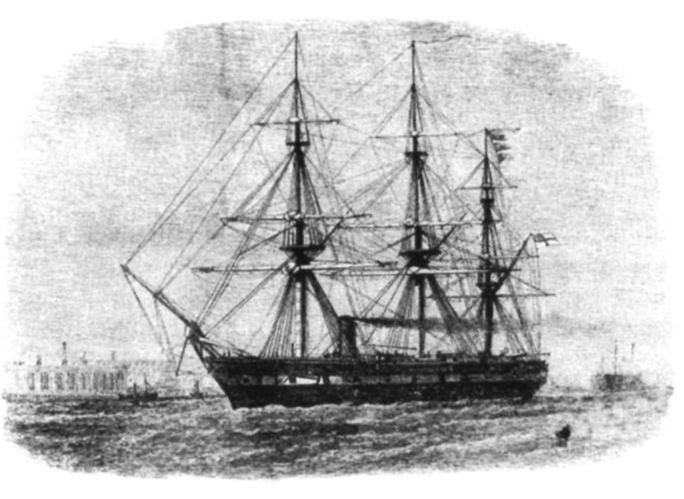


Figure 6. HMS Challenger. *[Image taken from* The Report of the Scientific Results of the Exploring Voyage of HMS Challenger during the years 1873–1876.*]*

Charles Wyville Thomson supervised the scientific exploration that sailed 127,580 km and which yielded many new discoveries. Over 4,000 unknown species were catalogued and 50 volumes of scientific reports on the results of the expedition were published between 1885-1895 (Perry and Fautin 2003). During the cruise, the vessel visited the Cape in October and November 1873 (Perry and Fautin 2003, Tizard *et al.* 1885). The benthic fauna collections from South Africa and other parts of the world, that range from fish to polychaetes to bryozoans, are lodged in the Natural History Museum in London.

During the next two decades, after the *Challenger Expedition*, few targeted scientific voyages were conducted along the South African coastline, but rather international scientific voyages visited as they passed (Day 2000). These included the German SS *Valdivia* which surveyed in the Atlantic, Indian and Antarctic oceans in 1898-1899, whose expedition was led by zoologist Carl Chun (Lutjeharms and Shannon 1997).

Nearing the end of the 19th century, it was evident that the Cape supported exploitable quantities of fish stock (Day 2000). Therefore, largely upon the recommendation of Sir John Murray of the *Challenger Expedition*, Scottish-born John Dow Fisher Gilchrist (Figure 7 and 8) was offered a job as the Government Fisheries Biologist in 1895 at the

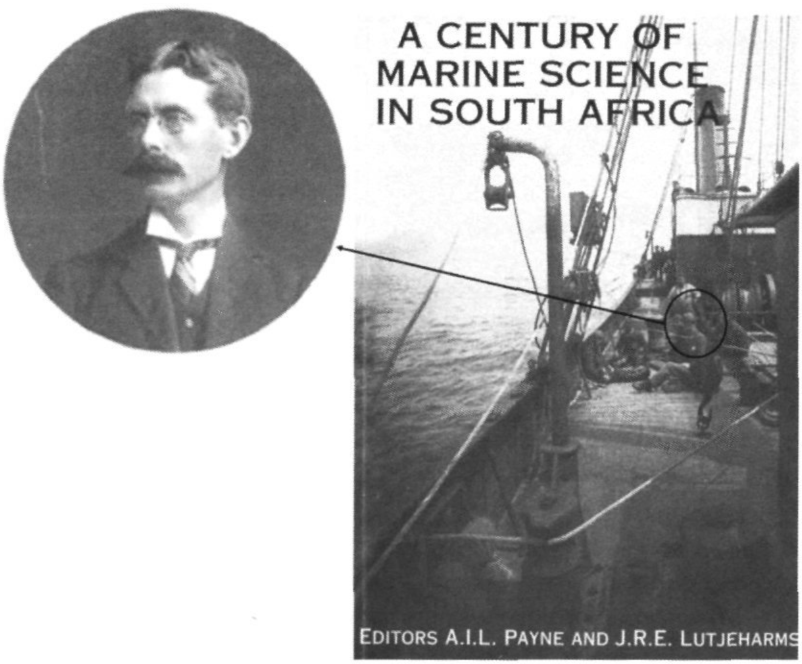


Figure 7 (left) . John D.F. Fisher Gilchrist (1866-1926) when Professor in Zoology at the University of Cape Town. [Image taken from Brown (1997, p. 8)]

Figure 8 (right). This is the cover page of the Transactions of the Royal Society of South Africa *volume 52, part 1, specially-bound to commemorate the arrival of John D.F. Gilchrist in South Africa in 1896. This photograph was taken around the beginning of the 20th century, with Dr J.D.F. Gilchrist sitting in the front with the rest of crew members on the SS* Pieter Faure, *the first oceanographic research ship in South Africa.*

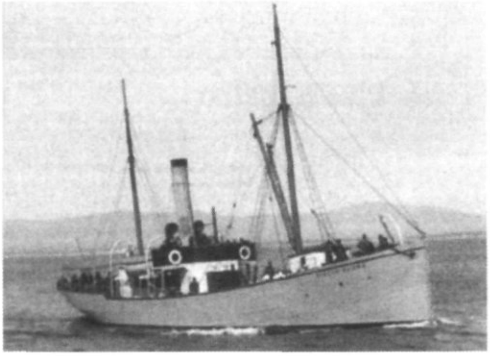


Figure 9 (left). The SS Pieter Faure*, in Cape Town harbour, commissioned by Gilchrist in 1897 for fisheries research in South Africa. [Image taken from Lutjeharms and Shannon (1997, p. 22)]*

Figure 10. (right) The SS 'Pickle' *replaced the* Pieter Faure *vessel in the early 1920s. [Image taken from Brown (1997, p. 10)]*

Cape of Good Hope (Brown 1997, Day 2000). At the time of the offer, Gilchrist was an assistant lecturer in Zoology at University of Edinburgh from 1892, but his research also included prior work done in Naples, Monaco and Port Erin, Isle of Man (Brown 1997). Gilchrist became associated with the South African Museum shortly after his arrival in Cape Town in 1896 and served both the Department of Agriculture (now the Department of Agriculture, Forestry and Fisheries) and the museum for more than a decade.

In 1897, the Cape Government imported a small trawling ship from Scotland, the SS *Pieter Faure* (Figure 9), which Gilchrist used to conduct research on fish stocks around the Cape, especially on the Agulhas Bank (Brown 1997, Day 2000). Within a year, Gilchrist and his team discovered rich stocks off Mossel Bay. Results from earlier voyages conducted by Gilchrist, including those undertaken in the *Pieter Faure*, was published in the Reports of the Marine Biologist (1896-1900) and the Reports of the Government Biologist (1901-1908) (Brown 1997). During this time, Gilchrist became Professor and Head of the Zoology Department of the South African College, which later became the University of Cape Town (UCT) in 1918, and remained in post until he retired.

Other surveys to collect data around South Africa, especially in the Cape, included the *Planet* in May 1906 (Brennecke 1909) and the Seiner Majestät Schiff (SMS) *Möwe* in April 1911 (Brennecke 1915). Thereafter, a lack of funding and the requisitioning of the *Pieter Faure* which was used by the Royal Navy during World War I, hampered surveying until the 1920s (Day 1980, Lutjeharms and Shannon 1997). However, Gilchrist continued to undertake research and published many papers during that period (see list of his publications in Brown, 1997, pp. 12-15).

Marine surveying markedly recommenced when the *Pieter Faure* was replaced by the converted whaler, the '*Pickle*' (Figure 10), in the early 1920s (Brown 1997). Not long after, in 1926, Gilchrist retired from the University of Cape Town owing to his failing health and on 28 October that year he passed away while working in his St James laboratory near Cape Town (Brown 1997).

Another giant of marine science of South Africa, John Hemsworth Osborne-Day (Figure 11), who specialised in polychaete taxonomy, came to University of Cape Town in 1937 as a junior lecturer from England (Simon and Van Niekerk 2012). However, his stay was short-lived as World War II was commenced, and his academic career was suspended when he became a squadron leader in the bomber command (Simon and Van Niekerk 2012). Day returned to the University of Cape Town in 1945 as a lecturer and became the Head of Zoology from 1946 until his retirement in 1974 (Day 2000, Simon and Van Niekerk 2012). During this time and into his retirement, Day authored more than 26 papers, four book chapters and three books (see list of Day's publications in Simon and van Niekerk 2012), and he was responsible for the erection and description of 156 new species.

Interest in marine sciences and physical oceanography of the South African coastline increased, due to the growing interest in the Agulhas Current System and the Indian Ocean (Lutjeharms and Shannon 1997), which lead to more scientific surveys. The German RV *Meteor* (1925-1927) conducted extensive research on the South Atlantic Ocean and came to Cape Town harbour in July 1925 (Lutjeharms and Shannon 1997) (Figure 12). Day also used a wooden trawling boat, the *John D.F. Gilchrist*, to train graduate students until the boat was replaced in 1966 when the University of Cape Town commissioned their own custom-made vessel, the RV *Thomas B. Davie* (Day 2000).

Figure 11. John Day at Langebaan with some students. [Image provided by Prof Charles Griffiths (UCT) from Simon and Van Niekerk (2012)]

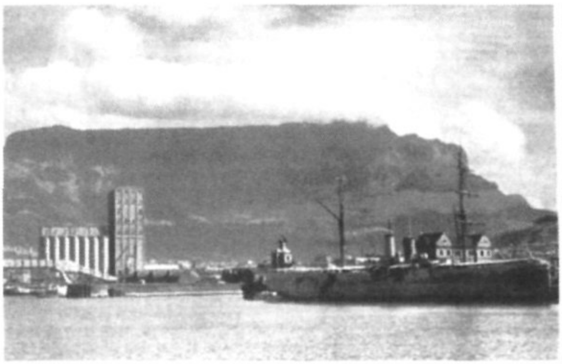


Figure 12 (left). The German RV Meteor *in Cape Town harbour in July 1925 upon the commencement of the South Atlantic expedition. [Image taken from Lutjeharms and Shannon, 1997, p. 30]*

Figure 13 (right). RV Meiring Naudé *research vessel in Durban, designed and built by the CSIR. [Image taken from Lutjeharms and Shannon, 1997, p. 35]*

The Council for Scientific and Industrial Research (CSIR) designed and built the first local coastal research vessel, RV *Meiring Naudé* (Figure 13), named after Dr Meiring Naudé, former president of the South African CSIR, which was launched in 1968 (Lutjeharms and Shannon 1997, Schumann 1998). The offshore research capabilities improved and the CSIR covered regions along the coast from the southeastern parts of the Cape up to Port Elizabeth (Schumann 1998), and completed coastal surveys of South Africa and preliminary surveys along the Namibian and Mozambican coastline (Day 2000). The FRS *Africana I* commissioned in 1982, replaced the '*Pickle*', which played a large role in the collection of benthic organisms and pelagic fish surveys along the south and east coast (Lutjeharms and Shannon 1997).

At this stage in the 20th century, a total of 14 coastal research vessels were managed and used to conduct research in South Africa, and a number of expeditions contributed largely to South African marine collections (Table 3). The SA *Agulhas*, a well-equipped Antarctic research vessel and the South African Navy vessel, the South African Ship (SAS) *Natal*, were also active during this period. These research vessels allowed for the advancement of international research collaborative programmes documenting physical oceanographical observations. During the 1980 and early 1990s, there was a sudden decline in marine research in South Africa, possibly due to funding that was cut to invest in other major marine research projects, for example the Antarctic research programme. As a result, only three of the 14 research vessels were still in use by 1994 - most vessels were sold ((Lutjeharms and Shannon 1997).

In conclusion to the aforementioned sections, the history of the European colonization and slave trade played a pivotal role in society (the imported Cape slaves and interactions with the indigenous people), infrastructure (e.g. establishment of institutions), exploration of southern Africa (including the coastline), scientific advancement (migrant scholars) and changes in faunal and floral community assemblages (e.g. introduced species due to

Table 3. List of special expeditions that resulted in the growth of marine invertebrate collection stored at SAMC. Adapted from a report compiled by Wayne K. Florence.

Expedition name	Region covered	Period	Collected By
SS *Pieter Faure*	St Helena Bay to Zululand	1897-1907	SS *Pieter Faure*
UCT Ecological Survey	Durban to Cape Town	1909-1989	*John D.F. Gilchrist* and RV *Africana II*
Lamont Geological Observatory	West Africa into south Atlantic	1950-1952	RV *Vema*
SA Museum's *Meiring Naudé* Cruises	Kosi Bay to south of East London	1975-1979	RV *Meiring Naudé*
Natal Museum's Dredging Programme	Zululand to Cape Columbine	1981-1990	RV *Meiring Naudé*
UCT Marion Island Survey	Marion Island	1984-1989	RV SA *Agulhas*
Cruise 060	Columbine and Cape Point Canyons	1988	RV *Africana*
Mozambique Scad Survey	Off Mozambique	1994	RV *Algoa*

shipping activities, agriculture, land development). As the interest in global marine faunal and floral biodiversity increased significantly in the mid-19th century, the number of migrant scholars and scientific research also increased.

4. Historical overview of the last 135 years of bryozoology in South Africa

Bryozoans were once thought to be plants and their animal affinities were confirmed around the mid-18th century. Globally, the diversity of marine Bryozoa is unknown (Florence *et al*. 2007). More so, the oft-quoted 4,000 species global bryozoan fauna has been grossly underestimated, especially considering the new level of taxonomic accuracy, available technology and exploration of unexamined habitats previously inaccessible (Hayward and Ryland 1999). In South Africa, the state of our regional taxonomic richness for marine invertebrate taxa, including Bryozoa, is largely incomplete (Griffiths *et al*. 2010, Gibbons 1999). Consequently, taxonomic studies on the South African Bryozoa are, in part, outdated and fragmented (Figure 14).

The first bryozoans from South African waters were collected during the *Challenger Expedition* in 1873. Thomas Hincks was the first to describe bryozoans from South Africa in 1880, while George Busk (Figure 15) in the late 19th century and Charles O'Donoghue (Figure 16) around the mid-20th century described a number of bryozoans from South Africa. In the late 20th century, Patricia Cook and Peter Hayward contributed significant papers on South African bryozoology.

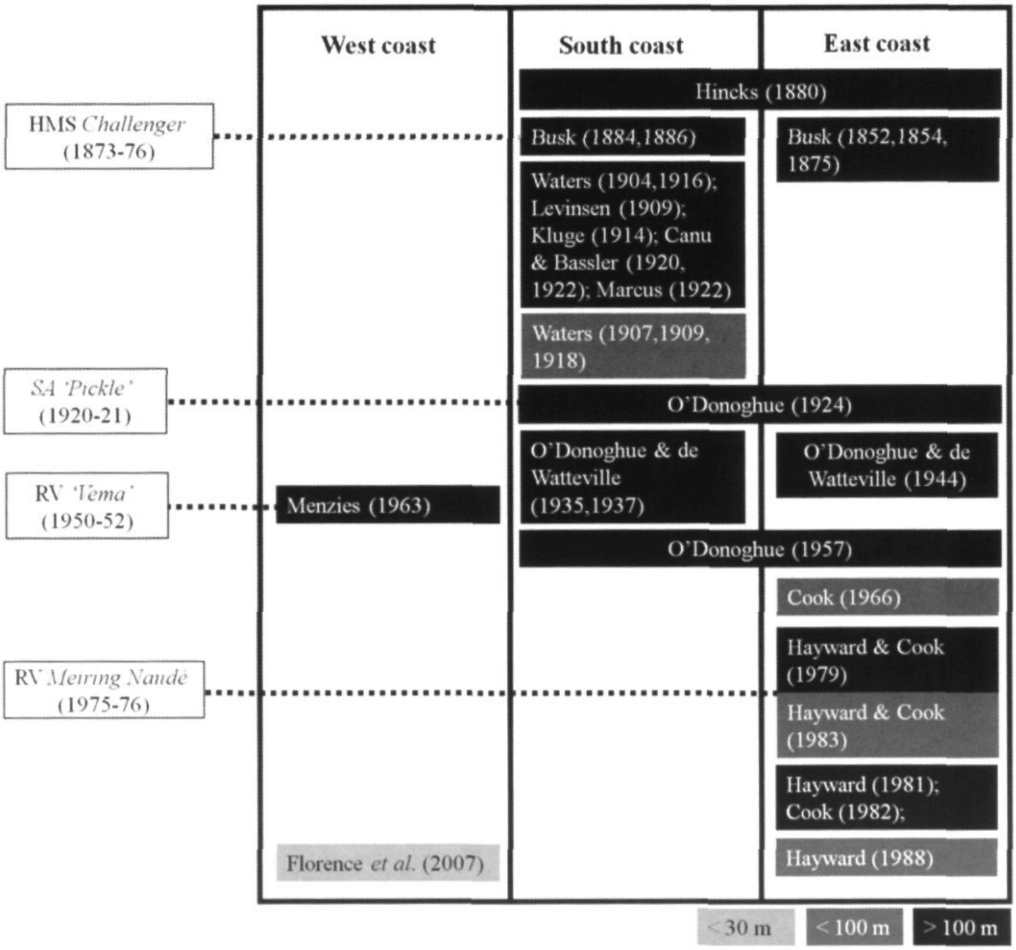


Figure 14. A summary of the published works of described South African Bryozoa since the 1800s, and, if applicable, the expedition cruise associated with the collected specimens.

4.1 Hincks and Busk, 19th century

Thomas Hincks (1818-1899) was born in Exeter, England (Wyse Jackson and Spencer Jones 2002, Calder 2009). As a Unitarian minister, he served in Ireland, in Cork and Dublin and later in England, but was also a naturalist and taxonomist. Two of his major publications were *A history of the British hydroid zoophytes* (1868) and *A history of the British marine Polyzoa* (1880), the latter publication included a large proportion of South African material.

Thirteen species, mainly from the east- and south coast of South Africa, including the new Indo-Pacific species, *Figularia fissa* (Hincks, 1880), were described (Hincks 1880). These specimens appeared to have been collected by W. Oates and some possibly by Eliza Jelly (Florence et al. 2007). In other reports, Hincks recorded *Schizoretepora tessellata*

(Hincks, 1878), *Exochella tricuspis* (Hincks, 1881) and *Rhynchozoon longirostris* (Hincks, 1881).

An additional seven species were described from Port Elizabeth in Hincks (1891), namely *Gregarinidra spinuligera* (Hincks, 1891), *Flustra nobilis* Hincks, 1891, *Laminopora bimunita* (Hincks, 1891), *Schizoporella inconspicua* Hincks, 1891, *S. scabra* Hincks, 1891, *S. pectinata* (Busk, 1884) and *Lepralia lancifera* Hincks, 1891. The latter genus *Lepralia* is considered invalid – some "*Lepralia*" species were moved to the *Schizoporella* genus – and need to be revised.

Born in St Petersburg (Russia), George Busk (1807-1886) was a British Naval surgeon, zoologist and palaeontologist (Woodward 1901, Cook 1997, Foote 2004). Elected as a Fellow of the Royal Society in 1850, Busk also served as Secretary and Vice-President of the Linnean Society of London. Additionally, he made some valuable contributions to the debate on hominid evolution (Cook 1997, Wyse Jackson and Spencer Jones 2002) having discovered the skull of Neanderthal Man, although it was another bryozoologist William King of Galway Ireland who coined the scientific name *Homo neanderthalensis*.

Figure 15. George Busk (1807-1886) who described numerous South African Bryozoa. [Image taken from http://britishbryozoans.myspecies.info/category/biographies/busk-george-1807-1886]

Figure 16. Charles H. O'Donoghue (1885-1961) who published five papers on South African bryozoans sampled from the south- and east coast. [Image taken from http://britishbryozoans.myspecies.info/content/odonoghue-charles]

Between 1849 and 1886, Busk made huge taxonomic strides in the field of bryozoology. He erected the Orders Ctenostomatida, Cyclostomatida and Cheilostomatida in a publication that reported on bryozoans collected during the HMS *Rattlesnake* expedition to Australia (Busk 1852a). Busk also examined a large amount of catalogued material in the British Museum (today, the Natural History Museum, London).

A number of specimens in this collection appeared to have been collected in Algoa Bay and Cape of Good Hope (South Africa) and published in a serial monograph, *Catalogue of Marine Polyzoa in the Collection of the British Museum (Parts 1-3)* (Busk 1852b, 1854, 1875). Altogether, in these three volumes, approximately 308 species were described (not taking into account the number of potential synonymies associated with various species), with 25 species recorded from South Africa. About 17 cheilostome species were described in Busk (1852b, 1854), while four cyclostome species, namely *Lichenopora ciliata* (Busk, 1875), *Tennysonia stellata* Busk, 1875 recorded from the Cape of Good Hope; *Mecynoecia clavaeformis* (Busk, 1875) and *Idmidronea contorta* (Busk, 1875) from Algoa Bay were described. *Discoporella algoensis* Busk, 1875 from Algoa Bay was described, but appears to be unrecognizable and not described in other known literature.

The *Challenger* collection (see "*A brief history of scientific voyages around South Africa, 19th and 20th century*" in this paper), lodged at the Natural History Museum, London, include various marine calcareous specimens such as ostracods, echinoderms, brachiopods, molluscs (gastropods and bivalves), foraminiferans, corals and bryozoans. The South African bryozoan material, collected in Simon's Bay and south of the Cape of Good Hope, was examined by Busk and published in the *Report on the Polyzoa collected by H.M.S. Challenger during the years 1873-1876 (Part 1 and 2)*. In these reports about 28 cheilostome and two cyclostomes bryozoans were described (Busk 1884, 1886).

4.2 After Busk, 20th century

In the early 1900s, the British bryozoologist Arthur William Waters (1846-1929), a Fellow of the Linnean Society, reported about 18 bryozoan species from South Africa in six publications (Waters 1904, 1907, 1909, 1916, 1918, 1919). In Waters (1904) seven species reported from Antarctic or sub-Antarctic regions, also occur in South Africa. The five Antarctic species included *Chaperiopsis cervicornis* (Busk, 1854), *Turritigera stellata* Busk, 1884, *Hippothoa divaricata* Lamouroux, 1821, *Exidmonea atlantica* (Forbes in Johnston, 1847) and *Neofungella claviformis* (Waters, 1904), while *Beania magellanica* (Busk, 1852) and *Microporella malusii* (Audouin, 1826) were recorded from sub-Antarctic regions.

Waters also examined material from the Cyril Crossland collection (Waters 1908, 1918) and reported eight species from the Sudanese Red Sea and Cape Verde Islands that occur in South Africa. However, in many of these works by Waters, species present in South Africa were merely noted, and therefore in many instances invalid (Florence *et al.* 2007).

A few other reports also included some South African bryozoan species (Levinsen

1909, Kluge 1914, Canu and Bassler 1920, 1922, Marcus 1922. Georg Marius Reinald Levinsen (1850-1914) was the museum curator at the Zoological Museum of Copenhagen. His work comprised mainly morphological and systematic studies on cheilostomatous bryozoans. Twelve cheilostome species from South Africa were listed in Levinsen (1909) and he referred to some of Hincks's and Busk's illustrations.

The Russian zoologist German (Herman) Avgustovich Kluge (1871-1956) examined bryozoan material collected from the Southern Ocean and from South Africa, as part of the German South Polar Expedition during 1901-1903 (Kluge, 1914). The six species described from South Africa, included *Bugula calathus* Norman, 1868, *Chaperiopsis multifida* (Busk, 1884), *Chaperia acanthina* (Lamouroux, 1825), *Beania vanhoeffeni* Kluge, 1914, *Membranipora polystachys* Kluge, 1914 and *Aetea annulata* Kluge, 1914, with the latter three species considered as erroneous. For example, *A. annulata* is considered to be the junior synonym of *Sertularia anguina* (Linnaeus, 1758), which is the basionym of *A. anguina*.

Ray Smith Bassler (1878-1961) grew up in Cincinnati (USA) and initially specialized in Ordovician fossils (Cuffey et al. 2002, Wyse Jackson and Spencer Jones 2007). Later, his expertise included Recent Bryozoa and published the first volume of the *Treatise on Invertebrate Paleontology* (Bassler 1953). In 1904 he was appointed as an assistant curator in the Department of Geology at the National Museum of Natural History in Washington DC and continued his affiliation at the museum until he retired.

Bassler began corresponding with the French palaeontologist Ferdinand Canu (1863-1932) in 1902, but they only met for the first time in 1926 (Sanner 2002). They developed a productive collaboration that resulted in a large number of important publications (Canu and Bassler 1920, 1922, 1927, 1929, 1930). Canu received the Daniel Giraud Elliot Medal in 1923 for his contribution on *North American Later Tertiary and Quaternary Bryozoa* (Sanner 2002). Canu and Bassler (1920, 1922) recorded one cheilostome species, *Mastigophora hyndmanni* (Johnston, 1847), and two cyclostome species, *T. stellata* (Busk, 1875) and *T. contorta* (Busk, 1875), from South Africa.

Ernst Gustav Gotthelf Marcus (1893-1968) was born in Germany and studied zoology in 1912 at the University of Berlin originally intending to become a coleopterist. Research towards his doctoral studies (on Coleoptora) begun in the Entomology Department at the Berlin Museum were interrupted by World War I. After the war he returned to the University of Berlin and completed his doctorate in 1919. Marcus continued working at the museum, but later immersed himself in taxonomic study of bryozoans, working up collections from German, Danish and Swedish expeditions to the Pacific, Australia, South Africa and from various European museum collections (Winston 2002).

From the South African material in Gothenburg Natural History Museum, Sweden, Marcus (1922) recorded 21 bryozoan species from the Cape of Good Hope. The cheilostome species include *Beania magellanica* (Busk, 1852), *Chaperia capensis* (Busk, 1884), *Chaperiopsis multifida* (Busk, 1884), *Gregarinidra spinuligera* (Hincks, 1891), *Hoplitella armata* (Busk, 1852), *Menipea crispa* (Pallas, 1766), *M. ornata* (Busk, 1852), *Foveolaria imbricata* (Busk, 1884), *Alysidium parasiticum* Busk, 1852, *Cellaria punctata*

(Busk, 1852), *Laminopora jellyae* (Levensen, 1909), *Schizoporella inconspicua* Hincks, 1891, *Calyptotheca nivea* (Busk, 1884), *Flustramorpha flabellaris* (Busk, 1854) and *Jellyella tuberculata* (Bosc, 1802).

Hayward (1988) noted that *Adeonella glypta* Marcus, 1922 was well described and figured from material collected off Port Alexander in Angola, but the type material was not available for examination and no other known material of this species has been collected. Three cyclostomes species, *Bicrisia edwardsiana* (d'Orbigny, 1841), *T. contorta* (Busk, 1875), *Hornera americana* d'Orbigny, 1842, and one ctenostome, *Alcyonidium flustroides* Busk, 1886 were recorded. The latter species was also recorded in O'Donoghue (1924).

Another major contributor to early South African Bryozoa taxonomy, was Charles Henry O'Donoghue (1885-1961) who was Professor of Zoology in the University of Reading from 1939 to 1952 (Anon 1939). O'Donoghue (1924, 1957), and together with Dora de Watteville (1935, 1937, 1944), attempted to record comprehensively the bryozoan fauna of South Africa. He reported on the bryozoan fauna collected by the SS '*Pickle*', commissioned by the Fisheries and Marine Biological Survey during 1920-1921 and headed by Dr J.D.F. Gilchrist (O'Donoghue 1924). In addition, this work also includes specimens collected along the shoreline and by trawlers, which were collected from Table Bay, False Bay, Cape Infanta and as far east as the mouth of the Illovo River. In this paper he recorded 55 bryozoan species of which 17 species were previously located from South Africa, 15 were reported from elsewhere and 25 were new.

In total O'Donoghue and de Watteville recorded a total of 68 species from South Africa of which 17 were new records for the region, and 14 were considered new. Professor T.A. Stephenson collected these specimens during ecological studies by the University of Cape Town. O'Donoghue (1957) recognised 36 species of which one, *Parasmittina natalense* O'Donoghue 1957, was new and three species, *Acanthodesia savartii* (Audouin, 1826), *Conopeum reticulum* (Linnaeus, 1767) and *Cryptosula pallasiana* (Moll, 1803) appeared to be new records for South Africa.

Despite the efforts by Busk and O'Donoghue to describe South African specimens, several taxonomic problems arose. Eurocentric tendencies to assign European names to South African specimens frequently arose (Hayward and Cook 1983). These synonymies are still to be resolved.

During the second half of the 20th century, the German expedition cruise of the RV '*Vema*' in 1950-1952 sampled the deep-sea fauna at depths exceeded 2000 m, along the Atlantic Ocean of West Africa. Specimens of *Kinetoskias* were examined within this collection; only one species, *Kinetoskias pocillum* Busk, 1881 was recorded off South Africa in the South Atlantic in a sample taken at 3,049 m (Menzies 1963). The genus *Kinetoskias* consists of abyssal species found mostly in the Arctic Ocean and near-Arctic localities (Kluge 1953).

Patricia Lynette Cook (b. 1927) worked as an assistant and later in 1964 became Head of the Bryozoa Section at the Natural History Museum, London. Her published work includes descriptions of African collections and studies of larval development in

Membranipora (Cook 1962, Cook and Hayward 1966). Cook (1966) described specimens collected by Dr J.D.F. Gilchrist between 1903 and 1904 off Durban on the east coast of South Africa; in this paper she erected four cheilostome species, namely *Conescharellina africana* Cook, 1966, *Anoteropora inarmata* Cook, 1966, *Batopora murrayi* Cook, 1966 and *Lacrimula pyriformis* Cook, 1966. Cook also examined some African species in the Family Adeonellidae, which included an assessmant of South African *Laminopora* and *Adeonella* species (Cook 1982).

Peter Joseph Hayward was first introduced to bryozoans as a scientific assistant at the Natural History Museum, London at the age 16. Subsequently, he graduated from University of Reading in 1970 in Zoology and received his Ph.D. in 1974 from the University of Swansea under the supervision of John S. Ryland, with whom he collaborated on the serial monographs of *Synopses of the British Fauna*. Hayward has published extensively on the taxonomy, morphology and biology of marine bryozoans of the North Atlantic, Antarctica, Southwest Pacific and the deep sea.

Cook and Chimonides (1981) examined a few specimens from the RV *Meiring Naudé* collection, and erected one new cheilostome species *Tropidozoum burrowsi*. Hayward and Cook co-authored two comprehensive taxonomic reports on RV *Meiring Naudé* material (Hayward and Cook 1979, 1983). In the first paper a total of one ctenostome, two cyclostomes and 48 cheilostome bryozoans were described, of these 23 species were considered new. Moreover, three new genera, *Notocoryne*, *Leiosalpinx* and *Inversiscaphos*, and one new family, Setosellinidae were introduced. These samples were collected during 1975 and 1976 at depths ranging from 376-1300 m along the south and east coast.

Samples collected in 1977 and 1979 from shallower depths (<100 m) of the same area yielded a total of 38 anascan cheilostomes, 76 ascophoran cheilostomes and 16 cyclostomes, of which 44 species were new and one new genus *Dactylostega* introduced (Hayward and Cook 1983). The authors noted that the South African bryozoan fauna includes a high proportion of endemic species, but also it exhibits a marked faunal affinity with the Indo-West-Pacific region.

Additionally, Hayward (1988) reviewed *Adeonella* by examination of the material in the Natural History Museum, London. Globally, 41 species were recorded, of which 15 species were newly defined in this paper. Of the newly described species, nine were recorded from South Africa, which now has yielded a total of 31 *Adeonella* species of which 27 species have not been found elsewhere. The highest diversity of *Adeonella* species occurs on the eastern coast of South Africa.

4.3 Bryozoology in 21st century

Florence *et al*. (2007) conducted the first study of the shallow-water (depths <30 m) bryozoans of the west coast of South Africa. Sixty three species were recorded, of which 15 cheilostome species (*Beania minuspina*, *Bicellariella bonsai*, *Bitectipora umboavicula*, *Celleporina solida*, *Chaperia septispina*, *Escharoides custodies*, *Fenestrulina elevora*, *Klugeflustra jonesii*, *Membranipora rustica*, *Micropora latiavicula*, *Microporella madiba*, *Rhynchozoon abscondum*, *Schizosmittina lizzya*, *Thalamoporella spiravicula*) and one cyclostome species (*Eurystrotos planus*) was newly described. In total hitherto, more than 270 valid species (within the three orders Cheilostomatida, Cyclostomatida and Ctenostomatida) represented in 74 families and 130 genera have been recorded in South Africa.

Bryozoan projects are currently underway, for example, the compilation of a species list for shallow-water bryozoan species from the south and east coast. An incidental collection of bryozoans made by the *Dr Fritjov Nansen*, a demersal trawler, in deep-water (95 m) on the south coast of South Africa, revealed twelve species, with one as yet unnamed new species (Wayne K. Florence, unpublished data). Additionally, more than 1,500 undetermined specimens are estimated to be contained in the bryozoan collection lodged in SAMC—the majority of which were collected during the University of Cape Town Ecological Survey, and is currently being examined.

Future projects include sampling in deeper waters on the west coast and assessments of the molecular biology in conjunction with analyses of the morphological taxonomy of bryozoans. Taking into account that there are spatial gaps in bryozoan distribution (e.g. deep-water regions poorly sampled) and taxonomic bias (shortage of bryozoan taxonomists and lack of interest), the true species richness and diversity in South Africa may be grossly underestimated.

4.4 Iziko South African Museum marine invertebrate collections

Annual surveys such as the University of Cape Town Ecological Survey, pelagic and benthic surveys by the Department of Environmental Affairs and the Department of Agriculture, Forestry and Fisheries, has undoubtedly increased our biodiversity knowledge of the benthic invertebrate fauna. A set of comprehensive collections resulting from these surveys with undetermined specimens are housed in the Marine Collection at SAMC.

It is important to note that these extensive marine collections within SAMC are managed by only two curators - one for the Marine Invertebrate Collections and one for the Marine Fish Collections. Only three African bryozoologists (two from South Africa and one from Tunisia) attended the International Bryozoological Association meeting (June 2013) in Catania, Italy in June 2013. It is imperative that interest in bryozoans from Africa is raised so that targeted research will take place on bryozoans occurring along the African coast, There is also a need for additional trained taxonomists.

The primary marine invertebrate collections stored at SAMC comprises of approximately 129,000 records, and constitutes significant coverage of all major marine invertebrate taxa, excluding almost 17,000 catalogued marine invertebrate fossil records for this region (Table 4; also see Griffiths *et al*. 2010). The current Bryozoa collection at SAMC has 1,225 catalogued specimens, excluding unworked specimens within the collection estimated to be more than 1,500 samples, the majority of which are yet to be determined to species-level.

Table 4. Summary of extant marine invertebrates in the SAMC collections in decreasing order. An estimated number of unaccessioned lots per phylum are listed. Compiled by using Specify 6.5.02 *software and personal communication with collections' managers in SAMC.*

Taxonomic group	**Number of lots accessioned**	**Estimated number of lots unaccessioned**
Kingdom Protoctista		
Foraminefera	142	0
Dinoflagellata	33	0
Plankton	0	60,000
Kingdom Animalia		
Molluscs	26,658	1,700
Crustacea	18,406	4,500
Cnidaria	4,830	2,400
Echinodermata	2,607	600
Annelida	1,942	600
Bryozoa	1,225	1,000
Pycnogonids	391	44
Porifera	245	1,000
Ascidiacea	234	50
Helminth worms and Nemertea	157	70
Brachiopoda	138	0
Sub-totals	57,008	71,964

Estimated total number of specimens: 128,972

Of the 1,225 catalogued specimens, 1,028 specimen records have location data (Figure 17), and this shows that the known ranges of bryozoan species occurring in South African waters is very patchy. In addition to unstudied extant bryozoans samples, there are a large number of fossil bryozoans in the collection, but only one fossil bryozoan has been catalogued (Eugene Bergh, pers. comm.). Although bryozoans are considered to be one of the most abundant animal fossils (McKinney and Jackson 1989), to date, few studies have been conducted on fossil Bryozoa in South Africa. Tate (1867) reported on some South African Jurassic bryozoans, while more recently Kohring and Hörnig (2002) described rare fossilised statoblasts of freshwater bryozoans from the Triassic of the Molteno Formation of the Karoo Supergroup. This suggests either a lack of interest in fossil Bryozoa (which seems unlikely), or more probably a lack of specialist taxonomists in the country, which is unfortunate considering southern Africa's rich fossil record.

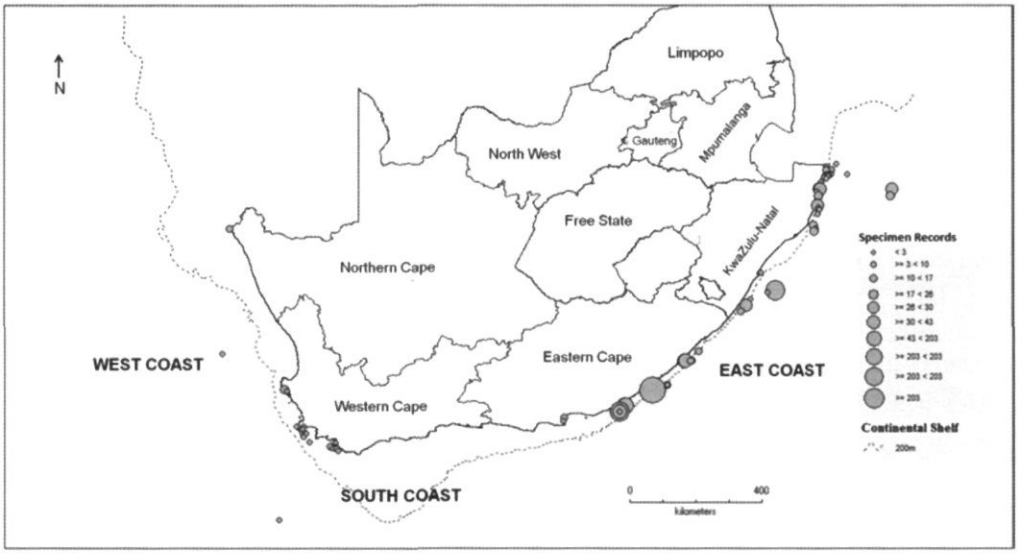


Figure 17. Approximately 1,028 catalogued bryozoan specimens (with location data) currently housed at SAMC. Clear gaps exist as west and south coast samples have remained unsorted and undetermined for years. Additionally, lack of sampling in deeper waters highlight gaps in biodiversity knowledge and bryozoan diversity.

5. Conclusion

Research on South African marine biology and biodiversity commenced during the colonial years in the 17th century. Infrastructure grew rapidly with an increase in the European settler population allowing for the establishment in 1825 of the first museum in sub-Saharan Africa, the South African Museum. The European settlers of South Africa included naturalists and taxonomists from Britain and Europe, who came to study the local biota. European colonialism, therefore, brought upon a new era of scientific discoveries, for example by conducting large marine surveys along the South African coastline, and bringing considerable scientific expertise to the region.

In addition to the large collections assembled by various scientific cruises such as the HMS *Challenger* and RV *Meiring Naudé*, systematic research was carried out in order to understand biodiversity and distribution patterns along the South African coast. These studies, however, were focussed mainly on fish, molluscs and crustaceans, and certain benthic marine invertebrates, such as sponges and bryozoans, were neglected. Consequently, taxonomic studies on the South African Bryozoa are, in part, outdated and fragmentary with spatial and temporal gaps in our biodiversity knowledge.

The first published account of South African bryozoan was that of Hincks (1880), but majority of description of species were provided by George Busk using specimens in the British Museum and *Challenger* collections. Most of the South African collections were taken back to Europe and lodged at various European museums, including the Natural

History Museum, London. The sensitive issue surrounding repatriation of collections belonging to South Africa is debatable. Assigning European names to South African specimens were very common and synonymies still need to be resolved.

Florence *et al.* (2007) estimated that, to date, over 270 valid bryozoan species have been recorded in South African waters, but temporal and spatial gaps in our biodiversity knowledge may yield several new species and records. Over 1,500 bryozoan samples, the majority from south coast collections stored at SAMC, have remained undetermined. Therefore, valuable historical and recent data "locked" in museum collections have the potential to aid in understanding marine benthic diversity and biogeography of the marine realm around South Africa.

Acknowledgments

MB would like to thank Mary Spencer Jones for hosting a research visit to the Natural History Museum in London in June and July 2013 that led to conceptualizing this paper. We thank Eugene Bergh (Iziko South African Museum, Cape Town) and Genevieve Thompson (South African National Biodiversity Institute) for their comments on the manuscript.

References

Anon. 1939. Dr. C.H. O'Donoghue. *Nature* **143**, 510.

Bassler, R.S. 1953. Bryozoa. Part G. *Treatise on Invertebrate Paleontology*. Geological Society of America, Boulder and University of Kansas Press, Lawrence.

Brennecke, W. 1909. Oseanographie. *Forschungsreise S.M.S. "Planet" 1906-1907*. Reichs-Marine-Ampt, Band 3, Berlin.

Brennecke, W. 1915. Ozeanographische Arbeiten S.M.S. *Möwe* im westlichen Indischen Ozean 1913. *Annalen der Hydrographie und Maritimen Meteorologies* **43**, 3–16.

Brown, A.C. (ed.) 1977. *A history of scientific endeavour in South Africa: a collection of essays published on the occasion of the centenary of the Royal Society of South Africa*. Royal Society of South Africa, Cape Town, pp. xx+516 pp.

Brown, A.C. 1997. John D.F. Gilchrist and the early years of marine science in South Africa. *Transactions of the Royal Society of South Africa* **52**, 2–16.

Busk, G. 1852a. An account of the Polyzoa, and sertularian zoophytes, collected in the Voyage of the Rattlesnake, on the coasts of Australia and the Louisiade Archipelago, pp. 343–402. *In* J. Macgillivray in *Narrative of the voyage of H.M.S. Rattlesnake*. T. & W. Boone, London.

Busk, G. 1852b *Catalogue of Marine Polyzoa in the collection of the British Museum. 1. Cheilostomata (part)*. Trustees of the British Museum, London, pp. 1–39.

Busk, G. 1854. *Catalogue of Marine Polyzoa in the collection of the British Museum. 2. Cheilostomata*. Trustees of the British Museum (Natural History), London, pp. 1–55–120.

Busk, G. 1875. *Catalogue of the marine Polyzoa in the collection of the British Museum. 3. Cyclostomata*. Trustees of the British Museum (Natural History), London, pp. 1–39.

Busk, G. 1884. Report on the Polyzoa collected by H.M.S. Challenger during the years 1873-1876. Part 1. The Cheilostomata. *Report on the Scientific Results of the Voyage of the H.M.S. "Challenger", Zoology* **10**, 1–216.

Busk, G. 1886. Report on the Polyzoa collected by H.M.S. Challenger during the years 1873-1876. Part II. The Cyclostomata, Ctenostomata and Pedicellinea. *Report on the Scientific Results of the Voyage of the H.M.S. "Challenger", Zoology* **17**, 1–47.

Calder, D.R. 2009. The Reverend Thomas Hincks FRS (1818-1899): taxonomist of Bryozoa and Hydrozoa. *Archives of Natural History* **36**, 189–217.

Canu, F. and Bassler, R.S. 1920. North American early Tertiary Bryozoa. *Bulletin of the United States National Museum* **106**, 1–879.

Canu, F. and Bassler, R.S. 1922. Studies on the cyclostomous Bryozoa. *Proceedings of the United States National Museum* **61**, 1–160.

Canu, F. and Bassler, R.S. 1927. Classification of the cheilostomatous Bryozoa. *Proceedings of the United States National Museum* **69**, 1–42.

Canu, F. and Bassler, R.S. 1929. Bryozoa of the Phillipine Region. *Bulletin of the United States National Museum* **9**, 1–685.

Canu, F. and Bassler, R.S. 1930. The bryozoan fauna of the Galapagos Islands. *Proceedings of the United States National Museum* **76**, 1–78.

Coates, P. 2012. Was the South African Library an Anthenaeum? *Quarterly Bulletin of the National Library of South Africa* **66**, 11–23.

Cook, G.C. 1997. George Busk FRS, 1807–1886, nineteenth-century polymath: surgeon, parasitologist, zoologist, and palaeontologist. *Journal of Medical Biography* **5**, 88–101.

Cook, P.L. 1962. The early larval development of *Membranipora seurati* (Canu) and *Electra crustulenta* (Pallas), (Polyzoa Ectoprocta). *Cahiers de Biologie Marine* **3**, 57–60.

Cook, P.L. 1966. Some "sand fauna" Polyzoa (Bryozoa) from Eastern Africa and the northern Indian Ocean. *Cahiers de Biologie Marine* **7**, 207–223.

Cook, P.L. 1982. Notes on some African Adeonellidae (Bryozoa, Cheilostomata). *Journal of Natural History* **16**, 833–846.

Cook, P.L. and Chimonides, P.J. 1981. Morphology and systematics of some interior-walled cheilostome Bryozoa. *Bulletin of the British Museum (Natural History), Zoology* **41**, 53–89.

Cook, P.L. and Hayward, P.J. 1966. The development of Conopeum seurati (Canu), and some other species of Membraniporine Polyzoa. *Cahiers de Biologie Marine* **7**, 437–443.

Costello, M.J., Coll, M., Danovaro, R., Halpin, P., Ojaveer, H. and Miloslavich, P. 2010. A census of marine biodiversity knowledge, resources, and future challenges. *PLoS One* **5**, 1–15.

Cowling, R.M., MacDonald, I.A.W. and Simmons, M.T. 1996. The Cape Peninsula, South Africa: physiographical, biological and historical background to an extraordinary hot-spot of biodiversity. *Biodiversity and Conservation* **5**, 527–550.

Cuffey, R.J., Davis, R.A. and Utgaard, J. 2002. The Cincinnatian bryozoologists, pp. 59–79. *In* P.N. Wyse Jackson and M.E. Spencer Jones (eds) *Annals of Bryozoology: aspects of the history of research on bryozoans*. International Bryozoology Association, Dublin.

Day, J.A. 2000. Marine and estuarine studies in South Africa: an historical perspective. *Transactions of the Royal Society of South Africa* **55**, 101–105.

Day, J.H. 1977. Marine Biology in South Africa, pp. 86-108. *In* A.C. Brown (ed.) *A history of scientific endeavour in South Africa: a collection of essays published on the occasion of the centenary of the Royal Society of South Africa*. Royal Society of South Africa, Cape Town, pp. xx+516 pp.

Day, J.H. 1980. *Unpublished notes on the history of the Zoology Department, University of Cape Town.*

Duda, A.M. and Sherman, K. 2002. A new imperative for improving management of large marine ecosystems. *Ocean & Coastal Management* **45**, 797–833.

Florence, W.K., Hayward, P.J. and Gibbons, M.J. 2007. Taxonomy of shallow-water Bryozoa from the west coast of South Africa. *African Natural History* **3**, 1–58.

Foote, Y. 2004. Busk, George (1807–1886). *Oxford Dictional of National Biography* <http://dx.doi.org/10.1093/ref:odnb/4168>

Gibbons, M.J. (and numerous contributors) 1999. The taxonomic richness of South Africa's marine fauna: a crisis at hand. *South African Journal of Science* **95**, 8–12.

Goldblatt, P. and Manning, J. 2002. Plant diversity of the Cape Region of South Africa. *Annals of the Missouri Botanical Garden* **89**, 281–302.

Griffiths, C.L., Robinson, T.B., Lange, L. and Mead, A. 2010. Marine biodiversity in South Africa: An evaluation of current states of knowledge. *PLoS One* **5**, 1–13.

Hayward, P.J. 1988. The recent species of *Adeonella* (Bryozoa: Cheilostomata) including descriptions of fifteen new species. *Zoological Journal of the Linnean Society* **94**, 111–191.

Hayward, P.J. and Cook, P.L. 1979. The South African Museum's Meiring Naudé Cruises. Part 9, Bryozoa. *Annals of the South African Museum* **79**, 43–130.

Hayward, P.J. and Cook, P.L. 1983. The South African Museum's Meiring Naudé Cruises. Part 13, Bryozoa II. *Annals of the South African Museum* **91**, 1–161.

Hayward, P.J. and Ryland, J.S. 1999. Cheilostomatous Bryozoa. Part 2. Hippothoidea - Celleporoidea. *Synopses of the British Fauna*, New Series, **14**, 1–416. Field Studies Council, Shrewsbury.

Hill, A.E., Hickey, B.M., Shillington, F.A., Strub, P.T., Brink, K.H., Barton, E.D. and Thomas, A.C. 1998. Eastern ocean boundaries, coastal segment (E). Chapter. 2, pp. 29–67. *In* A.R. Robinson and K.H. Brink (eds). *The Sea*, Volume 11, *The Global Coastal Ocean: Regional Studies and Syntheses*, John Wiley & Sons, New York.

Hincks, T. 1880. *A history of the British Marine Polyzoa*. 2 volumes. Van Voorst, London.

Hincks, T. 1891. Contributions towards a general history of the marine Polyzoa. XV.

South African and other Polyzoa. *Annals and Magazine of Natural History* Series 6, **7**, 285–298.

Hughes, G.R. 1974. The sea turtles of south-east Africa II. The biology of the Tongaland loggerhead turtle *Caretta caretta* L. with comments on the leatherback turtle *Dermochelys coriacea* L. and the green turtle *Chelonia mydas* L. in the study region. *South African Association for Marine Biological Research. Investigational Report* **36**, 1–96.

Kennedy, D. 2004. Smith, Sir Andrew (1797–1872), army medical officer and naturalist. *Oxford Dictionary of National Biography* <http://dx.doi.org/10.1093/ref:odnb/25772>

Kluge, G.A. 1914. Die Bryozoen der deutschen Südpolar-Expedition 1901-1903 I. Die Familien Aetidae, Cellularidae, Bicellaridae, Farciminaridae, Flustridae, Membraniporidae und Cribilinidae. *Deutsch Südpolar-Expedition Zoology* **15**, 599–678.

Kluge, G.A. 1953. The distribution of Bryozoa belonging to the genus *Kinetoskias* (Danielssen). *Trudy Zool. Instituta, Ross. Akad. Nauk. St. Peterbg. [= Proc. Zool. Inst. Russ. Acad. Sci. St. Petersburg]* **13**, 210–215 (in Russian).

Kohring, R. and Hörnig, A. 2002. Freshwater bryozoan remains from the Molteno Formation (Upper Triassic) of South Africa, pp. 171–174. *In* P.N. Wyse Jackson, C.J. Buttler and M.E. Spencer Jones (eds). *Bryozoan Studies 2001*. A.A. Balkema, Lisse.

Kolb, P. 1727. *Naaukeurige en uitvoerige beschrijving van de Kaap de Goede Hoop*. Balthazar Lakeman, Amsterdam. Volume 1, i–xviii+1–529 pp.

Levinsen, G.M.R. 1909. *Morphological and Systematic Studies on the Cheilostomatous Bryozoa*. Nationale Forfatteres Forlag, Copenhagen.

Lombard, A.T., Strauss, T., Harris, J., Sink, K., Attwood, C. and Hutchings, L. 2004. *South African National Spatial Biodiversity Assessment 2004 Technical Report. Volume 4: Marine Component*. South African National Biodiversity Institute, Pretoria.

Lutjeharms, J.R.E. 2006. The ocean environment off southeastern Africa: a review. *South African Journal of Science* **102**, 419–427.

Lutjeharms, J.R.E. and Shannon, L.V. 1997. A century of physical oceanography in South Africa; in search of the legacy of John D.F. Gilchrist. *Transactions of the Royal Society of South Africa* **52**, 17–50.

Marcus, E. 1922. Südafrikanische Bryozoen aus der Sammlung des Gothenburger Museums. *Göteborgs Kongligen Vetenskaps och Vitterhets Samhalles Handlingar* **25**, 1–45.

McKinney, F.K. & Jackson, J.B.C. 1989. *Bryozoan Evolution*. Unwin Hyman, Boston.

Mead, A., Carlton, J.T., Griffiths, C.L. and Rius, M. 2011. Revealing the scale of marine bioinvasions in developing regions: a South African re-assessment. *Biological Invasions* **13**, 1991–2008.

Menzies, R.J. 1963. Abyssal Bryozoa collected by expeditions of the Lamont Geological Observatory 1. Bicellariellidae (Bugulidae of Authors), *Kinetoskias*. *American Museum Novitates* **2130**, 1–8.

Mittermeier, R.A., Myers, N., Thorsen, J.B., da Fonseca, G.A.B. and Olivieri, S. 1998.

Biodiversity hotspots and major tropical wilderness areas: approaches to setting conservation priorities. *Conservation Biology* **12**, 516–520.

Mittermeier, R.A., Robles-Gil, P. and Mittermeier, C.G. 1997. *Megadiversity: Earth's biologically wealthiest nations*. CEMEX conservation book series. Volume 5. 501, pp.

Morris, R.O. 1986. Surveying ships of the Royal Navy from Cook to the computer age. *The Mariner's Mirror* **72**, 385–410.

Myers, N., Mittermeier, R.A, Mittermeier, C.G., da Fonseca, G.A.B. and Kent, J. 2000. Biodiversity hotspots for conservation priorities. *Nature* **403**, 853–858.

O'Donoghue, C.H. and de Watteville, D. 1935. A collection of Bryozoa from South Africa. *Zoological Journal of the Linnean Society* **39**, 203–218.

O'Donoghue, C.H. and de Watteville, D. 1937. Notes on South African Bryozoa. *Zoologischer Anzeiger* **117**, 12–22.

O'Donoghue, C.H. and de Watteville, D. 1944. Additional notes on Bryozoa from South Africa. *Annals of the Natal Museum* **10**, 407–432.

O'Donoghue, C.H. 1924. *The Bryozoa (Polyzoa) collected by the S.S. "Pickle". Report on the Fisheries Marine Biological Survey of South Africa* **10**, 1–63.

O'Donoghue, C.H. 1957. Some South African Bryozoa. *Transactions of the Royal Society of South Africa* **35**, 71–95.

Olson, D.M. and Dinerstein, E. 1998. The Global 200: A representation on approach to conserving the Earth's distinctive ecoregions. *Conservation Biology* **12**, 502–515.

Perry, S.M. and Fautin, D.G. 2003. Challenger Expedition (1872-1876). <http://hercules.kgs.ku.edu/hexacoral/expeditions/challenger_1872-1876/challenger.html>

Pletcher, K. (ed.) 2010. *The Brittanica Guide to explorers and explorations that changed the modern world*. Brittanica Educational Publishing, Rosen Educational Services, 350 pp.

Rennell, J. 1778. *Chart of the Bank and Current of Cape Lagullas*.

Rennell, J. 1832. *An Investigation of the Currents of the Atlantic Ocean, and of those which prevail between the Indian Ocean and the Atlantic*. J.G. & T. Rivington, London, 359 pp.

Sanner, J. 2002. Canu and Bassler, pp. 243–250. *In* P.N. Wyse Jackson and M.E. Spencer Jones (eds) *Annals of Bryozoology: aspects of the history of research on bryozoans*. International Bryozoology Association, Dublin.

Schumann, E. H. 1998. The coastal ocean off southeast Africa, including Madagascar (15,W), pp. 557–581. *In* A.R. Robinson and K.H. Brink (eds). *The Sea*, Volume 11, *The Global Coastal Ocean: Regional Studies and Syntheses*. John Wiley & Sons, New York.

Scott, R.J., Griffiths, C.L. and Robinson, T.B. 2012. Patterns of endemicity and range restriction among southern African coastal marine invertebrates. *African Journal of Marine Science* **34**, 341–347.

Shannon, L.V. 1985. The Benguela ecosystem. I. Evolution of the Benguela, physical features and processes. *Oceanography and Marine Biology: an annual review* **23**, 105–182.

Shillington, F.A., Reason, C.J.C., Duncombe Rae, C.M., Florenchie, P. and Benven, P. 2006. Large-scale physical variability of the Benguela Current large marine ecosystem (BCLME), pp. 47–68. *In* Shannon, V., Hempel, G., Malanotte-Rizzoli, P., Moloney, C. and Woods, J. (eds) *Large Marine Ecosystems*. Volume 14. Elsevier Science.

Simon, C.A. and Van Niekerk, S.E. 2012. A brief history of John Day. *A Guide to the shell-infesting spionids of South Africa*. <http://www0.sun.ac.za/polychaete/>

Sink, K.J., Attwood, C.G., Lombard, A.T., Grantham, H., Leslie, R., Samaai, T., Kerwath, S., Majiedt, P., Fairweather, T., Hutchings, L., van der Lingen, C., Atkinson, L.J., Wilkinson, S., Holness, S. and Wolf, T. 2011. *Spatial planning to identify focus areas for offshore biodiversity protection in South Africa. Final Report for the Offshore Marine Protected Area Project*. South African National Biodiversity Institute, Pretoria.

Sink, K.J., Holness, S., Harris, L., Majiedt, P., Atkinson, L., Robinson, T., Kirkman, S., Hutchings, L., Leslie, R., Lamberth, S., Kerwath, S., von der Heyden, S., Lombard, A., Attwood, C., Branch, G., Fairweather, T., Taljaard, S., Weerts, S., Cowley, P., Awad, A., Halpern, B., Grantham, H. and Wolf, T. 2012. *National Biodiversity Assessment 2011: Technical Report*. Volume 4: Marine and Coastal Component. South African National Biodiversity Institute, Pretoria, pp. 325.

Sloan, S., Jenkins, C.N., Joppa, L.N., Gaveau, D.L.A. and Laurance, W.F. 2014. Remaining natural vegetation in the global biodiversity hotspots. *Biological Conservation* **177**, 12–24.

Summers, R.F.H. 1975. *A history of the South African Museum, 1825 - 1975*. Published for the Trustees of the South African Museum by A.A. Balkema, 245 pp.

Talbot, W.J. 1977. Pathfinders and pioneers, explorers and scientists 1487-1976, pp. 1-32. *In* A.C. Brown (ed.) *A history of scientific endeavour in South Africa: a collection of essays published on the occasion of the centenary of the Royal Society of South Africa*. Royal Society of South Africa, Cape Town, pp. xx+516 pp.

Tate, R., 1867. On some secondary fossils from South Africa. *Quarterly Journal of the Geological Society of London* **23**, 139–175.

Thom, H.B. 1952. *Journal of Jan van Riebeek*. Volume 1. A.A. Balkema, Cape Town (for the Van Riebeeck Society), pp. xlvi+393.

Tittensor, D.P., Mora C., Jetz W., Lotze H.K., Ricard D., Vanden Berghe E., and Worm B. 2010. Global patterns and predictors of marine biodiversity across taxa. *Nature* **466**, 1098–1103.

Tizard, T.H., Moseley, H.N., Buchanan, J.Y. and Murray, J. 1885. *Narrative of the cruise of H.M.S. Challenger with a general account of the scientific results of the expedition. Challenger Report (Narrative), Volume 1, Part I & II*. Her Majesty's Stationary Office, London, 1172 pp.

Walker, N.D. 1989. *Sea surface temperature-rainfall relationships and associated ocean-atmosphere coupling mechanisms in the southern African region*. Council for Scientific and Industrial Research, Division of Earth, Marine and Atmospheric Science and Technology, 171 pp.

Waters, A.W. 1904. Bryozoa. *Résultats du Voyage du S.V. 'Belgica', Zoologie. Expedition*

Antarctique Belge **4**, 1–114.

Waters, A.W. 1907. *Tubucellaria*; its species and ovicells. *Journal of the Linnean Society (Zoology)* **30**, 126–133 .

Waters, A.W. 1909. Reports on the marine biology of the Sudanese Red Sea, from collections made by Cyril Crossland, M.A., B.Sc., F.Z.S.; together with collections made in the Red Sea by Dr R. Hartmeyer, 7. The Bryozoa, Part 1, Cheilostomata. *Journal of the Linnean Society (Zoology)* **31**, 123–181.

Waters, A.W. 1916. Some species of *Crisia*. *Annals and Magazine of Natural History* Series 8, **18**, 469–477.

Waters, A.W. 1918. Some collections of the littoral marine fauna of the Cape Verde Islands made by Cyril Crossland, M.A., B.Sc., F.Z.S., in the summer of 1904. Bryozoa. *Journal of the Linnean Society (Zoology)* **34**, 1–45.

Waters, A.W. 1919. *Batopora* (Bryozoa) and its allies. *Annals and Magazine of Natural History* Series 9, **3**, 79–94.

Winston, J.E. 2002. Ernst Gustav Gotthelf Marcus (1893–1968) and Eveline Agnes du Bois-Reymond Marcus (1901-1990), pp. 339–361. *In* P.N. Wyse Jackson and M.E. Spencer Jones (eds) *Annals of Bryozoology: aspects of the history of research on bryozoans*. International Bryozoology Association, Dublin.

Woodward, B.B. 1901. Busk, George, pp. 357–358. *In* Lee (ed.) *Dictionary of National Biography. Supplement 1*. Smith, Elder & Co., London.

Worden, N. and Groenewald, G. (eds) 2005. *Trials of Slavery: Selected documents concerning slaves from the criminal records of the Council of Justice at the Cape of Good Hope, 1705-1794*. Van Riebeeck Society for the Publication of South African Historical Documents, Second Series, **36**, lxi+681 pp.

Wyse Jackson, P.N. and Spencer Jones, M.E. 2002. From Rondelet to Stockholm; four centuries of bryozoological research, pp. 363–381. *In* P.N. Wyse Jackson and M.E. Spencer Jones (eds) *Annals of Bryozoology: aspects of the history of research on bryozoans*. International Bryozoology Association, Dublin.

Wyse Jackson, P.N. and Spencer Jones, M.E. 2007. The quiet workforce: the various roles of women in geological and natural history museums during the early to mid-1900s. *In* Burek, C.V. and Higgs, B. (eds) *The role of women in the history of geology*. Geological Society Special Publication **281**, 97–113.

Notes

1 The majority of the information in this subsection was sourced from South African History Online, www.sahistory.org.za. Accessed 14 April 2014.

2 This subsection highlights some events that led to the establishment of the South African Museum and the first director, Dr Andrew Smith. It draws extensively on a detailed history of the South African Museum, including its holdings and directorship following Smith, that was compiled by R.F.H. Summers (1975) using museum records. Therefore, this section does not set out to repeat Summers' impressive compilation, but rather highlights certain events. While

specific references to Summers (1975) are not cited herein due to them being extensive, readers are advised to consult his history.

Jeremy Jackson, Bryozoa, and the Punctuated Equilibrium Debate

Alan H. Cheetham
3101 Old Pecos Trail, Unit 647, Santa Fe, NM 87505, USA

1. Introduction

In *The Adventures of Punctuated Equilibria, A Struggle for Authority in the Evolutionary Sciences*, sociologist Andrew Grimshaw (2001) attributed a share of the responsibility for the lengthy debate following Niles Eldredge and Steve Gould's (1972) introduction of their theory to "the poor quality of communication" between its proponents (mainly paleontologists) and its opponents (chiefly biologists). He further suggested that one way in which conflicting views could be reconciled is through collaborative efforts between members of the two groups, going on to say, "Indeed there is only one example of a sustained research programme between a paleontologist and biologist attempting to address the macroevolution-microevolution divide—the joint projects of paleontologist Alan Cheetham of the Smithsonian Institution and biologist Jeremy Jackson of the Scripps Institution of Oceanography in California" (Grimshaw, 2001, p. 164). Many of the respondents to the questionnaires that he used to supplement his analysis of the punctuated equilibrium literature admitted that this was a type of long-term effort to which few scientists would be willing to commit.

Just how did it come about that Jeremy, a marine biologist/reef ecologist, committed to a 20-year-long collaboration with a paleontologist/bryozoan taxonomist on such an undertaking? It began formally in 1986 when the Smithsonian Institution funded our proposal entitled "Are skeletons enough to tell species apart? A test using cheilostome Bryozoa." However, its roots go back at least 10 years before that, to the time shortly after

Jeremy's arrival at Johns Hopkins when he began spending time in my lab in Washington identifying bryozoans from his experiments with the cryptic reef communities in Jamaica. From that work, Jeremy and one of his students, Leo Buss, developed the notion of non-transitive competitive networks ("A beats B, B beats C, but C beats A") among encrusting organisms (Jackson, 1979; Buss and Jackson, 1979), an idea that proved useful to subsequent workers investigating the contrasting fates of major bryozoan clades from the Mesozoic into the Cenozoic (McKinney, 1995). Then, in 1981, as though anticipating our future collaboration, Jeremy spent some of his own grant money, when travel funds had been frozen by the incoming federal administration, to allow me to attend his symposium in New Haven on the biology of clonal organisms (Jackson et al., 1985). Moreover, I was not the only bryozoan paleontologist with whom Jeremy was collaborating in 1986; he was also working on a book on bryozoan evolution with Ken McKinney (McKinney and Jackson, 1989).

2. A Question and a Challenge

One day late in 1983 or early in 1984, seeing me struggle to fit more than a dozen morphologically distinct groups, or morphotypes, of the cheilostome bryozoan *Metrarabdotos* from Miocene and Pliocene deposits in the Dominican Republic into what I was convinced could be no more than four species, Jeremy asked a simple question: "Have you considered the possibility that your 'morphotypes' could all be species?"

Both of us were quite aware of the results that the biologist Frank Maturo (1973) had obtained from an experiment with two morphotypes, long considered conspecific, of another cheilostome, *Parasmittina*. By rearing larvae of known maternal morphotype, but unknown paternity, he expected, as he put it in the oral presentation of his results two years earlier at a meeting of the International Bryozoology Association, to become the "Mendel of Bryozoa." Both morphotypes, however, bred true; they also show consistent, although small, morphological differences strongly supporting the conclusion that they are different species (Maturo, 1973).

My reluctance to accept a similar conclusion for the *Metrarabdotos* morphotypes stemmed from their greater variability and significant overlap with each other, in addition to the fact that the genus is not very closely related to *Parasmittina*. In an oral presentation in 1983 of preliminary results with the Dominican Republic material (Cheetham, 1985), I interpreted most of the morphotypes as "intermediates" between various pairs of the four inferred species. However, the fact remained that the distinctiveness of all the morphotypes was based on high levels of significance in statistical tests that considered simultaneously all of more than 40 morphological characters. With some misgivings because of the looseness of the analogy to the species on which Maturo's (1973) genetic results were obtained, I accepted a statistical cutoff level that made 13 of the Dominican Republic *Metrarabdotos* morphotypes species. In doing so, I also had to accept that most of the resulting species had stratigraphic durations overlapping by millions of years in the Dominican Republic sections. That, together with the close spacing of occurrences through the sections, made it obvious that here was a good example on which to test evolutionary tempo with a variety of statistical methods. As one of the many paleontologists who were skeptical about accepting the punctuated equilibrium model, I formulated the tests to make it as difficult as possible to reject gradualism and thus accept punctuation (Cheetham, 1986).

The results (Cheetham, 1986, 1987) all supported the punctuated equilibrium model. By the time the first paper was published, however, Jeremy reawakened my hesitation about accepting the *Metrarabdotos* morphotypes as species. As he put it to Richard Kerr (1995) of *Science* magazine, "Clearly, the strength of any discovery of punctuated equilibrium—a model of speciation—depends on our ability to recognize species. So I challenged him [Cheetham] to submit his methods to biological examination." Thus we embarked in 1986 on the project to test whether "cheilostome bryozoan skeletons are enough to tell species apart."

3. The Test

Our project consisted of three parts, each of which required a feat of collecting—of both specimens and biological data—on Jeremy's part. The first collection, of specimens from both coasts of Panama, would provide the material with which I would apply the morphometric/statistical methods used in the *Metrarabdotos* study to discriminate a series of morphospecies based on measurements and other characters of their skeletons; these results would form the framework for the "biological examination" to follow. Unfortunately, *Metrarabdotos* itself would not be part of the test; unlike their fossil congeners, surviving species are few and uncommon. Pat Cook (1973) had grown colonies of one species (*M. cookae*) in West Africa, but it includes just a single morphotype refractory to further division, even in the latest morphometric/statistical analysis (Cheetham et al., 2007).

Instead, we settled on three distantly related cheilostome genera of quite different morphology, including the one that had been the subject of Maturo's (1973) experiment on inheritance. All of them were common on one or both of the Panamanian coasts, and each showed significant evidence of variation in morphotype. In the anascan genus *Steginoporella*, we distinguished three morphospecies and in the ascophorans *Stylopoma* and *Parasmittina* four and 16, respectively. Thus, the generality of the results Maturo obtained with just two morphotypes of a single genus could be tested; if the results were sufficiently consistent, they would strengthen the analogy for *Metrarabdotos*.

The maternal colonies for the second part of our project, the experiment on heritability of species identity, were all collected on the Caribbean coast of Panama from different water depths at sites as much as 110 km apart; they included two species of *Steginoporella*, two of *Stylopoma*, and three of *Parasmittina*. The offspring of the 131 colonies were all grown in a common environment at the field station of the Smithsonian Tropical Research Institute in the San Blas, an environment that was different from those in which any of the maternal colonies were collected. The morphospecies identities of both the maternal and offspring colonies remained uncertain until the end of the experiment. Then, skeletal measurements from both sets of colonies were incorporated into the morphometric/ statistical analyses (one for each genus) on which the first part of the project was based. All but nine of 450 offspring (two percent) were assigned by the analyses to the same morphospecies as their maternal parent (paternity was unknown); this slight difference from the results obtained by Maturo (1973) could have been the result of a mix-up in returning fallen colonies to their positions after a storm (Jackson and Cheetham, 1990).

For the third part of the test—analysis of enzyme variation by electrophoresis—Jeremy collected another 402 colonies, all from Panama's Caribbean coast. He sorted them into morphospecies by visual inspection, three species each of *Steginoporella* and *Stylopoma* and two of *Parasmittina*. Subsequent morphometric/statistical analysis of voucher portions (remaining after sampling for electrophoresis) of 10-20% of the specimens confirmed the visual assignments. Between each of the pairs of morphospecies within each genus, he found diagnostic alleles at one or more of seven loci, and no diagnostic alleles between colonies of the same species from different localities, showing that the morphospecies are unambiguously distinct genetically.

By December 1988, the second part of the test had been completed, and I was dispatched to the annual meeting of the American Society of Zoologists to present the results (Cheetham and Jackson, 1988) in a symposium on "Species and Evolution in Clonal Organisms" (Budd and Mischler, 1990). In the fall of the next year, Jeremy presented the results of the whole project at the annual meeting of the Geological Society of America (Jackson and Cheetham, 1989), and in 1990, the complete study was published (Jackson and Cheetham, 1990).

While accepting the principal conclusion of our test—the correspondence between skeletal morphology and genetics—Jeffrey Levinton (1991), one of the most outspoken critics of the punctuated equilibrium model, questioned whether any of the species we used were sufficiently closely related to each other to provide an analogy for the punctuated pattern of morphological change in *Metrarabdotos* that we inferred to be a record of speciation. The genetic distances (Nei's unbiased D) that we reported for *Steginoporella* and *Stylopoma*, ranging from 0.34 to 2.12 (mean 1.2), "cannot be distinguished from distances between fairly distantly related nonsibling species" (Levinton, 1991), and the single distance for *Parasmittina* was even greater. The morphological distances (square root of Mahalanobis' D^2) we had obtained were also much greater than those among most species of *Metrarabdotos*, averaging 77, 41, and 58 in *Steginoporella*, *Stylopoma*, and *Parasmittina*, respectively, with a total range of 14 to 103 (Jackson and Cheetham, 1990), compared to 26 in *Metrarabdotos*, with a total range of 5.5 to 46 (Cheetham et al., 2007).

In 1992, the Smithsonian funded our second grant—"Does morphologic stasis of fossils reflect biologic evolution at the species level?"—that enabled us to enlarge the dataset in order to address some of these deficiencies. Morphological and genetic data were collected from a wider range of geographic localities, and morphological data were obtained from fossil bryozoans as well as the living ones. For logistic reasons, including

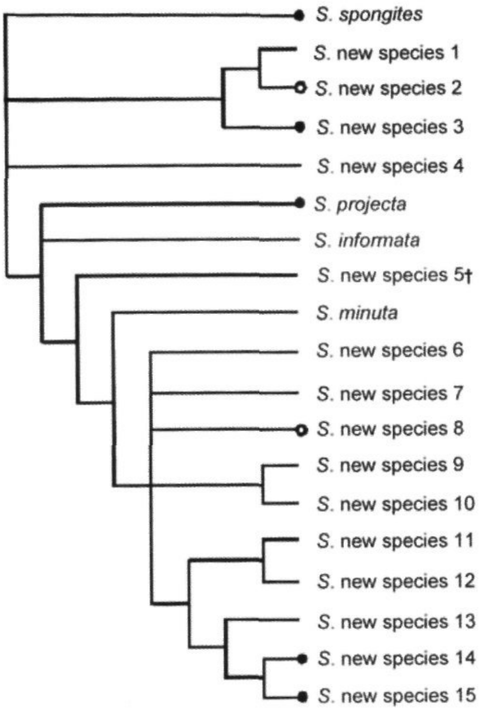


Figure 1. Cladogram for tropical American species of Stylopoma, *redrawn from Jackson and Cheetham (1994, fig. 5). Circles mark species analyzed electrophoretically, solid circles for species from Panama, open ones for those from Curacao. Cross (†) marks apparently extinct species.*

the readiness with which specimens could be recognized in collecting by scuba, we focused the new study on *Stylopoma*. Jeremy made new collections from Curacao, more than 1000 km from Panama, and submitted replicate specimens from 11 local populations to electrophoresis. Morphological measurements from these and more than 100 suitable fossil and recent museum specimens (including type specimens of three named species of *Stylopoma*) from the Caribbean, Gulf of Mexico, and southeastern United States were added to those from our first study. Then, the morphological analysis was completely redone.

The new analysis yielded 19 *Stylopoma* species. The three species from Caribbean Panama in the original study split into five (Fig. 1; Jackson and Cheetham, 1994). *Stylopoma* species 1 of Jackson and Cheetham (1990) separated into *S. spongites* (which included all of the *S.* species 1 specimens from the maternal inheritance experiment) and *S.* new species 3; *S.* species 2 remained distinct but now included the holotype of *S. projecta* from the Panamanian Pleistocene; *S.* species 3 was resolved into *S.* new species 14 and *S.* new species 15; and the new material from Curacao yielded two species, *S.* new species 2 and *S.* new species 8, neither of which occurs in Panama. Only three of the 19 species in total, including *S.* new species 15 from Panama and *S.* new species 8 from Curacao, lack fossil records. One of the 19 species, *S.* new species 5, is known only from fossils. Thus, the strategy of broadening the scope of the dataset appeared to achieve the objective of making the results more comparable to the *Metrarabdotos* record.

The morphological distances between species in *Stylopoma* became more comparable

Table 1. Genetic (Nei's D) and morphological (square root of Mahalanobis D^2) distances between pairs of Stylopoma *species analyzed electrophoretically (Panamanian species in boldface). These data were the source for figure 4a in Jackson and Cheetham (1994).*

Species pair	Nei's D	Mahalanobis D
S. spongites-S. new species 2	0.479	3.37
***S. spongites-S*. new species 3**	0.050	3.88
S. spongites-S. projecta	0.963	4.18
S. spongites-*S*. new species 8	0.817	3.37
***S. spongites-S*. new species 14**	1.438	7.06
***S. spongites-S*. new species 15**	1.505	10.97
S. new species 2- ***S*. new species 3**	0.601	4.58
S. new species 2-***S. projecta***	1.606	4.93
S. new species 2-*S*. new species 8	1.566	6.41
S. new species 2-***S*. new species 14**	2.526	7.55
S. new species 2-***S*. new species 15**	2.616	11.46
S*. new species 3-*S. projecta	1.161	5.87
***S*. new species 3**-*S*. new species 8	1.035	5.90
***S*. new species 3-*S*. new species 14**	2.300	6.10
***S*. new species 3-*S*. new species 15**	2.273	10.18
S. projecta-*S*. new species 8	0.632	5.26
***S. projecta-S*. new species 14**	2.337	7.39
***S. projecta-S*. new species 15**	3.836	11.22
S. new species 8-***S*. new species 14**	1.298	4.18
S. new species 8-***S*. new species 15**	1.385	8.67
***S*. new species 14- *S*. new species 15**	0.004	5.79
Mean		

to those in *Metrarabdotos* also (Table 1; Jackson and Cheetham, 1994), with mean morphological distance (6.6) only slightly greater than the smallest distance in *Metrarabdotos* (5.5). Moreover, although the mean genetic distance between the 21 pairs of *Stylopoma* species (1.45) was greater than that between the three pairs in the original study (0.86), distances between species of two pairs (0.05 and 0.004, Table 1) were well below the level (0.34) that Levinton (1991) had pointed to as indicating "fairly distantly related non-sibling species." Finally, as additional evidence of the correspondence between morphology and genetics, the correlation between Nei's D and Mahalanobis D for the 21 species pairs is highly significant ($r_s = 0.739$, $p < 0.001$, with 19 degrees of freedom; Jackson and Cheetham, 1994, table 3).

4. Implications for the Tempo of Speciation

The results of the test of correspondence between morphology and genetics not only provided justification for interpreting the punctuated pattern of morphological change in *Metrarabdotos* as a record of speciation, but they also suggested a similar tempo of change in *Stylopoma*. The stratigraphic record of *Stylopoma* species in tropical America is less dense than that of *Metrarabdotos* (Cheetham and Jackson, 1994), making the statistical approach used to establish the static morphologies of species in the latter genus less appropriate. However, of the 18 extant species of *Stylopoma*, eight persisted for millions of years from Late Miocene or Pliocene time with probabilities exceeding 0.9 (and five of the eight with $p > 0.99$) (Jackson and Cheetham, 1994, fig. 5b). "Moreover," Jeremy wrote, "11 of the species originate fully formed at $p > 0.9$, with no evidence of morphologically intermediate forms, and all ancestral species but one survived unchanged along with their descendants, as required by Levinton's (1988) persistence criterion" (Jackson and Cheetham, 1994, p. 420).

The criticisms of Levinton (1991) and of Bob Anstey (quoted in Grimshaw, 2001, p. 165) that the "relatedness" of species in our analyses was "clouded" by our reliance on phenetic rather than cladistic methods was blunted by our inclusion of cladograms for both *Stylopoma* (Fig. 1; Jackson and Cheetham, 1994, fig. 6) and *Metrarabdotos* (Jackson and Cheetham, 1994, fig. 7). Although we found that none of the *Metrarabdotos* cladograms

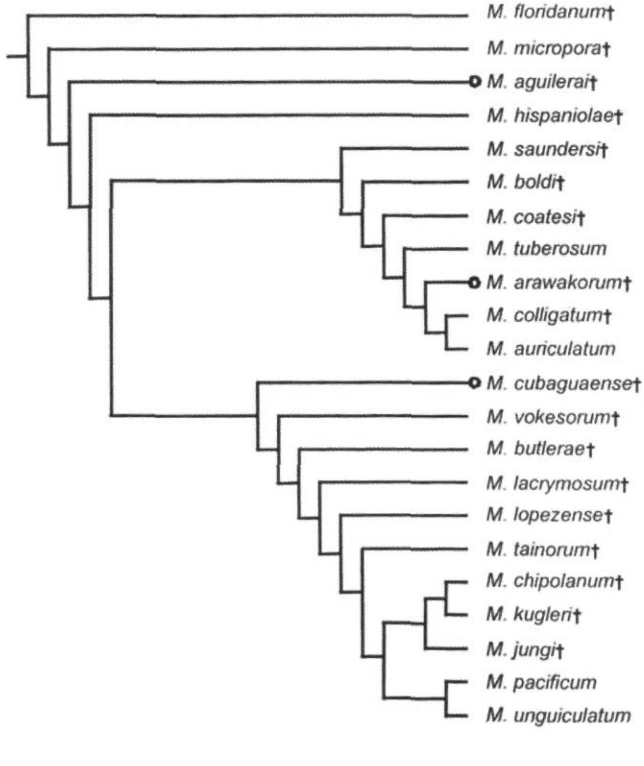


Figure 2. Cladogram for tropical American species of Metrarabdotos, *redrawn from Cheetham et al. (2007, fig. 8). Three Venezuelan species showing significant evidence of clonal propagation are marked with open circles. Crosses (†) mark extinct species.*

in 1994 was closely consistent with stratigraphic ranges, we produced a new, more congruent cladogram in our later, complete re-analysis of *Metrarabdotos* (Fig. 2; Cheetham et al. 2007, fig. 8); it resulted in no change in our conclusions regarding within-species morphological stasis and the persistence of putative ancestors after cladogenesis (Cheetham et al., 2007, p. 18-20, fig. 10). Moreover, our results in *Stylopoma* showed that genetic distances between species were at least as highly correlated with morphological distances ($r_s = 0.739$) as they were with cladistic distances ($r_s = 0.730$), $p < 0.001$ with 19 degrees of freedom in both cases (Jackson and Cheetham, 1994, table 3).

In concluding the 1994 paper, Jeremy wrote (Jackson and Cheetham, 1994, p. 421):

> "[T]he tight correlation between phenetic, cladistic, and genetic distances among *Stylopoma* species suggests little or no conflict between molecular and morphological approaches to phylogeny reconstruction in cheilostomes, unlike that found in some other taxa ... Moreover, changes in all measures of interspecific difference may have occurred together during speciation, as predicted by the punctuated equilibrium model. Morphological stasis and an episodic pace of speciation thus may imply an episodic pattern of molecular evolution, rather than a constantly evolving molecular clock. This would suggest that calculations of the timing of cheilostome speciation based on allozyme data may be erroneous, and phylogenies based on allozymes should be no better or worse than those based on morphology, assuming equal analytical rigor."

To estimate how prevalent punctuated speciation may have been beyond these two cheilostome bryozoans is a difficult undertaking. In their 1995 book, *New Approaches to Speciation in the Fossil Record*, Doug Erwin and Bob Anstey tabulated 58 cases from the paleontological literature under three headings, "gradualism," "gradualism with stasis," and "punctuation with stasis" (Erwin and Anstey, 1995, table 1.1). Gradualism (with or without stasis), accounted for 32, or 55%, of the cases, and punctuation (with stasis) for 26 cases, or 45%.Thus, they concluded, no single pattern is prevalent, although "they concede that many of these studies have their weaknesses" (Kerr, 1995).

In order to test whether or not a case in the fossil record supports punctuated equilibrium theory, Jeremy laid out a rigorous set of requirements (Jackson and Cheetham, 1999, p. 72-73):

> "[S]upport for punctuated equilibria requires that changes in morphology within a species are so small and unsustained in direction that they cannot account for morphological differences between ancestors and descendants. This in turn requires rigorous taxonomy, sampling, stratigraphy and phylogenetic analysis.
>
> "To compare the morphology of populations in space and time quantitatively, taxonomic resolution must be sufficient to discriminate species with confidence. Consequently, good preservation of abundant, morphologically complex fossils is necessary to obtain enough specimens and characters for biometrical discrimination of morphospecies (species defined on the basis of morphology). These requirements largely limit studies to marine shelly invertebrates.

Likewise, genetic support for morphospecies is necessary to have confidence in their equivalence to recent biological species. Genetic calibration effectively limits studies to the past 25 million years (Neogene and Quaternary), when most modern clades originated.

"To resolve biogeographic and stratigraphic ranges with confidence, the density and distribution of sampling must be sufficient. These sampling requirements also limit studies to shelly clades that are common throughout most of their history. Biogeographic resolution is necessary to distinguish ecophenotypic change or biogeographic replacement from evolution. Stratigraphic precision is required to constrain phylogenies that are routinely plagued by extreme problems of convergent evolution when species of disparate geological age are combined in cladistic analyses. Well determined ages of first and last occurrence are critical because well resolved phylogenies are necessary to establish ancestor-descendant pairs of species with high confidence. Resolving these relationships depends at least as much on the quality of the taxonomy and sampling as the method of phylogenetic analysis."

Use of these criteria to evaluate cases in the paleontological literature—which eliminated on stratigraphic grounds alone more than half of the cases tabulated by Erwin and Anstey (1995)—led to the conclusion that 29 out of 31 species (94%) of Neogene benthic invertebrates "exhibited punctuated change at cladogenesis that is consistent with the theory of punctuated equilibria" (Jackson and Cheetham, 1999, p. 75). Even though the evidence was tilted more in the direction of anagenesis for the 16-18 Neogene planktonic species (only six of which showed cladogenesis), "most but not all cases of speciation in the sea are punctuated" (Jackson and Cheetham, 1999, p. 75).

5. The Speciation Process and the Red Herring of Bryozoan Clonality

In concluding the 1999 paper, Jeremy wrote, "Most cases of speciation in the sea over the past 25 My show prolonged morphological stasis punctuated by geologically sudden morphological shifts at cladogenesis ... Prolonged stasis requires stabilizing selection but causes of punctuated speciation are unresolved. We cannot reject genetic drift for cheilostomes, so if directional selection is important for speciation in these animals it must act extremely fast" (Jackson and Cheetham, 1999, p. 76).

The data that enabled us to reach this conclusion are from the maternal inheritance experiment on which the second part of our original project was based (Jackson and Cheetham, 1990). The original purpose of the experiment was simply to test the "heritability of morphospecies identity by raising offspring of colonies from different populations in a common garden ... through two generations of offspring" (Jackson and Cheetham, 1990, p. 580). However, the morphospecies themselves were delineated by data on individual morphological characters, which, with standard methods of quantitative genetics, could provide estimates of the heritable variation in each character and the correlations, genetic as well as phenotypic, between pairs of characters. These values then were the raw material for calculations of putative selection forces and divergence rates in the morphological differentiation of a pair of species.

To make these calculations, large numbers of parent and offspring colonies of each of two species were required for reliable estimates of genetic parameters. Of the three genera in the breeding experiment, only *Stylopoma* measured up to this requirement (Jackson and Cheetham, 1990, table 2). Thus, we could estimate values from two species (*S.* species 1 and *S.* species 2, or *S. spongites* and *S. projecta*, in the nomenclature of Jackson and Cheetham, 1994) independently, rather than following the questionable practice of extrapolating values from one species to another. The heritabilities we calculated for the two species (Table 2; Cheetham et al., 1993, table 5) justified this concern. For example, heritabilities of eight of 10 characters are significant in *S. spongites*, whereas only five of 10 are so in *S. projecta*, even though their mean heritabilities are very nearly equal (0.3395 and 0.3404, respectively).

Using the genetic parameters estimated for the two species of *Stylopoma*, methods developed by quantitative geneticists, especially Russell Lande (1977, 1979) and Michael Lynch (1988, 1990), and the assumption that rates of mutation in these bryozoans are in the vicinity of those in many other groups of organisms, we calculated that mutation alone could be sufficient to account for the observed morphological differences between *S. spongites* and *S. projecta* in as few as tens of thousands of years (Cheetham et al., 1993). This geologically very brief time scale, well within the limits of stratigraphic resolution

Table 2. Heritabilities (estimated from parents and two generations of offspring) and among-colonies variance components (estimated by single-classifaction ANOVA of parental colonies) for 10 morphological characters in two species of Stylopoma *(modified from Cheetham et al., 1993, tables 1, 2, and 5). Nomenclature has been changed from* S. *species 1 and* S. *species 2 to conform to that in Jackson and Cheetham (1994). Significance of heritabilities: * p < 0.05, ** p < 0.01, *** p < 0.001.*

Morphological character	*Stylopoma spongites* Heritability	Variance component	*Stylopoma projecta* Heritability	Variance component
Zooid length	0.3056**	0.5683	0.1516	0.4492
Zooid width	0.2269*	0.3732	0.1948***	0.4334
Frontal pore density	0.2438*	0.4704	0.5818***	0.3064
Orifice length	0.7719***	0.5011	0.2818	0.3308
Orifice width	0.3402*	0.4269	0.7050***	0.4284
Oral sinus length	0.1968	0.3961	0.4191**	0.3604
Oral sinus width	0.1635	0.3778	0.1934	0.3376
Avicularium length	0.3053*	0.3066	0.8178***	0.5336
Avicularium position	0.4158***	0.4020	0.2134	0.2854
Avicularium orientation	0.4254***	0.2130	-0.1549	0.0642
Mean	0.3395	0.4035	0.3404	0.3529

for the best sampled species of *Metrarabdotos* (Cheetham, 1986), is especially instructive given that these two species of *Stylopoma* are probably not nearest relatives (Fig. 1) and *S. spongites* is more similar morphologically and genetically to *S.* new species 2 and *S.* new species 3 than to *S. projecta* (Table 1). On shorter time scales of course, species divergence would require the intervention of directional selection, but our calculations also showed that directional selection acting alone would require unrealistically high levels of minimum selective mortality throughout the interval of divergence. Conversely, their divergence on time scales of millions of years would require stabilizing selection to mitigate the effects of mutational pressure, even if they did not exhibit the morphological stasis so typical of *Metrarabdotos* species. Thus we concluded that the results obtained for *Stylopoma* "... are consistent with theoretical models in which phenotypic evolution is mediated by interaction between mutation, random genetic drift, and stabilizing selection" (Cheetham et al., 1993, p. 1536).

The maternal inheritance data for *Stylopoma* also gave us a more direct way of gaining access to the genetic basis for morphological divergence and stasis in fossil bryozoans such as *Metrarabdotos*, rather than having to rely on analogy between fossil and living bryozoans. To do so, we made use of the modular morphology of bryozoans in which asexually budded modules (zooids) remain physically connected to form a colony, thus genetically a clone. The phenotypic variation in zooidal morphology in populations of colonies can be partitioned statistically into within-colony and among-colonies components, the latter corresponding to a measure termed clonal repeatability in quantitative genetics. Clonal repeatability in general sets an upper limit to heritability, but in the two species of *Stylopoma* (Table 2), the correspondence between mean heritability and mean repeatability is close, within the limits of sampling error in *S. projecta*, perhaps because within-colony variance includes a small, but significant heritable component itself (Cheetham et al., 1995). For individual characters, however, the correlation between heritability and repeatability (Table 2) is much less close ($r_s = 0.684$, $p < 0.05$ in *S. projecta*; $r_s = 0.166$, not significant in *S. spongites*; with eight degrees of freedom in each case). Nevertheless, by substituting clonal repeatabilities for heritabilities and similarly estimated phenotypic values for genetic correlations in the calculations we had made in *Stylopoma* for divergence times and selection forces, we obtained results that were inconsequentially different from those based on the actual genetic values (Cheetham et al., 1993).

With the good fit between calculations with genetic and phenotypic values in *Stylopoma* as justification, we went on to make similar calculations for six pairs of fossil species of *Metrarabdotos*, with results generally similar to those obtained for the single pair of species of *Stylopoma* (Cheetham et al., 1994; Cheetham and Jackson, 1995). In concluding the 1994 paper, we wrote:

> "In general, these results support genetic models of speciation involving relatively sudden shifts between multiple adaptive peaks on which phenotypes remain more or less static through long-term stabilizing selection ... Models based on shifting balance among local demes (Wright, 1982) and isolation on the peripheries of large distributions (Mayr, 1954, 1963) are both

plausible for *Metrarabdotos* and other cheilostomes, based on their Neogene to Holocene distribution patterns in tropical America (Cheetham and Jackson, 1994). Random processes may be sufficient to explain phenotypic differentiation at speciation in these models, or directional selection may be required [depending on divergence time]. In either case, the agents of speciation are different from the pervasive stabilizing selection required to explain phenotypic stasis within species. In this sense, the results presented here are consistent with the 'stronger' version of punctuated equilibria theory decoupling speciation from forces acting within species (Maynard Smith, 1988)."

It was the last sentence in this passage that led Jeremy to write (Jackson and Cheetham, 1999, p. 76), "Finally, granted the prevalence of punctuated equilibria, macroevolutionary trends must arise through differential rates of origination and extinction, and not by adaptive evolution within single species," i.e., by sorting or selection at the level of species rather than individuals, thus putting us squarely in the camp of the punctuated equilibrium model's strongest proponents. Evolutionary biologists for the most part have continued to follow John Maynard Smith in regarding higher level selection as ultimately reducible to selection acting on individuals in populations and thus unnecessary as a concept (Grimshaw, 2001, p. 178). On the other hand, paleontologists have been receptive to the need for such a concept to explain macroevolutionary trends (Grimshaw, 2001, p. 172), albeit with some reservations about whether differential rates of species origination and extinction require traits "emergent" at the species level. Thus, Grimshaw (2001, p. 172) found that species selection or sorting is the aspect of punctuated equilibrium theory most likely to be a stumbling block to communication between the paleontologists and biologists.

The methods that we used to reconstruct genetic parameters in *Metrarabdotos* also enabled us to dispel the notion that, because Bryozoa are often characterized as clonal animals (e.g., Eldredge et al., 2005, p. 135), the principles governing their speciation might differ from those in exclusively sexually reproducing organisms. At the 1988 symposium "Species and Evolution in Clonal Organisms" in which we presented the first results of our research (Cheetham and Jackson, 1988), much of the roundtable discussion centered on whether the biological species concept has any meaning for clonal organisms at all (Budd and Mischler, 1990), because cloning decreases or eliminates the opportunity for genetic recombination (thus compromising the model of genetic cohesion on which the biological species concept is based) and reduces the pool of genetic variation from which new species may arise.

Bryozoa do have the potential to propagate clonally, given their growth as colonies of physically connected, genetically identical modules. Colonies originating by accidental or programmed fragmentation of other colonies are abundant in some species of groups such as the free-living cupuladriids, but we had seen little to indicate clonal propagation in either *Stylopoma* or *Metrarabdotos*. The maternal inheritance experiment of Jackson and Cheetham (1990), like that of Maturo (1973), was based on rearing sexually produced larvae. Even when grown in isolation for a year, colonies of *Stylopoma spongites* and *S. projecta* produce viable offspring sexually by self-fertilization, as Jeremy and his colleague Amalia Herrera-Cubilla demonstrated (Jackson and Herrera, 1995).

An opportunity to investigate the effect of clonal propagation—in no less pertinent a group than *Metrarabdotos* itself—came unexpectedly one morning in 1999 when Jeremy appeared in my lab in Washington with fossil bryozoans he had collected from three different formations of Miocene and Pliocene age from two regions in Venezuela. These collections were part of the Panama Paleontology Project, begun by Jeremy and Tony Coates in 1986 at the Smithsonian Tropical Institute, which by the 1990s had burgeoned into a collaboration involving dozens of specialists in numerous marine taxa (Collins, 2009).

The Venezuelan material yielded three new species of *Metrarabdotos* (Cheetham et al., 2001), *M. aguilerai*, *M. arawakorum*, and *M. cubaguense* in the nomenclature of

Table 3. Mean among-colonies variance components (heritability estimates) for 15 morphological characters in two groups of tropical American species of Metrarabdotos *(based on Cheetham et al., 2001, table 2). "Clonal" species are the three from Venezuela with half their colonies originating from pre-existing fragments; "aclonal" species are the 16 remaining species with few or no such colonies. Characters left blank are invariant in all species of that group.*

Morphological Character	Mean among-colonies variance component	
	"Clonal" species	"Aclonal" species
Zooid length	0.6192	0.5612
Zooid width	0.3125	0.5257
Number of frontal areolae	0.4259	0.4858
Orifice length	0.5459	0.5862
Orifice width	0.6001	0.3994
Number of denticles		0.1278
Distance between lateral denticles	0.6136	0.4960
Length of smaller avicularium	0.4028	0.2520
Position of smaller avicularium	0.3903	0.1720
Lateral-medial orientation of smaller avicularium	0.3482	0.1753
Distal-proximal orientation of smaller avicularium	-0.0526	0.1253
Length of larger avicularium	0.5170	0.3273
Position of larger avicularium	0.3690	0.2109
Lateral-medial orientation of larger avicularium	0.2368	0.1143
Distal-proximal orientation of larger avicularium		0.4058
Mean	0.4099	0.3310

Cheetham et al. (2007); approximately half of the colonies in each species originated asexually. However, genetic variation in their zooidal characters (estimated from among-colonies variance components) is no less than in *Metrarabdotos* species showing no or negligible evidence of asexual propagation (Table 3). The three "clonal" species proved not to be closely related (Fig. 2), suggesting separate but similar responses to an environmental condition, such as elevated nutrient levels in a region of coastal upwelling, that promoted vegetative growth without reducing their sexual productivity (Cheetham et al., 2001). A similar situation occurs among the European and African species of *Metrarabdotos*, where one (*M. thomseni*) of the six species in Cheetham et al. (2007) shows significant evidence of clonal propagation, but apparently unreduced levels of heritable variation in zooidal morphology (Cheetham, 2002).

6. After Words

In summarizing the results of the quantitative genetic tests, Jeremy attempted to communicate directly with evolutionary biologists dismissive of punctuated equilibrium theory when he wrote, "The genetic analyses help clarify two important misunderstandings about punctuation and stasis. First, stasis does not imply lack of morphological evolution, but lack of net morphological change. Stabilizing selection *is* evolution [emphasis added]. Second, punctuation is not about absolute time required for species to originate, rather it is about the time required for a species to originate relative to how long the species persists with no new morphological change before it becomes extinct" (Jackson and Cheetham, 1999, p. 76).

There is evidence that this attempt has been at least partly successful. In several chapters of his new evolutionary biology textbook, *Evolution*, Doug Futuyma (2005) discusses punctuated equilibrium, both as pattern and process (including the macroevolutionary importance of species selection and sorting). This stands in contrast to the brief, perfunctory discussions in biology textbooks at the time of Grimshaw's (2001) analysis. However, acceptance of the importance of punctuated equilibrium remains stronger among paleontologists, as indicated by the extensive coverage of these topics in the new edition of the widely used textbook *Principles of Paleontology* (Foote and Miller, 2007).

Continuing research by Jeremy and his associates at the Smithsonian Tropical Research Institute on the cupuladriids *Cupuladria* and *Discoporella*, with similar morphometric methods and more advanced molecular techniques than we used in *Stylopoma*, has confirmed and expanded upon the relationship between morphology and genetics in cheilostomes (Dick et al., 2003; Herrera-Cubilla et al. 2005, 2008). Both cupuladriid genera have dense and abundant fossil records in the tropical American Neogene similar to that of *Metrarabdotos* (Cheetham et al., 1999; Cheetham and Jackson, 2000), and thus the potential for yielding patterns of speciation just as pertinent to the punctuated equilibrium debate. Moreover, abundant and diverse living cupuladriid faunas on both coasts of Panama provide the opportunity to relate life histories to evolutionary patterns (O'Dea and Jackson, 2002; O'Dea et al., 2004), as well as to study the genetics of both genera directly. Although such opportunity was barred for *Metrarabdotos* by the extinction of most of its species (Fig. 2), our interpretation of its fossil record as a history of speciation stands as a monument to Jeremy's willingness to devote years of effort to acquiring the genetic data to back it up.

7. Acknowledgments

I thank Nancy Budd and John Pandolfi for inviting me to participate in this tribute to Jeremy; JoAnn Sanner and Amalia Herrera-Cubilla for help with references and dates; and Doug Erwin for comments on the manuscript.

References

Budd, A.F. and Mischler, B.D. 1990. Species and evolution in clonal organisms—summary and discussion. *Systematic Botany* **15**, 166-171.

Buss, L.W. and Jackson, J.B.C. 1979. Competitive networks: non-transitive competitive relationships in cryptic coral reef environments. *American Naturalist* **113**, 223-234.

Cheetham, A.H. 1985. Patterns of morphologic change in late Tertiary cheilostome bryozoans from the Dominican Republic: *Metrarabdotos* revisited, p. 65-66. *In* C. Nielsen and G. P. Larwood (eds), *Bryozoa: Ordovician to Recent*. Fredensborg, Denmark: Olsen and Olsen.

Cheetham, A.H. 1986. Tempo of evolution in a Neogene bryozoan: Rates of morphologic change within and across species boundaries. *Paleobiology* **12**, 190-202.

Cheetham, A.H. 1987. Tempo of evolution in a Neogene bryozoan: Are trends in single morphologic characters misleading? *Paleobiology* **13**, 286-296.

Cheetham, A.H. 2002. Asexual propagation in the cheilostomes *Metrarabdotos* and *Coscinopleura*: Effects on genetic variation and larval productivity, p. 73-80. *In* P.N. Wyse Jackson, C.J. Buttler and M.E. Spencer Jones (eds), *Bryozoan Studies 2001, Proceedings of the Twelfth International Bryozoology Association Conference*. Lisse/ Abingdon/ Exton (PA)/ Tokyo: A.A. Balkema Publishers.

Cheetham, A.H. and Jackson, J.B.C. 1988. Morphologic versus genetic distinctions between species of living Bryozoa. American Society of Zoologists, 1988 Annual Meeting.

Cheetham, A.H. and Jackson, J.B.C. 1994. Speciation, extinction, and the decline of arborescent growth in Neogene and Quaternary cheilostome Bryozoa of tropical America, p. 205-233. *In* J.B.C. Jackson, A.F. Budd and A.G. Coates (eds), *Evolution and Environment in Tropical America*. Chicago and London: University of Chicago Press.

Cheetham, A.H. and Jackson, J.B.C. 2000. Neogene history of cheilostome Bryozoa in tropical America, p. 1-16. *In* A. Herrera and J.B.C. Jackson (eds), *Proceedings of the*

11th International Bryozoology Association Conference. Lawrence, KS: Allen Press.

Cheetham, A.H. and Jackson, J.B.C. 1995. Process from pattern: Tests for selection versus random change in punctuated bryozoan speciation, p. 184-207. *In* D.H. Erwin and R.L. Anstey (eds), *New Approaches to Speciation in the Fossil Record*. New York: Columbia University Press.

Cheetham, A.H., Jackson, J.B.C. and Hayek, L.C. 1993. Quantitative genetics of bryozoan phenotypic evolution. I. Rate tests for random change versus selection in differentiation of living species. *Evolution* **47**, 1526-1538.

Cheetham, A.H., Jackson, J.B.C. and Hayek, L.C. 1994. Quantitative genetics of bryozoan phenotypic evolution. II. Analysis of selection and random change in fossil species using reconstructed genetic parameters. *Evolution* **48**, 360-375.

Cheetham, A.H., Jackson, J.B.C. and Hayek, L.C. 1995. Quantitative genetics of bryozoan phenotypic evolution. III. Phenotypic plasticity and the maintenance of genetic variation. *Evolution* **49**, 290-296.

Cheetham, A.H., Jackson, J.B.C. and Sanner, J. 2001. Evolutionary significance of sexual and asexual modes of propagation in Neogene species of the bryozoan *Metrarabdotos* in tropical America. *Journal of Paleontology* **75**, 564-577.

Cheetham, A.H., Jackson, J.B.C., Sanner, J. and Ventocilla, Y. 1999, Neogene cheilostome Bryozoa of tropical America: Comparison and contrast between the Central American Isthmus (Panama, Costa Rica) and the north-central Caribbean (Dominican Republic). *Bulletins of American Paleontology* **357**, 159-192.

Cheetham, A.H., Sanner, J. and Jackson, J.B.C. 2007. *Metrarabdotos* and related genera (Bryozoa: Cheilostomata) in the late Paleogene and Neogene of tropical America. *Paleontological Society Memoir* 67, *Journal of Paleontology* **81**: supplement to no. 1.

Collins, L. 2009. About the Panama Paleontology Project. <www.fiu.edu/~collinsl/pppabout.html>

Cook, P.L. 1973. Settlement and early colony development in some Cheilostomata, p. 65-71. *In* G. P. Larwood (ed.), *Living and Fossil Bryozoa, Recent Advances in Research*. London and New York: Academic Press.

Dick, M.H., Herrera-Cubilla, A. and Jackson, J.B.C. 2003. Molecular phylogeny and phylogeography of free-living Bryozoa (Cupuladriidae) from both sides of the Isthmus of Panama. *Molecular Phylogenetics and Evolution* **27**, 355-371.

Eldredge, N. and Gould, S.J. 1972. Punctuated equilibria: an alternative to phyletic gradualism, p. 82-115. *In* T.J.M. Schopf (ed.), *Models in Paleobiology*. San Francisco: Freeman, Cooper.

Eldredge, N., Thompson, J.N., Brakefield, P.M., Gavrilets, S., Jablonski, D., Jackson, J.B.C., Lenski, R.E., Lieberman, B.S., McPeek, M.A. and Miller, W. III. 2005. The dynamics of evolutionary stasis, p. 133-145. *In* E.S. Vrba and N. Eldredge (eds), *Macroevolution, Disparity, Contingency, Essays in Honor of Stephen Jay Gould*. *Paleobiology*, Supplement to Volume 31(2).

Erwin, D.H. and R.L. Anstey (eds). 1995. *New Approaches to Speciation in the Fossil Record*. New York: Columbia University Press.

Erwin, D.H. and R.L. Anstey. 1995. Speciation in the fossil record, p. 11-38. *In* D.H. Erwin and R.L. Anstey (eds), *New Approaches to Speciation in the Fossil Record*. New York: Columbia University Press.

Foote, M. and Miller, A.I. 2007. *Principles of Paleontology* (Third Edition). New York: W. H. Freeman and Company.

Futuyma, D.J. 2005. *Evolution*. Sunderland, MA: Sinauer Associates.

Grimshaw, A.J. 2001. *The Adventures of Punctuated Equilibria. A Struggle for Authority in the Evolutionary Sciences*. <http://tux.lib.deakin.edu.au/adt-VDU/public/adt-VDU20051110.141422/>

Herrera-Cubilla, A., Dick, M.H., Sanner, J. and Jackson, J.B.C. 2005. Neogene Cupuladriidae of tropical America. I. Taxonomy of recent *Cupuladria* from opposite sides of the Isthmus of Panama. *Journal of Paleontology* **80**, 245-263.

Herrera-Cubilla, A., Dick, M.H., Sanner, J. and Jackson, J.B.C. 2008. Neogene Cupuladriidae of tropical America. II. Taxonomy of recent *Discoporella* from opposite sides of the Isthmus of Panama. *Journal of Paleontology* **82**, 279-298.

Jackson, J.B.C. 1979. Overgrowth competition between encrusting cheilostome ectoprocts in a Jamaican cryptic reef environment. *Journal of Animal Ecology* **48**, 805-823.

Jackson, J.B.C., Buss, L.W. and Cook, R.E. (eds). 1985. *Population Biology and Evolution of Clonal Organisms*. New Haven: Yale University Press.

Jackson, J.B.C. and Cheetham, A.H. 1989. Are skeletons enough to tell species apart? a test using cheilostome Bryozoa. Geological Society of America, 1989 Annual Meeting.

Jackson, J.B.C. and Cheetham, A.H. 1990. Evolutionary significance of morphospecies: A test with cheilostome Bryozoa. *Science* **248**, 579-583.

Jackson, J.B.C. and Cheetham, A.H. 1994. Phylogeny reconstruction and the tempo of speciation in cheilostome Bryozoa. *Paleobiology* **20**, 407-423.

Jackson, J.B.C. and Cheetham, A.H. 1999. Tempo and mode of speciation in the sea. *Trends in Ecology and Evolution* **14**, 72-77.

Jackson, J.B.C. and Herrera, A. 1995. Sex and selfing in *Stylopoma*. International Bryozoology Association, 10th International Conference, Wellington, New Zealand.

Kerr, R. A. 1995. Did Darwin get it all right? *Science* **267**, 1421-1422.

Lande, R. 1977. Statistical tests for natural selection on quantitative characters. *Evolution* **31**, 442-444.

Lande, R. 1979. Quantitative genetic analysis of multivariate evolution, applied to brain: body size allometry. *Evolution* **33**, 402-416.

Levinton, J. 1988. *Genetics, Paleontology and Macroevolution*. Cambridge, United Kingdom: Cambridge University Press.

Levinton, J. 1991. Bryozoan morphological and genetic correspondence: What does it prove? *Science* **251**, 318-319.

Lynch, M. 1988. The rate of polygenic mutation. *Genetical Research Cambridge* **51**, 137-148.

Lynch, M. 1990. The rate of morphological evolution in mammals from the standpoint of neutral expectation. *American Naturalist* **136**, 727-741.

Maturo, F.J.S., Jr. 1973. Offspring variation from known maternal stocks of *Parasmittina nitida* (Verrill), p. 577-584. *In* G.P. Larwood (ed.), *Living and Fossil Bryozoa, Recent Advances in Research*. London and New York: Academic Press.

Maynard Smith, J. 1988. *Games, Sex and Evolution*. Hemel-Hempstead, UK: Harvester-Wheatsheaf.

Mayr, E. 1954. Geographic speciation in tropical echinoids. *Evolution* **8**, 1-18.

Mayr, E. 1963. *Animal Species and Evolution*. Cambridge, MA: Harvard University Press.

McKinney, F.K. and Jackson, J.B.C. 1989. *Bryozoan Evolution*. London: Unwin.

McKinney, F.K. 1995. One hundred million years of competitive interactions between bryozoan clades: Asymmetrical but not escalating. *Biological Journal of the Linnean Society* **56**, 465-481.

O'Dea A. and Jackson, J.B.C. 2002. Bryozoan growth mirrors contrasting seasonal regimes across the Isthmus of Panama. *Palaeogeography, Palaeoclimatology, Palaeoecology* **185**, 77-94.

O'Dea, A., Herrera-Cubilla, A., Fortunato, H. and Jackson, J.B.C. 2004. Life history variation in cupuladriid bryozoans from either side of the Isthmus of Panama. *Marine Ecology – Progress Series* **280**, 145-161.

Wright, S. 1982. Character change, speciation, and the higher taxa. *Evolution* **36**, 427-443.

Collections and climate change research: *Flustra foliacea* (L.) (Bryozoa) in the Natural History Museum, London

Helena Fortunato[1] and Mary E. Spencer Jones[2]

[1]*Institute of Geology, Kiel University, Ludewig-Meyn-Str. 10, D-24118 Kiel, Germany*

[2]*Department of Life Sciences, Natural History Museum, Cromwell Road, London, SW7 5BD, UK*

1. Introduction

Museums give pleasure by evoking wonder and awe. They allow us to explore the world, making other cultures and places real and tangible. In this ever changing world they give users a strong sense of place, identity and belonging based on the past. Museums have a considerable economic impact and stimulate science, creativity and industry. In this paper we focus on one of their major functions - providing evidence, ideas and opportunities for research and learning.

Museum collections represent huge databases accumulated over time thus providing an historical perspective for modern surveys. As old collections become used and studied, old information is corrected in a continuous validation process that represents an important component of our general knowledge. Collections are especially important for groups that are either too big (i.e. some invertebrates), difficult to collect like those living in extreme locations, or groups that may have various restrictions in their collecting such as happens with many vertebrate taxa.

Biological collections are cornerstones in such diverse areas as environmental monitoring, public health, taxonomy and systematics and even in national security

(Ponder *et al.* 2001, Hellberg *et al.* 2001, Hoffmaster *et al.* 2002, EPA 2002). They play a crucial role in biodiversity loss, biological invasions, biogeography and evolution studies. Without these collections many species would be unknown, even more so in the light of present day biodiversity loss as a consequence of the rapid environmental degradation of the 21st century.

In spite of their intrinsic value, museum collections also pose many problems to the user. Among these is the lack of detailed information in older lots, or the use of obsolete locality names. Museum collections are usually arranged taxonomically thus posing problems for ecological studies. Other problems include temporal and spatial gaps, several types of sampling biases, not enough specimens to evaluate species variability, etc. In many cases collections are not completely databased, though more and more museums dedicate large resources to this end. Indeed, in recent years, natural history museum collections have changed in order to meet the challenges of interdisciplinary studies. Many have become fully digital and are freely available on the Internet providing endless opportunities for research.

An important role is played by curators and collections managers. Their collaboration with researchers in using the collections is indispensable especially at a time when museum resources become compromised. Though extra resources are always difficult to secure, researchers try to help by directing some funds in their proposals to help collections management and databasing. On another hand, curators and collections managers could start being more open towards accepting a certain amount of destructive sampling, especially in cases when expected results merit such exceptions or when not so perfect material is available. As bulk sampling replaces the traditional specimen collecting, these collections can be used as a source of unsorted material for ecological studies while those not so perfect specimens can be used for destructive sampling.

Another aspect where museum collections still lag behind is in their integration with other databases. This is especially important at a time of heightened awareness concerning observed rapid changes – it would be extremely useful if museum collections could be integrated as much as possible with meteorological data, geological reconstructions and library records. Unfortunately field books and collecting records are often kept separated from the collections they refer to which means extra steps in order to retrieve that data.

An area where museum collections have been an invaluable resource is palaeobiology. Such research usually implies sampling many geographic locations throughout the time interval of interest as well as knowledge about depositional conditions, good preservation, etc. The use of palaeobiological collections have been the source of many breakthroughs in science and several seminal works were based on them (Sepkoski and Koch 1995, Jackson *et al.* 1999).

2. Climate change research and museum collections

Among others, climate change research can highly benefit from the study of natural history collections. The rapid changes documented today call for data from as many species and locations as possible if we are to understand the underlying mechanisms of responses and adaptations at organisms' and populations' level. Besides, collections can also help find reliable organisms to be used as early indicators of environmental impact.

During the last decade and overwhelming evidence have been gathered showing how present day climate trends are already affecting the physiology, distribution and phenology of many species in a consistent way (Raven *et al.* 2005, Feely *et al.* 2009). Such data is being used to predict future changes and work out possible remediation and adaptation policies. Although natural variation is certainly responsible for many of these trends, human-induced climate is the most parsimonious explanation for others. The best evidence for these comes from intensive monitoring programs over an extended period (Fleming and Tatchell 1995, Phillips *et al.* 1998, Boyce *et al.* 2010) as well as studies comparing present day distributions and past data (Cresswell and McCleery 2003, Cruz-Motta *et al.* 2010, Genner *et al.* 2010, Hawkins *et al.* 2013). Results show how important long term data sets are to identify vulnerable species and communities (Harrington *et al.* 1999). Unfortunately, such data sets are relatively rare, and new baseline monitoring programs are very much needed. In the absence of these programs museum collections can play an extremely important and decisive role. Most climate studies use either mathematical models or experimental observations in order to predict future changes and advise policy makers. Natural history collections, recent and fossil alike, can bring a different perspective into this research. Indeed, the millions of specimens stored in museums document past (whether millions of years, hundreds or just decades) ecological conditions and how species adapted to these conditions and their turnover. The study of museum material allows us to document changes in biodiversity and abundances through time and space, and analyze how species answered environmental impacts. Museum collections are already being used to monitor geographic range extensions, the establishment or extinction of local populations, to track the advance of exotic species and the replacement of native fauna and flora, etc. Because museums are easily accessible to the non-specialist, collections should also be used to illustrate taxa so non-scientists can help monitoring 'newcomers' thus playing a major role in the assessment of the conservation status and level of threat of many species. The amount of new information that collections can provide is overwhelming and they can serve as a real baseline to help make more informed and accurate predictions. Of course, in order to correctly distinguish subjective changes in collecting effort and objective changes in species ranges and abundances (McCarthy 1998) we also need to develop better quantitative methods that allow us to extract the correct information from existing collections taking in account that collecting effort was not the same over time.

With over 70 million specimens, from mammoth skeletons to microscopic slides, a leading research institution and one of the most important world repositories of natural history collections, the Natural History Museum, London (NHM) is a good example of how museum science has changed during the last several decades.

The aim of this paper it is to describe the collection of *Flustra foliacea* (L.) (Bryozoa) collection housed at the NHM, and its potential use in climate change studies.

3. Why bryozoans?

Current data show that ongoing changes in ocean chemistry will severely impact marine taxa with unpredictable consequences for abundance, diversity and species distribution (Raven *et al.* 2005, Riebesell 2008, Feely *et al.* 2009, IPCC 5th Assessment Report 2013) as well as food chains and ecosystems. Taxa that mineralize calcium carbonate skeletons should be especially affected by such trends. In order to better understand observed events and be able to deal with its consequences we need more studies of the short and long term consequences of ocean acidification. Especially important are data on the combined effects of CO_2 and temperature.

The Phylum Bryozoa has an enormous potential concerning studies of ocean acidification impacts that have somewhat been overlooked even though they play an important role in benthic temperate ecosystems (Ryland 1970). Bryozoans can be found both in the ocean and in freshwater and they are well preserved and abundant as fossils with a record extending from the early Ordovician (some 488 million years ago) (Pohowsky 1978, McKinney and Jackson 1989, Jones 2006, Taylor *et al.* 2013). Important bio constructors both in past and recent environments, they are fundamental components of the marine sessile epifauna (Scholz and Krombein 1996, Massard and Geimer 2008). Many encrusting and erect species coexist, often in direct competition for space and food forming the so-called 'biomats' that may cover large areas thus increasing substratum complexity and the diversity of sessile communities (Stebbing 1971a). Bryozoan diversity of shapes, forms and growth strategies makes them a good subject study in benthic temperate ecosystems and an easy subject for inferences of environmental regimes.

Recently, a series of important studies using bryozoans as model systems for bio-invasions, larval dispersal and marine speciation, palaeotemperature proxies, sources of bioactive (antifouling and antimicrobial) compounds and acidification impact in calcification patterns became available. Being sessile organism, they are first to be impacted by pollution and stress. Several species have been successfully used as indicators in coastal pollution and changes in bottom communities. A few studies also indicate that particularly sensitive species could be used in programs monitoring the effects of ocean acidification and as early indicators of switches in carbonate regimes (Smith 2009, Smith and Garden 2013).

Several bryozoans studies have focused on skeletal mineralogy, growth rates and carbonate production (Smith *et al.* 1992) as well as their use to monitor seasonal changes in temperature and primary productivity in northern latitudes (Bader 2001, Bader and Schäfer 2005, Schäfer and Bader 2008). Bryozoans' skeleton composition can be calcite, aragonite or a combination of both elements. They exhibit a wide range of $MgCO_3$ (0 – 14 wt%) which was shown to be at least partially phylogenetically controlled (Smith *et al.* 2006, Taylor *et al.* 2009). Studies on dead skeletons have shown that their mineralic composition (LMG-/HMG-calcite, aragonite) conditions the way acidity effects them. Besides, different species will react to acidification impact differently and at different stages in their life cycle. As a result, more sensitive species could be used as 'sentinels' thus providing early warning signals of acidification impacts in shelf communities (Smith 2009, Smith and Garden 2013). Bryozoan species with bi-mineralic skeletons could be good candidates for this 'canary' status. Many of them form thickets on the seafloor being important ecologic elements and carbonate producers in mid-latitude northern- and southern-hemisphere shelf communities.

Bryozoan zooid morphology has been previously used in inferences of environmental regimes. Several species have easily discriminated growth bands that provide a reliable tool to calculate growth rates. These data have been used to infer relationships between growth and environmental parameters such as temperature and productivity levels (Menon 1975, Okamura 1987, Bader and Schäfer 2005). Zooid morphology was also shown to be temperature dependent in a few species (O'Dea and Okamura 1999, 2000a, 2000b, O'Dea and Jackson 2002, O'Dea 2005, Lombardi *et al.* 2006, Amui-Vedel *et al.* 2007).

4. *Flustra foliacea* – a 'canary' for the temperate north Atlantic coasts

Flustra foliacea (Figure 1) is a cheilostome bryozoan widely distributed in the North Atlantic Ocean, on both American and European coasts where it plays an important ecological function as habitat structuring. It often forms dense thickets dimensionally structuring the sea floor and providing habitat to a rich epifauna (Stebbing 1971a, Bitschovski *et al.* 2011, Bitschovski 2013). This is a widespread species on gravel grounds in the UK coast and many other regions around the temperate western North Atlantic (i.e. Normandy, Steingrund, Helgoland, etc.) but rare in several adjacent seas (i.e. Baltic, White, Kara and Barents seas). It is also quite abundant in the Bay of Fundy (US/Canada east coast) where recent coastal surveys show a notable range expansion during the last decades. This is interpreted as one of the possible reasons for the changes in community structure observed in the area (Kenchington *et al.* 2007). Interesting enough, *Flustra foliacea* may also be present in the Commander Islands, Bering Sea, (A. Grischenko pers. comm.) which if true would probably represent the remnants of an old distribution.

The first reference to *Flustra foliacea* was in 1665, when it was observed and its zooids described by Robert Hooke. In 1758, Linnaeus included it in the 10th edition of *Systema Naturae* under the name of *Eschara foliacea* which was later changed to its current name (Hansson 1999). *Flustra foliacea* is the type species of the genus (Ryland 1969).

This species is an important producer of biologically active metabolites. Flustramine E from North Sea colonies interferes with the development of *Botrytis cinerea* and *Rhizotonia solani*. Furthermore, Deformylflustrabromine was shown to be relatively toxic to the cell line HCT-116 (human colon cancer). This contributes to make *F. foliacea* a potential subject for medical studies (Lysek *et al.* 2002, Liebezeit 2005, Sala *et al.* 2005, Sharp *et al.* 2007) and an emblematic species.

Being mostly a cold temperate species, *F. foliacea* grows mainly during spring and summer producing annual growth rings. Colonies grow usually on shells and small rocks being usually restricted to sub littoral waters though they can be found deeper. They start

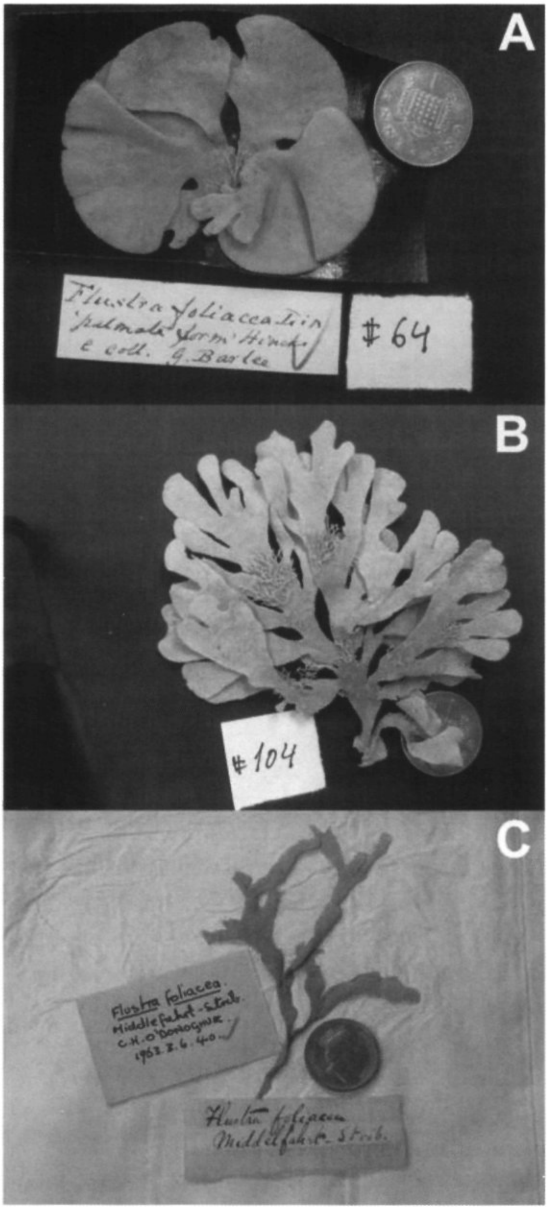


Figure 1. Flustra foliacea *(L.) - most common phenotypes: (A) palmate form (probably collected prior to 1900); (B) bush-like form (Skarreklit, Denmark, collected 5/1962, Alan Cheetham); (C) thin and elongated branches (Middlefart-Strib., Denmark).*

as flat encrustations and its characteristic loose fronds form from the second year onwards. They are produced when two growing lobes of the colony meet, and the two edges that make contact begin growing upwards, forming a bi-laminar, upright frond. This initial frond starts to branch and colonies may live up to 12 years growing in bushy clumps. Flat, lobate fronds can reach up to 20 cm and are flexible due to the small amount of calcium carbonate. Most of the zooecium walls are chitinous (Fish and Fish 2011).

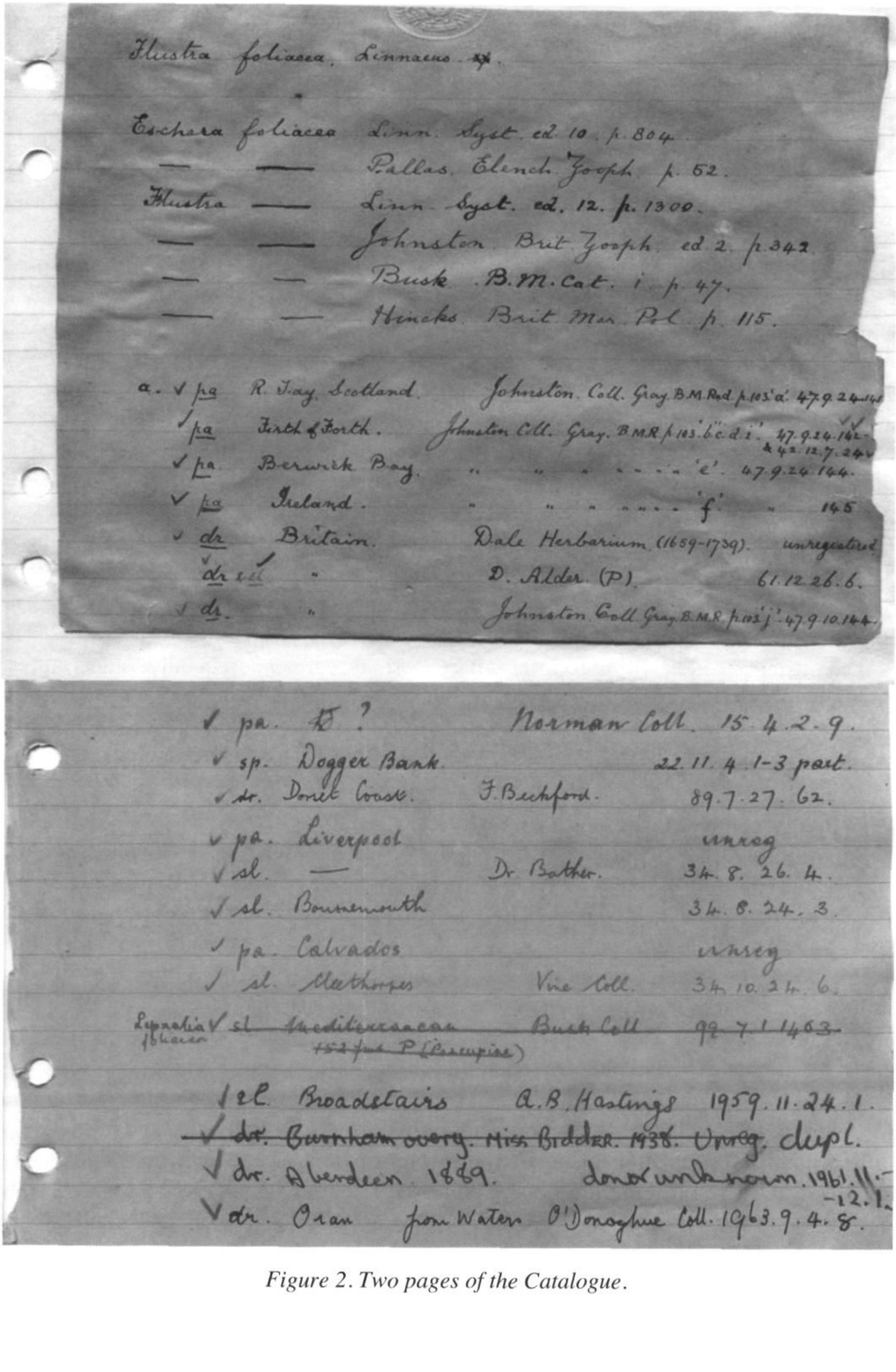
This species exhibits considerable morphologic variability along its distribution area (Figure 1) ranging from bush-like forms with shorter, wide fronds in the Atlantic open coastal areas to thin, elongated (often ribbon-like) branches in marginal habitats. Besides, specimens from open ocean areas of the western Atlantic usually present up to four well-developed spines on the zooids top. This could be a possible response to predation by nudibranchs (quite abundant in Atlantic coastal settings) as it was shown for *Membranipora membranacea* (Harvell 1984, 1992). In adjacent seas (i.e. Baltic, Barents Sea) spines are either absent or weekly developed.

Growth-check lines are more pronounced in the colony younger parts. Easily observable with naked eye and under an optical microscope, this was used by Stebbing (1971b) to study monthly growth rates in material collected from South Wales. Results indicated a linear growth pattern in height and similar growth rates at all ages. Later on, experimental data showed the existence of a direct relationship between temperature and growth rates and an inverse relationship with zooecia average size (Menon 1975). These data were used as the basis to use zooid profiling and seasonal growth cycles in *Flustra foliacea* as a tool to infer environmental regimes, especially temperature changes, in perennial bryozoan skeletons (O'Dea and Okamura 1999, 2000a, 2000b, O'Dea 2005). This is the so-called MART technique that has also been used as a tool in palaeoclimate studies (O'Dea and Jackson 2002).

The wide distribution and conspicuousness of *Flustra foliacea* makes it a good subject for climate change studies. Being a bi-mineralic species it can be used as an indicator in coastal north Atlantic areas. Fortunato *et al*. (2013) found higher variability in zooid frontal index and density in Baltic colonies than in North Sea ones. Despite similar carbon and carbonate contents in colonies from both areas, preliminary data from muffle oven tests show higher weight loss in Baltic colonies whereas Helgoland colonies show higher sensitivity to dissolution which may relate to the different phenotypes that inhabit these areas. On the other hand Schäfer *et al*. (2014) found that Baltic colonies exhibit a higher content of organic matter at the expense of carbonate. This may be seen as another way of fulfilling the skeleton main function, i.e. support, being also a better protection for the calcitic matrix in a higher corrosive environment. Similar conclusions were made by Rodolfo-Metalpa *et al*. (2010) in relation to *Myriapora truncata* grown under naturally acidic conditions in the Mediterranean Sea. Preliminary results from colonies grown under different temperature and CO_2 levels show changes in calcification levels (Fortunato unpub data).

Data using zooid profiling to infer environmental regimes, especially temperatures, have given somewhat contradictory data. Indeed, whereas *Conopeum seurati* shows a clear relation between temperature regimes and zooecia area rather than its linear size (O'Dea and Okamura 1999), *Pentapora fascialis* zooid sizes seem to be more sensitive to temperature regimes than zooid area (Lombardi *et al*. 2006) whereas *Cryptosula pallasiana* colonies collected during early summer had longer and wider zooids than those collected in January but colonies grown under different temperature regimes presented significantly longer and wider zooids at lower temperature values (Amui-Vedel *et al*. 2007). In order to understand how MART technique can be better used in climate change studies we need a baseline which can be obtained analyzing specimens from one single species collected since pre-industrial times and kept in museum collections. Such information can then be used to detect changes in growth rates and calcification levels that could eventually be related to ongoing environmental changes. Furthermore it could be used to calibrate experimental data and build inferences for future changes.

Flusta foliacea can fulfil this role. It is often washed up on beaches after storms and following high tides and is conspicuous enough to be frequently collected and in relatively large amounts. (It was often mistaken by collectors in the past as a plant and deposited in herbaria). As a result there are now excellent collections dating from the late 1600s onwards and housed in several museums. The collections housed in the NHM are extensive (Figure 2) and have recently been utilised to study *F. foliacea* growth patterns and calcification levels over the last couple of hundred years.


Flustra foliacea, Linnaeus.

Eschara foliacea Linn. Syst. ed. 10. p. 804.
— — Pallas. Elench. Zooph. p. 52.
Flustra — Linn. Syst. ed. 12. p. 1300.
— — Johnston. Brit. Zooph. ed 2. p. 342.
— — Busk. B.M. Cat. i. p. 47.
— — Hincks. Brit. Mar. Pol. p. 115.

a. ✓ pa R. Tay, Scotland. Johnston. Coll. Gray. B.M. Rad. p.103 'a'. 47.9.24.141
✓ pa Firth of Forth. Johnston Coll. Gray. B.M.R. p.103 'b.c.d.i'. 47.9.24.142 & 42.12.7.24
✓ pa. Berwick Bay. " " " " " 'e'. 47.9.24.144.
✓ pa Ireland. " " " " " 'f'. " 145
✓ dr Britain. Dale Herbarium (1659-1739). unregistered
✓ dr " D. Alder. (P). 61.12.26.6.
✓ dr. " Johnston Coll. Gray. B.M.R. p.103 'j'. 47.9.10.144.

✓ pa. ? ? Norman Coll. 15.4.2.9.
✓ sp. Dogger Bank. 22.11.4.1-3 part.
✓ dr. Dorset Coast. F. Beckford. 89.7.27.62.
✓ pa. Liverpool unreg
✓ sl. — Dr Bather. 34.8.26.4.
✓ sl. Bournemouth 34.8.24.3
✓ pa. Calvados unreg
✓ sl. Mathoses Vine Coll. 34.10.24.6.
Lepralia foliacea ✓ ~~sl Mediterranean Busk Coll 99.7.1.1463~~
~~152 fms P (Porcupine)~~
✓ el. Broadstairs A.B. Hastings 1959.11.24.1.
~~✓ dr. Burnham overy. Miss Bidder. 1938. Unreg.~~ dupl.
✓ dr. Aberdeen 1889. donor unknown. 1961.11.-12.1.
✓ dr. Oran from Waters O'Donoghue Coll. 1963.9.4.8.

Figure 2. Two pages of the Catalogue.

5. The Collections

The NHM collections present a unique opportunity to make direct comparisons between specimens of *Flustra foliacea* collected in different parts of the North Atlantic basin since pre-industrial times. Especially important is the fact that they allow comparisons across populations inhabiting different environments thus being ideal for both MART (O'Dea and Okamura 2000a, 2000b) and calcification rates studies. The collections were made over 300 years spanning a period from pre-industrialization through today and can thus be used to build up a temporal baseline necessary to assess eventual temperature changes in the ocean during the last several centuries. Zooid parameters will be used to obtain estimates of the temperature regime at the time the colony was alive. Data will then be used in ongoing climate change studies and related ocean acidification impact in carbonate builders to help assess observed morphologic changes and its relation to environmental factors.

Appendix 1 lists the *F. foliacea* collection stored at the NHM. A total of 111 samples were examined by stereo- and scanning electron microscopy. Figures 3-7 illustrate some of the most interesting lots. The museum also has a wet sample from the Canadian Atlantic coast which was not included in this study but is included in the database for future reference.

Due to their unique value, colonies from historical collections were studied only by stereomicroscopy. Images were captured and analyzed using the image capture system (Zeiss AxioCam High-resolution digital system, Figure 8) available in the Zoology department. Zooid sizes in calibrated digital images were measured using morphometric software.

Work followed a protocol (Appendix 2) developed earlier by Fortunato *et al.* (2013). The work proceeded the following way:

1. All lots were initially surveyed and entered in a database. Besides of the BM access number, each lot received a unique ID that will be used for further work. Besides of the information in the label, other information about the lots (i.e. colony morphology type, number of colonies in the lot, preservation condition, etc.) was registered in the database. All lots were photographed including the BM label and the ID.
2. If more than one colony was available in the lot, one of them was chosen, preferably one with a starting point well recognized by its incrusting attachment. In this colony a long branch was chosen for further work so a bigger time span would be followed. This colony was further identified in the original lot by another label specifying that it was studied by the author.
3. Measurements were done following a profile running from the growing tip of the branch and moving downwards towards its base following the sequential generations of budding zooids (Figure 9). Three zooids in each sequential generation along the profile were measured.
4. The following parameters were measured, counted or checked in every studied colony branch: maximum zooid length and width, presence and location of spines, number of

Figure 3 (left). Flustra foliacea*: two lots received from the Cambridge Botany School. Catalogue information places collection date around 1761.*

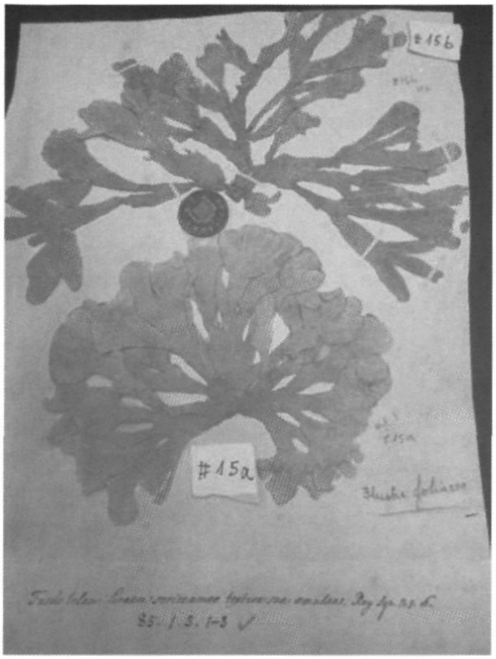
Figure 4 (below). Flustra foliacea*: lot collected probably around late 1700s.*

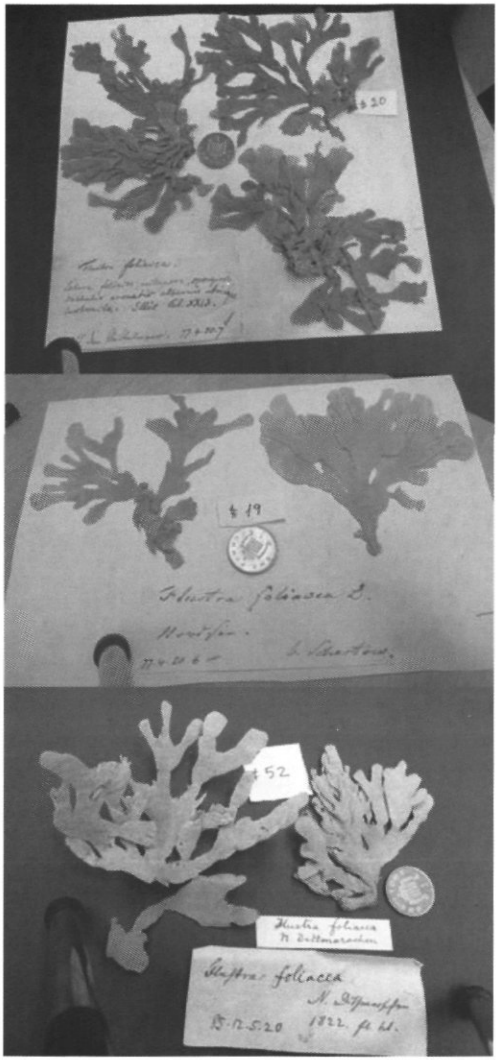
spines if present, number of ovicells per generation, number of avicularia per generation, number of generations in the branch. Geminated zooids, zooids with avicularia and ovicells were not used for measurements. If they occurred in the area of measurements, they were skipped and other nearby zooids used. Towards the base of the branch, in the encrusting area, it was difficult to find complete zooids; besides zooids were often heavily deformed and overgrown. For this reason measurements were either not taken in this area or zooids outside the transect were used if available.

5. Zooid density, collected every 4.6 mm intervals along the profile starting from the growing tip, was measured as the number of zooids in an area of 0.88 mm^2.
6. Two indices were calculated: index of zooid frontal area (length x width) and zooid shape (length/width) following O'Dea and Jackson (2002). The presence and frequency of ovicells was used to assess the reproductive status of the studied colonies.

Specimens from recent cruises and kept at the museum were studied through Scanning Electron Microscopy (LEO 1455). In this case, a selected colony was washed and dried to clean it as much as possible. This colony was then mounted, photographed and the photograph used to navigate in the electron microscope to help set up a transect along which SEM photos were taken for later zooid measurements. The same protocol of work described above for digital images was used here (see Appendix 2).

The present material will allow the study of growth rates in colonies collected during the 18^{th}, 19^{th} and 20^{th} centuries. Compiled information will be compared with data from





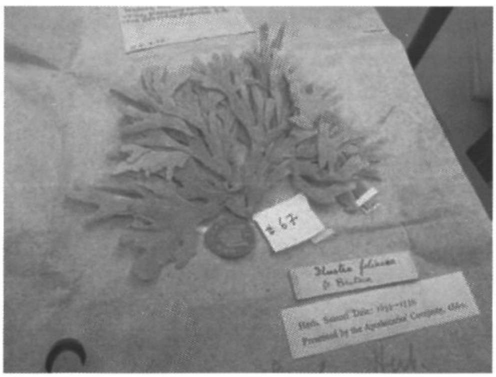


Figure 5 (top left). Flustra foliace: *lot transferred from the Cambridge Botanical School. The handwriting on the label considered by the Registrar to be that of Linné when young.*
Figure 6 (top right). Flustra foliacea: *three lots from the Nolté Herbarium. The upper lot locality is 'Mediterranean' which maybe a mistake. Collection dates probably around mid-1800s.*
Figure 7 (bottom left). Flustra foliacea: *lot from the Dale Herbarium. This is probably one of the oldest lots in the collection.*

recently collected specimens and those grown in experiments with varying CO_2 and temperature levels. Through the comparison of growth rates and calcification levels in older material and modern colonies we aim to be able to detect and analyze eventual changes in growth and calcification in *Flustra foliacea* which could be paralleled with the accelerated acidification trends documented for the western North Atlantic since pre-

Figure 8. Digital setup used to work with historical lots.

industrial times. Temperature related data obtained using the MART methodology will be used to calibrate our experimental based inferences concerning temperatures and environmental regimes. Results will finally be integrated in a database aimed to use *F. foliacea* as an environmental indicator of temperatures (and acidification levels) in the Northern Hemisphere coastal areas. This will represent an important contribution to the use of bryozoans as key elements to monitor changing oceanic pH and its effects in temperate northern shelf areas aiming to a better understanding of ocean acidification impact in benthic marine systems and its biodiversity.

6. Conclusions

Despite the growing amount of research using natural history museum collections (Suarez and Tsutsui 2004, Barnet *et al*. 2008, Pinto *et al*. 2010), this practice is not yet common. Natural history museum collections can and should be used more frequently as sources of information to complement ongoing surveys. They will add a temporal dimension necessary for a better understanding of ongoing trends and preparation for future changes. Furthermore, the use of natural history collections in high impact research areas such as climate change and global warming, medical and epidemiological surveys, invasive species monitoring and even national security will reinforce the need for the maintenance of these wonderful places, i.e. museums, thus justifying every penny spent

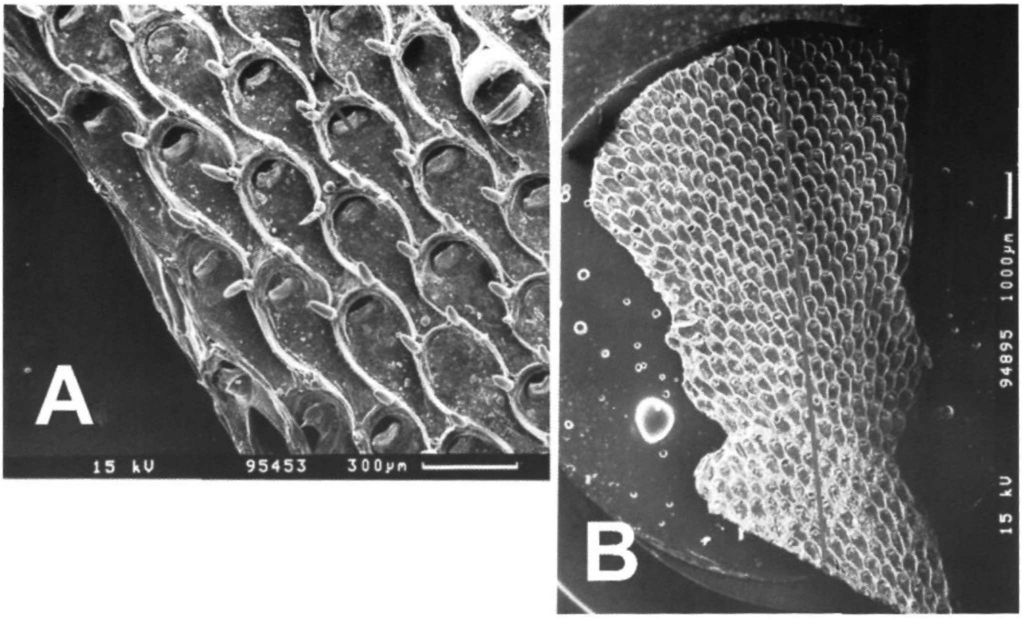


Figure 9. SEM pictures of a colony showing the scheme used for measurements. (A) Profile across generations from growing tip to base; (B) Close up of zooid showing max width and length measurements.

on them and their staff. In the end, we all stand to gain, science and society alike, from this practice.

7. Acknowledgments

This research was supported by a SYNTHESIS grant to Fortunato (GB-TAF-1679: The Bryozoan *Flustra foliacea* - an archive for climate studies) financed by the European Community Research Infrastructure Action under the Fp7 Integrating Activities Programme (http://www.synthesis.info). HF thanks the editors of the *Annals of Bryozoology* for providing a venue for this contribution, and is also grateful to all the scientific and support staff at the Natural History Museum for their full support during her visit.

References

Amui-Vedel, A-M., Peter, J.H. and Porter, J.S. 2007. Zooid size and growth rate of the bryozoan *Cryptosula pallasiana* Moll in relation to temperature, in culture and in its natural environment. *Journal of Experimental Marine Biology and Ecology* **353**, 1-12.

Bader, B. 2001. Modern Bryomol-sediments in cool-water, high-energy setting: the inner shelf off Northern Brittany. *Facies* **44**, 81-104.

Bader, B. and Schäfer, P. 2005. Impact of environmental seasonality on stable isotope composition of skeletons of the temperate bryozoan *Cellaria sinuosa*. *Palaeogeography, Palaeoclimatology, Palaeoecology* **226**, 58-71

Barnett, R., Yamaguchi, N., Shapiro, B. and Sabin, R. 2008. Ancient DNA analysis indicates the first English lions originated from North Africa. *Contributions to Zoology* **77** (1), 7-16.

Bitschowski, F. 2013. Distribution over space and time in some selected epizoobiontic North Sea Bryozoans, pp. 1-12. *In* A. Ernst, Schäfer, P. and Scholz, J. (eds), *Bryozoan Studies 2010*. Springer, Berlin-Heidelberg.

Bitschofsky, F., Forster, S. and Scholz, J. 2011. Regional and temporal changes in epizoobiontic bryozoan communities of *Flustra foliacea* (Linnaeus, 1758) and implications for North Sea ecology. *Estuary and Coastal Shelf Research* **9**(3), 423-433.

Boyce, D.G., Lewis, M.R. and Worm, B. 2010. Global phytoplankton decline over the past century. *Nature* **466**, 591-596.

Cresswell, W. and McCleery, R. 2003. How great tits maintain synchronization of their hatch date with food supply in response to long-term variability in temperature. *Journal of Animal Ecology* **72**, 356 -366.

Cruz-Motta, J.J., Miloslavich, P., Palomo, G., Iken, K., Konar, B., Pohle, G., Trott, T., Benedetti-Cecchi, L., Herrera, C., Hernandez, A., Sardi, A., Bueno, A., Castillo, J., Klein, E., Guerra-Castro, E., Gobin, J., Gomez, D.I., Riosmena-Rodrıguez, R., Mead, A., Bigatti, G., Knowlton, A. and Shirayama, Y. 2010. Patterns of Spatial Variation of Assemblages Associated with Intertidal Rocky Shores: A Global Perspective. *PLoS ONE* **5**(12), e14354. doi:10.1371/journal.pone.001.

EPA 2002. *National Water Quality Inventory 2000 Report*. Washington (DC).

Feely, R.A., Scott, C.D. and Cooley, S.R. 2009. Ocean acidification: Present conditions and future changes in a high-CO2 world. *Oceanography* **22**, 36-47.

Fish, J. and Fish, S. 2011. *Bryozoa (Ectoprocta). A Student's Guide to the Seashore*. (3rd ed.) Cambridge University Press.

Fleming, R.A. and Tatchell, G.M. 1995. Shifts in the flight periods of British aphids: a response to climate warming?, pp. 505-508. *In* R. Harrington and N. Stork (eds), *Insects in a Changing Environment*. Academic Press.

Fortunato, H., Schäfer, P. and Blaschek, H. 2013. Growth rates, age determination and calcification levels in *Flustra foliacea* (L.) (Bryozoa: Cheilostomata): preliminary results. *In* A. Ernst, P. Schäfer and J. Scholz (eds), *Bryozoan Studies 2010,* 59-74. Springer-Publisher, Berlin-Heidelberg.

Genner, M.J., Sims, D.W., Southward, A.J., Budd, G.C., Masterson, P., McHugh, M., Rendle, P., Southall, E.J., Wearmouth, V.J. and Hawkin, S.J. 2010. Body size-dependent responses of a marine fish assemblage to climate change and fishing over a century-long scale. *Global Change Biology* **16**(2), 517-527.

Hansson, H.G. (1999) *(Comp.), NEAT (North East Atlantic Taxa): South Scandinavian* *marine "Lophophorata" Check-List*. Internet pdf Ed., Feb [http://www.tmbl.gu.se].

Harrington, R., Woiwod, I. and Sparks, T. 1999. Climate change and trophic interactions. *Trends in Ecology and Evolution* **14**, 146–150.

Harvell, C.D. 1984. Predator-induced defense in a marine bryozoan. *Science* **224**, 1357-1359.

Harvell, C.D. 1992. Inducible defenses and allocation shifts in a marine bryozoan. *Ecology* **73**(5), 1567-1576.

Hawkins, S.J., Vale, M., Firth, L.B., Burrows, M.T., Mieszkowska, N. and Frost, M. 2013. Sustained Observation of Marine Biodiversity and Ecosystems. *Oceanography,* 1:e101. doi: 10.4172/ocn.1000e101.

Hellberg, M.E., Balch, D.P. and Roy, K. 2001. Climate-driven range expansion and morphological evolution in a marine gastropod. *Science* **292,** 1707-1710.

Hoffmaster, A.R., Fitzgerald , C.C., Ribot, E., Mayer, L.W. and Popovic, T. 2002. Molecular subtyping of *Bacillus anthracis* and the 2001 bioterrorism-associated anthrax out-break, United States. *Emergent Infectious Diseases* **8**, 1111-1116.

IPCC 5th Assessment Report 2013. http://www.ipcc.ch/report/ar5/wg1/#.Up2F -IszTo.

Jackson, J.B.C., Todd, J.A., Fortunato, H. and Jung, P. 1999. Diversity and assemblages of Neogene Caribbean Mollusca of lower Central America. *Bulletins of Paleontology* **357**, 193-230.

Jones, R.W. 2006. *Principal fossil groups. Applied palaeontology*. Cambridge University Press.

Kenchington, E.L., Kenchigton, J., Henry, L., Fuller, S. and González, P. 2007. Multi-decadal changes in the megabenthos of the Bay of Fundy: the effects of fishing. *Journal of Sea Research* **58**, 220-240.

Liebezeit, G. 2005. Aquaculture of "Non-Food Organisms" for natural substance production. *Advances in Biochemistry and Engineering Biotechnology* **97**, 1–28.

Lombardi, C., Cocito, S., Occhipinti-Ambrogi, A. and Hiscock, K. 2006. The influence of seawater temperature on zooid size and growth rate in *Pentapora fascialis* (Bryozoa: Cheilostomata). *Marine Biology* **149**, 1103-1109.

Lysek, N., Rachor, E. and Lindel, T. 2002. Isolation and structure elucidation of Deformylflustrabromine from the North Sea bryozoan *Flustra foliacea. Zeitschrift für Naturforschung* **57**, 1056-1061.

Massard, J.A. and Geimer, G. 2008. Global diversity of bryozoans (Bryozoa or Ectoprocta) in freshwater. *Hydrobiologia,* **595,** 93-99.

McKinney, F.K. and Jackson, J.B.C. 1989. *Bryozoan evolution*. Allen & Unwin, London.

McCarthy, M.A. 1998. Identifying declining and threatened species with museum data. *Biological Conservation* **83**(1), 9-17.

Menon, N.R. 1975. Observations on growth of *Flustra foliacea* (Bryozoa) from Helgoland waters. *Helgoländer wiss Meeresunters* **27**, 263-267.

O'Dea, A. 2005. Zooid size parallels contemporaneous oxygen isotopes in a large colony of *Pentapora foliacea* (Bryozoa). *Marine Biology* **146**, 1075–1081.

O'Dea, A. and Okamura, B. 1999. Influence of seasonal variation in temperature, salinity and food availability on module size and colony growth of the estuarine bryozoan *Conopeum seurati*. *Marine Biology* **9**, 267-273.

O'Dea, A. and Okamura, B. 2000a. Life history and environmental interference through retrospective morphometric analysis of bryozoans: a preliminary study. *Journal of the Marine Biological Association UK* **80**, 1127-1128.

O'Dea, A. and Okamura, B. 2000b. Intracolony variation in zooid size in cheilostome bryozoans as a new technique for investigating palaeoseasonality. *Palaeogeography, Palaeoclimatology, Palaeoecology* **162**, 319–332.

O'Dea, A., Jackson, J.B.C. 2002. Bryozoan growth mirrors contrasting seasonal regimes across the Isthmus of Panama. *Palaeogeography, Palaeoclimatology, Palaeoecology* **185**, 77-94.

Okamura, B. 1987. Seasonal changes in zooid size and feeding activity in epifaunal colonies of *Electra pilosa*, pp. 197-203. *In* J.R.P. Ross (ed.), *Bryozoa: Present and Past*. Western Washington University, Bellingham.

Pinto, C.M., Baxter, B.D., Hanson, J.D., Méndez-Harclerode, F.M., Suchecki, J.R., Grijalva, M.J., Fulhorst, C.F., Robert, D. and Bradley, R.D. 2010. Using museum collections to detect pathogens [letter]. *Emergent and Infectious Diseases [serial on the Internet]*. Feb [accessed Dec 3, 2013]. http://wwwnc.cdc.gov/eid/article/16/2/09-0998.htm DOI: 10.3201/eid162.090998.

Phillips, O.L., Malhi, Y., Higuchi, N., Laurance, W.F., Nu, P.V., Va□squez, R.M., Laurance,S.G., Ferreira, L.V., Stern, M., Brown, S. and Grace, J. 1998. Changes in carbon balance of tropical forests: evidence from long-term plots. *Science* **282**, 439-441.

Pohowsky, R.A. 1978. The boring ctenostomate bryozoa: taxonomy and paleobiology based on cavities in calcareous substrata. *Bulletins of American Paleontology*, **73,** 192.

Ponder, W.F., Carter, G.A., Flemons, P. and Chapmen, R.R. 2001. Evaluation of museum collection data for use in biodiversity assessment. *Conservation Biology* **15**, 648-657.

Raven, J., Caldeira, K., Elderfield, H., Hoegh-Guldberg, O., Liss, P., Riebesell, U., Shepherd, J., Turley, C. and Watson, A. 2005. *Ocean acidification due to increasing atmospheric carbon dioxide*. Royal Society Policy Document 12/05, the Royal Society, London, 68pp.

Riebsell, U. 2008. Acid test for marine biodiversity. *Nature* **454**, 46-47.

Rodolfo-Metalpa, R., Lombardi, C., Cocito, S., Hall-Spencer, J.M. and Gambi, M.C. 2010. Effects of ocean acidification and high temperatures on the bryozoan *Myriapora truncata* at natural CO2 vents. *Marine Biology* 31, 447-456.

Ryland, J.S. 1969. A nomenclatural index to 'A history of the British Marine Polyzoa' by T. Hincks (1880). *Bulletin of the British Museum (Natural History)* 17, 207–260.

Ryland, J.S. 1970. *Bryozoans*. Hutchinson University Library, London.

Sala, F., Mulet, J., Reddy, K.P., Bernal, J.A., Wikman, P., Valor, L., Lars Peters, L., König, G.M., Criado, M. and Sala, S. 2005. Potentiation of human alpha 4 beta 2 neuronal nicotinic receptors by a *Flustra foliacea* metabolite. *Neuroscience Letters*

373, 144-149.

Schäfer, P. and Bader, B. 2008. Geochemical composition and variability in the skeleton of the bryozoan *Cellaria sinuosa* (Hassall): biological vs. environmental control. *Virginia Museum of Natural History Special Publication* **15**, 269-279.

Schäfer, P., Fortunato, H. and Blaschek, H. 2014. Calcification patterns in the cheilostome bryozoan *Flustra foliacea* (L.) from the North Sea and Baltic Sea. *In* A. Rosso, P.N. Wyse Jackson and J.S. Porter (eds), *Bryozoan Studies 2013*. Studi Trentini di Scienze Naturali.

Scholz, J. and Krombein, W.E. 1996. Microbial mats and biofilms associated with bryozoans, pp. 283-298. *In* D.P. Gordon, A.M. Smith and J.A. Grant-Mackie (eds), *Bryozoans in space and time*. Wellington (National Institute of Water & Atmospheric Research).

Sepkoski, J.J. and Koch, C.F. 1995. Evaluating paleontological data relating to bio-events, pp. 21-34. *In* O.M. Walliser (ed.) *Global biological events in earth history*. Springer-Verlag, Berlin.

Sharp, J.H., Winston, M.K. and Porter, J.S. 2007. Bryozoan metabolites: an ecological perspective. *Natural Products Reports* **24**, 659-673.

Smith, A.M. 2009. Bryozoans as southern sentinels of ocean acidification: a major role for a minor phylum. *Marine and Freshwater Research* **60**, 475-482.

Smith, A.M. and Garden, C.J. 2013. Being a bimineralic bryozoan in an acidifying ocean. *In* A. Ernst, P. Schäfer and J. Scholz (eds) *Bryozoan Studies 2010*, 327-337, Springer-Publisher, Berlin-Heidelberg.

Smith, A.M., Key, M.M. Jr. and Gordon, D.P. 2006. Skeletal mineralogy of bryozoans: Taxonomic and temporal patterns. *Earth-Science Reviews* **78**, 287-306.

Smith, A.M., Nelson, C. and Danaher, P.J. 1992. Dissolution behavior of bryozoan sediments: taphonomic implications for non-tropical carbonates. *Palaeogeography, Palaeoclimatology, Palaeoecology* **93**, 213-226.

Stebbing, A.R.D. 1971a. The epizoic fauna of *Flustra foliacea* (Bryozoa). *Journal of the Marine Biological Association UK* **51**, 283-300.

Stebbing, A.R.D. 1971b. Growth of *Flustra foliacea* (Bryozoa). *Marine Biology,* **9**, 267-273.

Suarez, A.V. and Tsutsui, N.D. 2004. The value of museum collections for research and society. *Bioscience* **54**, 66-74.

Taylor, P.D., Berning, B. and Wilson, M.A. 2013. Reinterpretation of the Cambrian 'bryozoan' *Pywackia* as an octocoral. *Journal of Paleontology* **87**(6), 984-990.

Taylor, P.D., James, N.P., Bone, Y., Kuklinski, P. and Kyser, T.K. 2009. Evolving mineralogy of cheilostome bryozoans. *Palaios* **24**, 440-452.

Appendix 1. Lots of *Flustra foliacea* in the Natural History Museum, London (NHMUK) collections. The left-hand numbers are the current study IDs. Locality information in parentheses was deducted by the first author (HF) from the data on the labels. Information and notes marked (*) also from the first author.

ID	Registration number (NHMUK)	Locality, Region, Country	Collection Date	Details on Label
1	27.11.18.6	Calvados (Normandy, France)	1927?*	Busk coll (ex Lamouroux coll?)
2	2011.4.5.6			
3	2011.4.5.7			
4	2011.4.5.7	Herre Bay, Kent	1837	
5	82.7.7.70	GB		
6	2011.4.5.3			
7	2011.4.5.2			Mr Brodie coll
8	2011.5.25.1	Oxford, Suffolk	1761	1963.2.10.7; received from Cambridge Bot school, June 1934
9	81.12.5.35	Faroe (islands, Denmark)		Nolté Herbarium
10	1963.2.10.2	Scarborough (N Yorkshire)	1798	Ladbury coll
11	2011.4.5.4-5			
12	2011.4.4.1	River Jay, Scotland	1836	(HF: 4 colonies designated as a, b, c, d)*
13	2011.1.28.2	Aberdeen (Scotland)	1787-1790	R Brown coll
14	1963.2.10.11	Hastings (E Sussex)	1952?*	E Hailstone coll
15	85.1.3.1-3	Britain	1790?*	transferred from Bot dept; handwriting on label considered to be Linné's when young
16	81.7.24.1	Kurrachee (Manora Peninsula, Karachi, Pakistan)		(HF note: correct location name?)*
17	05.5.5.7	19 miles from Casquets (NW of Alderney, Channel Islands)		depth 45ftm; coll CJS Wallace
18		Calvados (Normandy, France)		original label on Lamouroux handwriting?
19	77.4.20.6	North Sea		Nolté Herbarium
20	77.4.20.7	Mediterranean		Nolté Herbarium
21	27.8.4.36	668 Jellys lead, Naples		
22	15.4.2.9	British		George Bailee collector; Norman coll
23	45.3.7.9	River Jay, Scotland		Capt. Duncan R.A.(P.); Gray BMRP 103h
24		Yarmouth, Liverpool, Lancashire coast		
25	1963.2.10.7?	Oxford, Suffolk	1761	rec from Cambridge Bot school, June 1934
26	1994.8.25.2	Loch Eil, Inverness and Falls of Lora, Loch Etive, Argyll (Scotland)		coll JR Lewis
27	2011.5.25.1	Oxford, Suffolk	1761	J Scholz #33; rec from Cambridge Bot school, June 1934
28	2011.5.25.1	Oxford, Suffolk	1761	J Scholz #35; rec from Cambridge Bot school, June 1934
29	2011.5.25.1	Oxford, Suffolk	1761	J Scholz #34; rec from Cambridge Bot school, June 1934
30	2011.5.25.1	Oxford, Suffolk	1761	J Scholz #36; rec from Cambridge Bot school, June 1934
31	2011.1.28.2a	Aberdeen (Scotland)		J Scholz #25; R Brown coll
50	1961.11.12.1	Aberdeen (Scotland)	1889	

51	1963.3.6.40	Middlefahrt - Strib. (Denmark)		coll CH O'Donoghue; (HF note: correct name is Middelfart)*
52	85.12.5.20	N Dithmarschen (Germany)	1822	Nolté Herbarium
32	2009.8.5.4	Spurn Point, Yorkshire Britain	1995	beach drift; coll PD Taylor
33	2010.4.23.5	east beach, Selsey, West Sussex	04/11/2009	beach cast; coll KJ Tilbrook
34	2010.4.23.1	Eastbourn, East Sussex UK		beach cast; coll KJ Tilbrook
35	2009.9.28.1	Outer Mulberry, Pagham, Sussex		1995 vertical concrete wall; coll G Mitchell
36	2009.8.12.1	Norfolk UK	07/2009	over strand, tide line
37		S of Sumburgh, NE Scotland	07/08/1993	St S93/255, depth 109m, RV Scotia; 59°40.0-59°43.45N/01°9.55-01°17.86W
38	2000.1.17.1	Aldeburgh, Suffolk England	07/06/1996	coll KJ Tilbrook
39	2000.1.17.2	Aldeburgh, Suffolk England	07/06/1996	coll KJ Tilbrook
40	2000.1.17.3	Aldeburgh, Suffolk England	07/06/1996	coll KJ Tilbrook
41	2000.1.17.4	Aldeburgh, Suffolk England	07/06/1996	coll KJ Tilbrook
42	2000.12.5.1	Ramsholt Cliff, N Bank River Deben, Suffolk	11/25/2000	coll KJ Tilbrook
43	1997.9.29.1	Britain		coll G Larwood
44	1997.9.29.2	Britain		coll G Larwood
45	1997.9.29.3	Barton-on-Sea, (Hampshire) England		08/31/1975 coll G Larwood
46	1997.9.29.4	Kællingdal shore, Jutland Denmark		09/27/1984 coll G Larwood
47	1997.9.29.5	Durham Britain	1971	coll G Larwood; material collected for IBA 1971
48	1997.7.28.3	Norbeck beach, Blackpool Britain		07/14/1997 coll M Spencer Jones
49		Fair Isle, Scotland	06/03/1999	St S99/259, depth 104m, RV Scotia; 59°13.1- 59°15.97N/01°29.5-01°25.7W; coll M Spencer Jones
71			1995	St 203, RV Scotia
72	2000.6.27.6		1997	St 194, RV Scotia
73		SE of Fair Isle, NE Scotland	07/03/1993	St 254, depth 102m, RV Scotia; 59°17.9-59°12.9N/01°24.68-01°29.48W
53	2000.4.6.1	Minster, Isle of Sheppey (UK)	1963	washed on beach; coll MV Hounsome; formerly in spirits
54	85.12.5.3b	Forth Island, Denmark	1830	Nolté Herbarium
55	97.8.9.33	N Swanage Bay (Dorset)	<1922*	depth 10ftm; coll R Kirkpatrick; material sent to Hull museum, 22.5.29; some material used for mineralogical analysis 7/2009; (HF note: probably collected around May)*
56	1899.7.1	Felixstowe (Suffolk) Britain		coll G Busk
57	1999.8.6.2	NNW North Rona Sea (Scotland)		depth 53 ftm; voyage of the 'Knight Errant'; coll G Busk
58	11.10.1.318	coast, Durham		coll Horman
59	89.7.27.62	off coast, Durham		depth 5-10 ftm; coll F Beckford
60	67.5.7.29	Belgique		coll Westendorp; note: common at locality
61	61.12.26.b	Britain		coll D Adler; part sent to the USNM
62	99.5.1.14	Antrim (Ireland)		coll Hincks
63	11.10.1.317	Guernsey (Normandy)		coll Horman
64	11.10.1.316	Britain	<1900*	coll Bailee; coll Horman; #316 in box; 'palmate form'
65	11.10.1.315	Britain	<1900*	coll Bailee; coll Horman; #315
66	1996.11.14.1			
67	R.b.5.16	UK	1659-1739	coll Samuel Dale; Dale Herbarium
68	1997.9.29.14	Shingle street, Suffolk England		coll G Larwood; leaves have *Crisia* and *Scrupocellaria*

69	1997.9.29.6	Britain		coll G Larwood; leaves have *Scrupocellaria*
70	1972.5.1.15	Charmouth (W Dorset) Britain	05/30/1972	on beach; coll AB Hastings
74	2003.6.3.2	Portmeirion, Wales	10/031996	strandline; coll KJ Tilbrook
75	1996.10.16.2	Clacton (Essex) UK	02/1985	washed on beach
76			06/03/1999	St S99/260, depth 125m, RV Scotia; 59°22.03-59°20.0N/01°10.4-01°4.7W; coll M Spencer Jones
77	2007.9.18	Leasowe, Wirral Peninsula UK	04/2006	strandline; coll T Knowles
78	1998.6.18.1	Southwold, Suffolk UK	02/14/1998	coll K Tilbrook
79		Bell rock, NE Scotland	06/01/1999	St S99/251, trawl, depth 58m, RV Scotia; 56°25.6-56°23.41N/02°10.13-02°3.95W; coll M Spencer Jones
80	42.12.19.2	Britain		coll Johnston; V Gray B M Rad p.112, spec 'f'
81	47.9.24.143	Firth of Forth (River Forth, Scotland)		coll Johnston; '85.d'
82	47.9.24.144	Berwick Bay (Scotland)		coll Johnston; '85.e'
83	47.9.24.142	Firth of Forth (River Forth, Scotland)		coll Johnston; '85.c'
84	47.9.24.142	Firth of Forth (River Forth, Scotland)		coll Johnston; '85.b'
85	47.9.24.141	Tay River, Dundee Scotland		coll Johnston; '85.a'
86	47.9.24.145	Ireland		coll Johnston; '85.f'
87	42.12.7.24	Firth of Forth (River Forth, Scotland)		coll Johnston; '81.i'
88	99.7.1.949	Firth of Forth (River Forth, Scotland)		coll Busk
89	34.10.24.6	Cleethorpes, Sheffield (South Yorkshire)		coll GR Vine; B-L 39
90	29.12.28.7-8-9	Calvados (Normandy, France)		coll Busk/ A Waters
91	97.5.1.428	Hastings (E Sussex		
92	99.7.1.296	Algoa Bay (South Africa?*)		coll Busk; (HF note: correct location name?)*
93	1963.3.30.205	Cromer (N Norfolk)	09/1881	probably found on beach; coll SF Harmer
94	1963.3.30.256	Cromer (N Norfolk)	09/1881	found on beach; coll SF Harmer
95	98.4.2.4-6	off of Poole (Dorset)		part of 89.7.27.47
96	61.12.26.6	Britain		D Adler (P)
97	81.7.24.1	Kurrachee (Manora Peninsula, Kurachi, Pakistan)		Mus. Kurrachee (P); (HF note: correct location name?)*
98	34.8.26.4			Dr Bother
99	99.7.1	Calvados (Normandy, France)	1816*	coll Busk
100	2009.11.4.2	Padstow, Cornwall	1972	coll PJ Hayward
101		Walkford, Dorset		strandline; coll M Spencer Jones
102		Holme Titchwell, Norfolk UK	09/30/2010	coll M Holloway
103	2009.2.3.5	River Hayle, Cornwall England	04/2007	mouth of river; coll KJ Tilbrook
104		Skarreklit, Bulbjerg Denmark	05/1962	washed on beach; coll A Cheetham
105		east of Fair Isle (Scotland)	06/03/1999	St S99/257, depth 103m, RV Scotia; 59°14.54-59°17.95N/01°26.28-01°26.51W;
		coll M Spencer Jones		
106		Mudeford, Dorset UK	12/26/2010	strandline, beach; coll M. Spencer Jones
107			1991	St 185, st ABBS dump, RV Scotia
108			1997	St 204, RV Scotia
109		Bell rock (NE Scotland)	05/30/1994	St 190
110				St S99/261, RV Scotia
111	2011.4.15.1	Snettisham, West Norfolk	03/22/2011	[TF6433] on beach; coll B Okamura
112	1966.2.8.1	Cheverie, Kings Co., Minos Basin, Nova Scotia		NA Powell

Appendix 2. Work protocol for digital imaging of *Flustra foliacea* collections housed at the Natural History Museum, London. All macro photographs used the same scale. Whenever possible, photos were done using the same magnifications.

Sequential steps	Procedure
	Preparation of material
1	Unique ID number given to each studied lot; ID is carried on to all further steps (SEM, photos, measurements, etc.).
2	Database lots, including labels' information, number of colonies / lot, number of branches/ colony. Includes a brief description of the colonies (general aspect (fresh, very old, fragile, etc.), morphology type (ribbon-like, bushy, mix type), coloration.
3	Macro-photograph of the lot including a scale and the original label. In the absence of a real scale a standard easily recognizable object (a coin) was used. The scale was used for all further photographs.
4	Choice of one colony for further work (when several available in the lot). Criteria for choice: colony aspect and preservation, presence of attachment area; branch size. Macro-photograph of this colony.
5	Choice and macro-photograph of a branch to measure in the colony used in (4). Longest branch was always chosen.
	Digital imaging
6	Photograph of the whole colony chosen in (4) using the smallest available magnification.
7	Photograph of the branch chosen in (5) using a small magnification.
8	Position at the bottom of the branch, increase the magnification, start photographing along the transect in the middle of the branch, moving upwards. Successive photos overlap a few generations on both the bottom and the top so as to recognize them and be able to reconstruct the branch. Photos received a sequential number (including the colony ID). All photos have a scale. These photos will be used to count number of avicularia and ovicells, as well as presence, position and number of spines (if present).
9	Position at the tip of the branch, increase the magnification, start photographing going down the transect in the middle of the branch towards the attachment area. Photos receive a sequential number that includes de colony ID. These photos will be used to measure zooids parameters.

An unknown archive of German A. Kluge: a bryozoan collection in the Museum of Invertebrate Zoology at Perm State National Research University

Andrei V. Grischenko

Department of Invertebrate Zoology and Aquatic Ecology, Biological Faculty, Perm State National Research University, Bukirev Street 15, Perm 614990, Russia

1. Introduction

The scientific activity of the prominent Russian bryozoologist German Avgustovich Kluge (1871–1956), who described over a hundred new species of bryozoans from the Arctic and other regions, and who wrote the monumental volume "Bryozoa of the Northern Seas of USSR" (Kluge, 1962), appears to be so multifaceted that its impact will still be felt many decades from now and can be detected in rather unexpected places.

As Head of the D.M. Fedotov and D.E. Kharitonov Museum of Invertebrate Zoology associated with the Department of Invertebrate Zoology and Aquatic Ecology of Perm State National Research University (Perm City, Western Ural, Russia), I recently found six old jars containing numerous bryozoan colonies fixed in ethanol, lying forgotten in a storeroom. A small sticker glued on each jar bore the inscription "*Bryozoa. Identified by G. Kluge*". Some jars contained labels with species and locality names, hand-written by

Figure 1. German Avgustovich Kluge

Kluge, mixed up with the colonies. According to these labels, most of the specimens were collected in Kola Bay, in the Barents Sea. Sorting and subsequent taxonomic identification of the material revealed 33 bryozoan species, including a couple of cyclostomes and 31 cheilostomes. Although specimens of the five species identified by Kluge had been displayed in the Museum's exhibition hall for decades, their significance was not evident until this recent discovery of the additional material.

Considering this unexpected find in a provincial university, distant both from the place where Kluge did most of his research (*Murmanskaya* Biological Station, Barents Sea) and from the present location of most of his specimens (Zoological Institute Russian Academy of Science, Saint Petersburg), I investigated how his bryozoans got to Perm State University. I present the results of this investigation herein.

2. German A. Kluge and his research at the *Murmanskaya* Biological Station of the Saint Petersburg Society of Naturalists

The life of German Avgustovich Kluge (Figure 1) is well known through recollections by his colleagues, scientific successors, and other authors (Ushakov, 1957; Ushakov, Androsova, 2002). Kluge was born on 27 May 1871 in Radomskaya Province (now in Poland). Soon after graduation from Kazan' University in 1896, he took a job at the *Solovetskaya* Biological Station of the Saint Petersburg Society of Naturalists (Solovetskiye Islands, White Sea), where he began his academic focus on bryozoology. In 1901, he traveled to the Naples Biological Station, Italy, where he continued his studies on marine bryozoans. His fluency in several foreign laguages (German, English, and French) helped him meet and communicate freely with colleagues, and allowed him wide access to bryozoan literature. From 1904 to 1907, Kluge traveled abroad, working at zoological museums in Germany, Sweden, Denmark, and England, where examined bryozoan collections from all over the world. In 1908, he took a position in the Zoological Museum of the Imperial Academy of Science, Saint Petersburg, and proceeded to study extensive bryozoan collections that had been made in the Russian Arctic.

In 1908, Kluge was elected Head of the *Murmanskaya* Biological Station of the Saint Petersburg Society of Naturalists; the station was situated near the port of Alexandrovsk (currently Polyarnyy Town) on the shore of Kola Bay. Successor to the *Solovetskaya* BS, the *Murmanskaya* BS had been established in 1899, primarily through the efforts of Professor Konstantin M. Derjugin (1878–1938). Kluge headed the *Murmanskaya* BS for

Figure 2. Dmitri Mikhailovich Fedotov during his time at Perm State University, 1916–1922 (photograph courtesy of Perm State National Research University)

nearly 25 years, during which period the station became a real scientific institution, recognized both nationally and internationally, and attracting up to 50 biological researchers every field season.

In August 1908 and during the summer of 1909, Professor K.M. Derjugin conducted the first intensive faunal investigation of Kola Bay (also known as Murmansk Fjord; ca. 57 km long and up to 7 km wide) from the schooner *Alexander Kovalevsky* (see Derjugin, 1915). All material collected was delivered to researchers at the *Murmanskaya* BS for detailed identification. Kluge sorted and identified bryozoan specimens obtained on the Derjugin Expedition of 1908–1909, and also by his colleagues from the *Murmanskaya* BS during the 1899 and 1903–1904 seasons. This study allowed him to compile a list of 146 species (Kluge in Derjugin, 1915). Kluge described ten new species from Kola Bay, including four cyclostomes (*Proboscina gracilis*, *Oncousoecia polygonalis*, *Tubulipora minuta*, *T. murmanica*) and six cheilostomes (*Eucratea arctica*, *Callopora derjugini*, *Bugula tricuspis*, *Dendrobeania murmanica*, *Scrupocellaria minor*, and *Pseudoflustra hincksi*). Only one paper had previously been published on this region (Smitt, 1879), from material collected by the Lieutenant H. Sanderberg (1877) Expedition, reporting only the 15 most common species (Derjugin, 1915: 11–12). After the publication of Kluge's list, Kola Bay became (Derjugin, 1915: 392) "one among the most examined regions in the world" in terms of the bryozoan fauna. Kluge later included all these taxa in his monograph Bryozoa from Russian Arctic Seas (Kluge, 1962).

The material from this region identified by Kluge was subsequently shipped to the Zoological Museum of the Imperial Academy of Science (currently Zoological Institute of the Russian Academy of Science), Saint Petersburg for cataloguing and permanent storage. A small part of this and some other of Kluge's material, however, ended up at Perm State University, Perm City, Western Urals, far from both the *Murmanskaya* BS and the Zoological Museum. It has become clear that this was due to the scientific activity of another prominent Russian zoologist, D.M. Fedotov.

3. Activities of Dmitri M. Fedotov

Dmitri Mikhailovich Fedotov (1888–1972) (Figure 2) was a honoured academic figure in the USSR. He published almost two hundred papers during his 60-year scientific career, covering comparative morphology, phylogeny, systematics, and palaeontology

Figure 3. Buildings of Perm University, a day before opening in October 1916 (photograph courtesy of Perm State National Research University)

(Beklemishev, 1959; Markevitch, 1959; Rumyantseva, 1959; Svetlov, 1968; Arnoldi et al., 1973; Boguta, 1976; Smirnov, 2011). His scientific achievements are so numerous that they exceed the scope of present paper. Suffice it to say that his monograph *Evolution and Phylogeny of Invertebrate Animals* (Fedotov, 1966) was a standard reference for evolutionary zoologists.

Fedotov was born in Saint Petersburg but grew up in Warsaw. In 1906 he graduated from the 1st Warsaw Men's Gymnasium and entered the Natural Department of the Physico-Mathematical Faculty of the Saint Petersburg University. He studied under the guidance of such prominent zoologists as V.T. Shevyakov and V.M. Shimkevitch. Fedotov's early research interest was spider taxonomy and biology. After graduating in 1910, he stayed on at the university to prepare for a professorship. For several years beginning in 1910, he worked every summer season at the *Murmanskaya* BS, where he studied marine invertebrates.

After obtaining his Master's degree in 1916, Fedotov was elected a privat-docent in the Department of Zoology and Comparative Anatomy at Petrograd University. The same year, at age 28, he was invited to head the Department of Zoology and Comparative Anatomy in the newly opened Perm Branch of the Petrograd University (Figure 3), which was shortly afterward reorganized into an autonomous educational institution, Perm State University (currently Perm State National Research University).

Accepting this invitation, Fedotov launched enthusiastic activity in the Department. In only two years, during a hard period of civil war and devastation, he set up a well-equipped zoological laboratory by importing expertise and equipment from Germany and Japan. In 1918, Fedotov invited a group of talented zoologists, including V.N. Beklemishev, A.A. Lyubischev, D.E. Kharitonov, and others (Figure 4) to assist him. Fedotov and his team built up a biological station on the right bank of the Kama River, where intensive biocoenological studies began.

Fedotov's research on echinoderm morphology and taxonomy at Perm State University (1916–1922) laid the groundwork for further achievements (Fedotov, 1934, 1951) that eventually brought him global fame.

Figure 4. Photograph of the staff of the Department of Zoology and Comparative Anatomy, Perm State University, March 1922. Front row, left to right: V.N. Beklemishev, A.O. Tausson, D.M. Fedotov, N.Ya. Oparina, A.A. Lyubischev. Back row, left to right: A.E. Plakhina, V. Baskina, G.M. Fridman, B.V. Vlastov, D.E. Kharitonov, P.G. Svetlov, unknown person (photograph courtesy of Perm State National Research University)

4. Museum of Invertebrate Zoology of Perm State University

Thanks to D.M. Fedotov's efforts and the support of his assistant D.M. Dyakonov, a zoological facility was established in October 1916, during the early days of Perm State University. This facility later became the Museum of Invertebrate Zoology in the Department of Zoology and Comparative Anatomy. Initially, specimen exhibits were borrowed from the collections of Petrograd University and the Zoological Museum, Petrograd.

Fedotov's trip to the *Misaki* Marine Biological Station, Japan, in 1917 played an important role in providing specimens for the Museum; see Spencer Jones et al. (2011) for the significance of the *Misaki* MBS in early biodiversity studies. In the course of his hydrobiological investigations in Sagami Bay and the Seto Inland Sea (Seto Naikai), Fedotov collected a huge number of benthic and pelagic animals, which were later moved to the Museum and made up the core of the material on display in the exhibition hall. The Musuem's resources were further augmented by collections of mollusks from V.N.

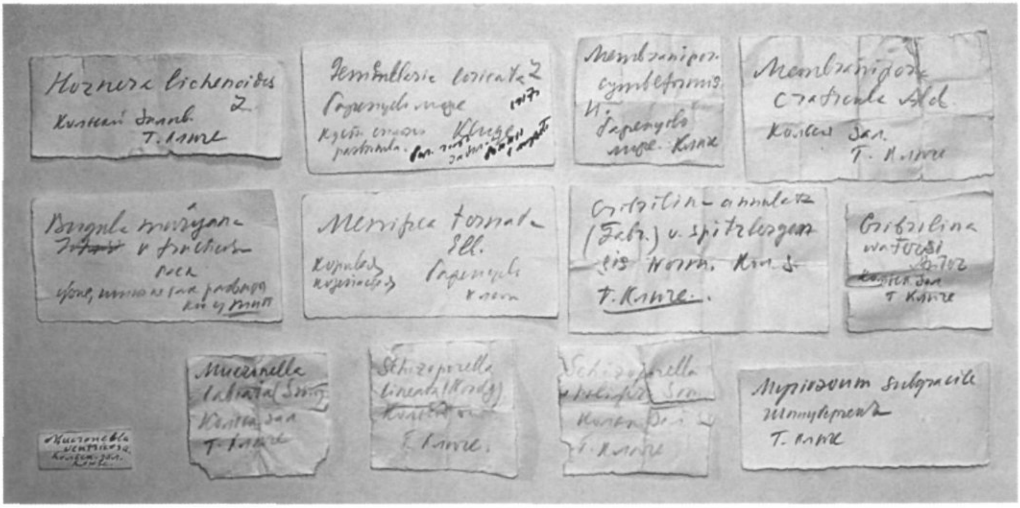


Figure 5. Specimen labels, written by Kluge, from the newly discovered bryozoan collection

Beklemishev (1890–1962); beetles and butterflies from D.E. Kharitonov (1896–1970); spiders from D.E. Kharitonov, including over 3200 prepared slides; and, in the 1950s–1960s, more spiders from Central Asia, deposited by A.S. Utochkin (1924–1992).

Other academics also contributed to the Museum's collections. Docent V.A. Lykov (1933–2009) donated part of his impressive, 30-year collection of gastropod shells (about 400 species). The arachnid collection begun by D.E. Kharitonov is growing continuously. Along with the Ural material, it contains collections of spiders and Opiliones from various Palearctic areas. The spider collection of Perm State University is one of four public collections in Russia and contains type material described by D.E. Kharitonov and his successors, including A.S. Utochkin, S.L. Esyunin, and V.E. Efimik. In addition, G.Sh. Farzalieva has built a myriapod collection from the Urals and Kazakhstan. The oldest instructor in the Department, Docent K.N. Beltyukova (1914–2008), spent more than ten years (1980s–1990s) thoroughly restoring many of the taxonomical and thematic collections, helping to create a modern Museum.

Currently the Museum of Invertebrate Zoology is named after D.M. Fedotov and D.E. Kharitonov, and is associated with the Department of Invertebrate Zoology and Aquatic Ecology of the Biological Faculty of Perm State National Research University. It is organized into exhibition, scientific, and academic divisions. The exhibition hall covers 80 m^2, and specimen exhibits display 1530 items, including 292 boxes of insects and 1238 additional separate specimens, fixed in 70% ethanol or dry. Despite its rather limited space, the Museum houses representatives of most main taxa of invertebrate animals, and it is one of the oldest depositories in the Ural region (Grischenko, 2012).

Figure 6. Specimens from the Kluge Collection of Bryozoa on exhibition in the Museum of Invertebrate Zoology, Perm State National Research University. A, Securiflustra securifrons, *PSU 804. B,* Eucratea loricata, *PSU 802. C,* Alcyonidium disciforme, *PSU 802. D,* Alcyonidium gelatinosum, *PSU 806. E,* Dendrobeania murrayana, *PSU 808. A 10-ruble coin (2012, diameter 22 mm) is shown for scale*

5. Collection of Bryozoa in the Museum of Invertebrate Zoology

Though official historical and biographical documents contain no information about contacts between G.A. Kluge and D.M. Fedotov, there is reason to believe that Fedotov obtained bryozoan material during his regular research visits to *Murmanskaya* BS in the period 1910–1916, prior to his work at Perm State University. He may also have obtained some additional material later (labelled 1917 and 1919), either mailed directly or transported to Perm City by colleagues of Kluge or Fedotov.

The bryozoan collection presented by Kluge to the Museum of Invertebrate Zoology, contains 37 species, including two cyclostomes (*Hornera lichenoides*, *Disporella hispida*), two ctenostomes (*Alcyonidium disciforme*, *A. gelatinosum*), and 33 cheilostomes (Appendix 1). Large colonies of five species from this collection (*Alcyonidium disciforme*, *A. gelatinosum*, *Eucratea loricata*, *Securiflustra securifrons*, and *Dendrobeania murrayana*) are exhibited in the Museum (Figure 6). Six jars recently discovered in the storeroom contain 33 species, including two cyclostomes (*Hornera lichenoides* and *Disporella hispida*) and 31 cheilostomes (Figures 7–12). Among these newly found bryozoans, only thirteen species (including *Eucratea loricata*, already in the exhibition) had been identified and labelled (Figure 5); the other 21 species had not been sorted or identified (all taxa lacking label details in Appendix 1).

Since the inventory register contains no records of receipt of these additional materials, they were likely initially intended for research. The specimens, however, show no trace of close examination, and look untouched and undamaged; it thus appears that they were never used for research or student practica. At the time there were no identification keys or well-illustrated publications about Arctic bryozoans in Russian, and Kluge's (1929, 1946, 1962) papers and identification manual had yet to appear. It is quite possible that because the colonies of different species were mixed up in the jars, mostly unlabeled, nonspecialists in the group simply ignored them, and they sat ignored in the Museum's storeroom.

Labels dated 1919 indicate that specimes of two ctenostomes (*Alcyonidium disciforme* and *A. gelatinosum*) and *Myriapora subgracilis* were collected near Spitzbergen. The labels for another four species (*Eucratea loricata*, *Cauloramphus cymbaeformis*, *Securiflustra securifrons*, *Tricellaria ternata*) indicate "Barents Sea", without further details. The labels on another nine species indicate the locality as Kola Bay, Barents Sea (Appendix). The collection localities of the remaining 21 species of cheilostome bryozoans remained unknown. To determine whether these specimens might have been collected in Kola Bay, I compared a list of them with the species reported by Kluge in Derjugin (1915). Fifteen of the 21 unlabeled species (including *Dendrobeania fessa*, preliminarily identified as *Bugula murryana* var. *fruticosa*; see Kluge in Derjugin, 1915: 379) had been recorded in Kola Bay. In other words, specimens of 24 (65%) of the 37 species represented in our Museum's collection might have come from Kola Bay.

Five of the species (*Flustra foliacea*, *Dendrobeania pseudomurrayana*, *Arctonula arctica*, *Escharoides bidenkapi*, *Reteporella watersi*) are not mentioned in Kluge in

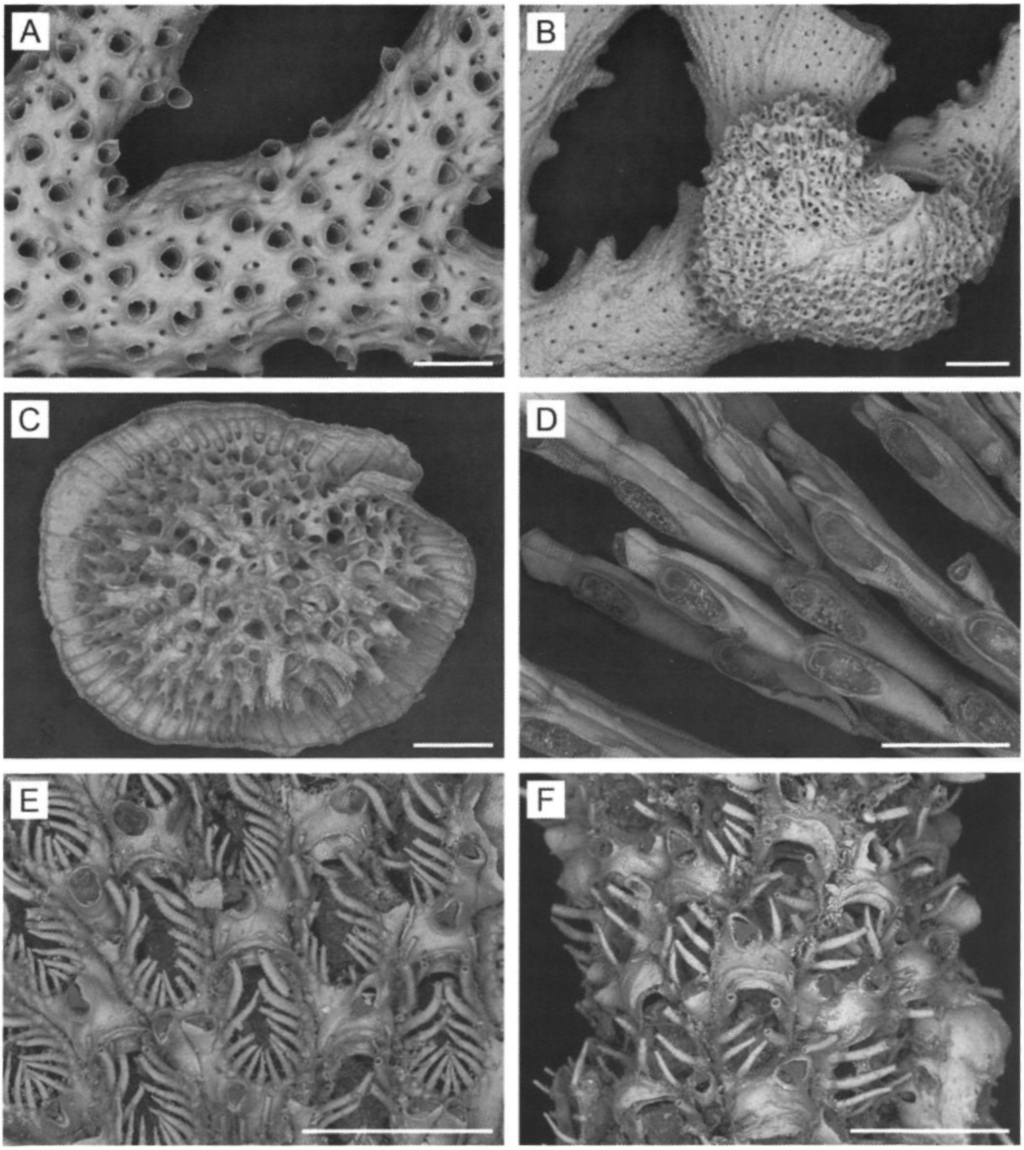


Figure 7. Scanning electron micrographs of specimens in the Kluge Bryozoan Collection. A, B, Hornera lichenoides, *PSU 810.01. C,* Disporella hispida, *PSU 810.02. D,* Eucratea loricata, *PSU 810.03. E,* Callopora craticula, *PSU 810.04. F,* Callopora lineata, *PSU 810.05. Scale bars: 0.5 mm*

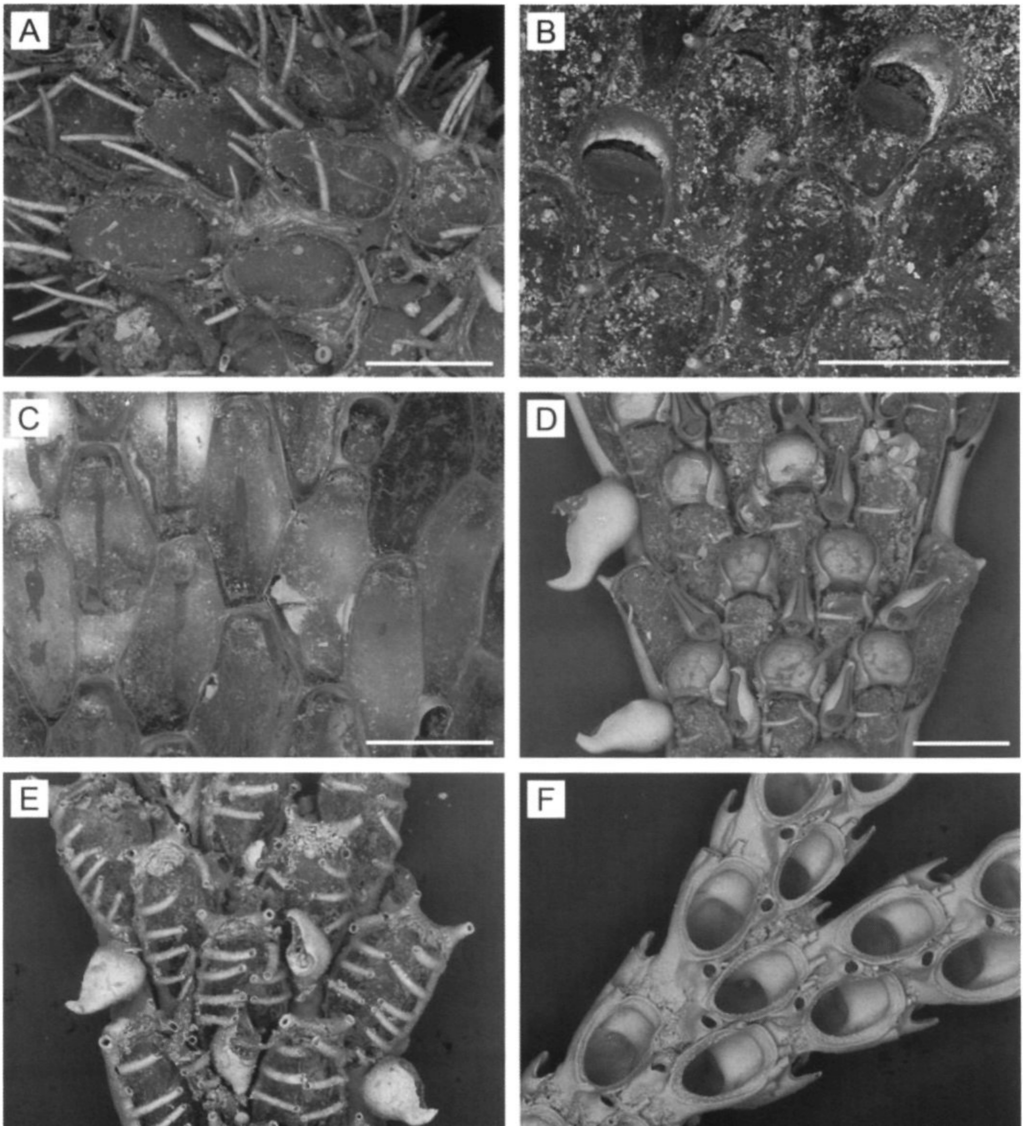


Figure 8. Scanning electron micrographs of specimens in the Kluge Bryozoan Collection. A, Cauloramphus cymbaeformis, *PSU 810.06. B,* Flustra foliacea, *PSU 810.07. C,* Terminoflustra membranaceotruncata, *PSU 810.08. D,* Dendrobeania fessa, *PSU 810.09. E,* Dendrobeania pseudomurrayana, *PSU 810.10. F,* Caberea ellisi, *PSU 810.11. Scale bars: 0.5 mm*

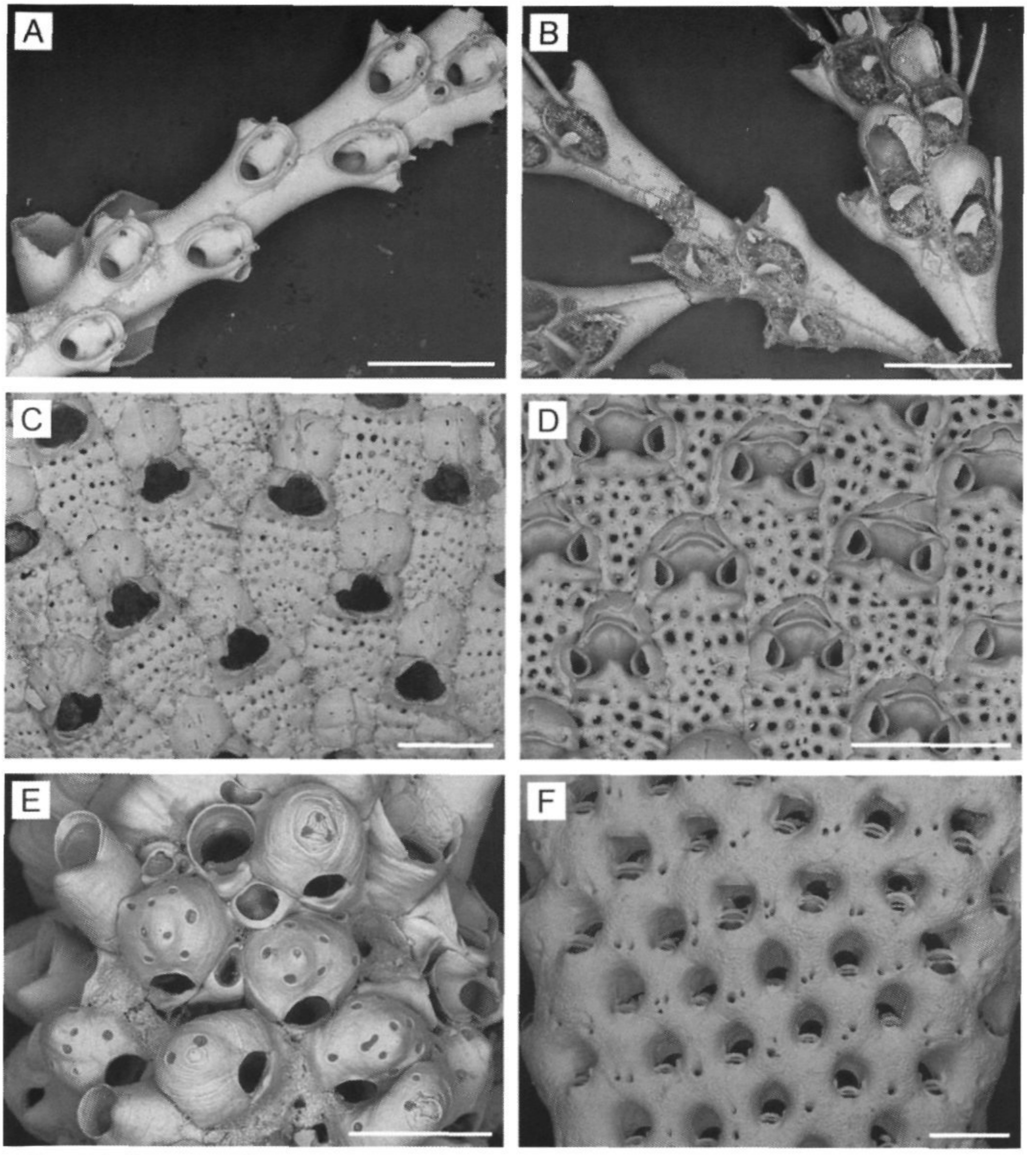


Figure 9. Scanning electron micrographs of specimens in the Kluge Bryozoan Collection. A, Tricellaria gracilis, *PSU 810.12. B,* Tricellaria ternata, *PSU 810.13. C,* Cribrilina spitzbergensis, *PSU 810.14. D,* Cribrilina watersi, *PSU 810.15. E,* Celleporella hyalina, *PSU 810.16. F,* Cystisella saccata, *PSU 810.17. Scale bars: 0.5 mm*

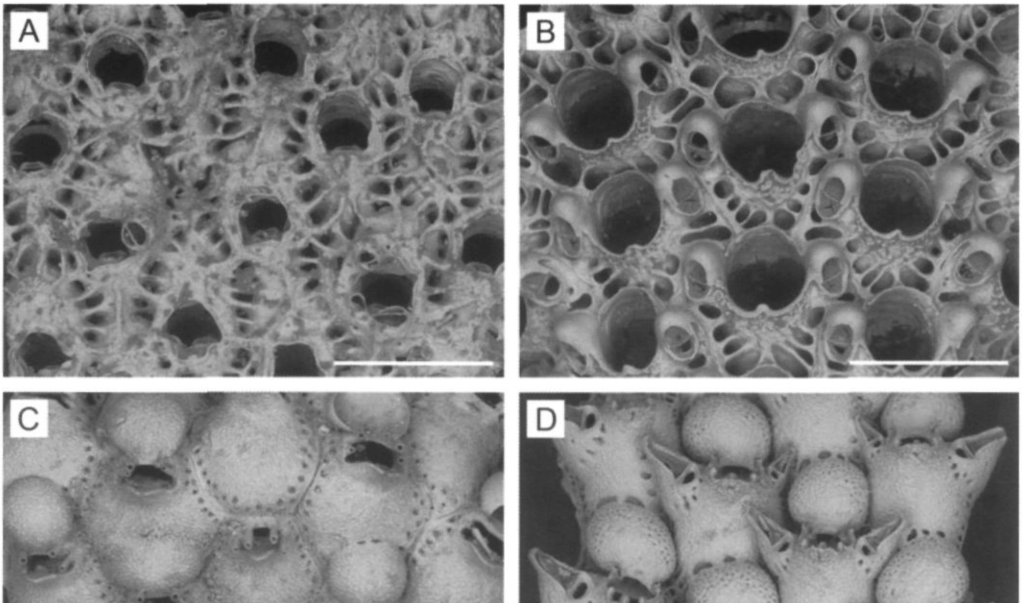


Figure 10. Scanning electron micrographs of specimens in the Kluge Bryozoan Collection. A, Porella smitti, *PSU 810.18. B,* Arctonula arctica, *PSU 810.19. C,* Escharella ventricosa, *PSU 810.20. D,* Escharoides bidenkapi, *PSU 810.21. E,* Rhamphostomella bilaminata, *PSU 810.22. F,* Rhamphostomella costata, *PSU 810.23. Scale bars: 0.5 mm*

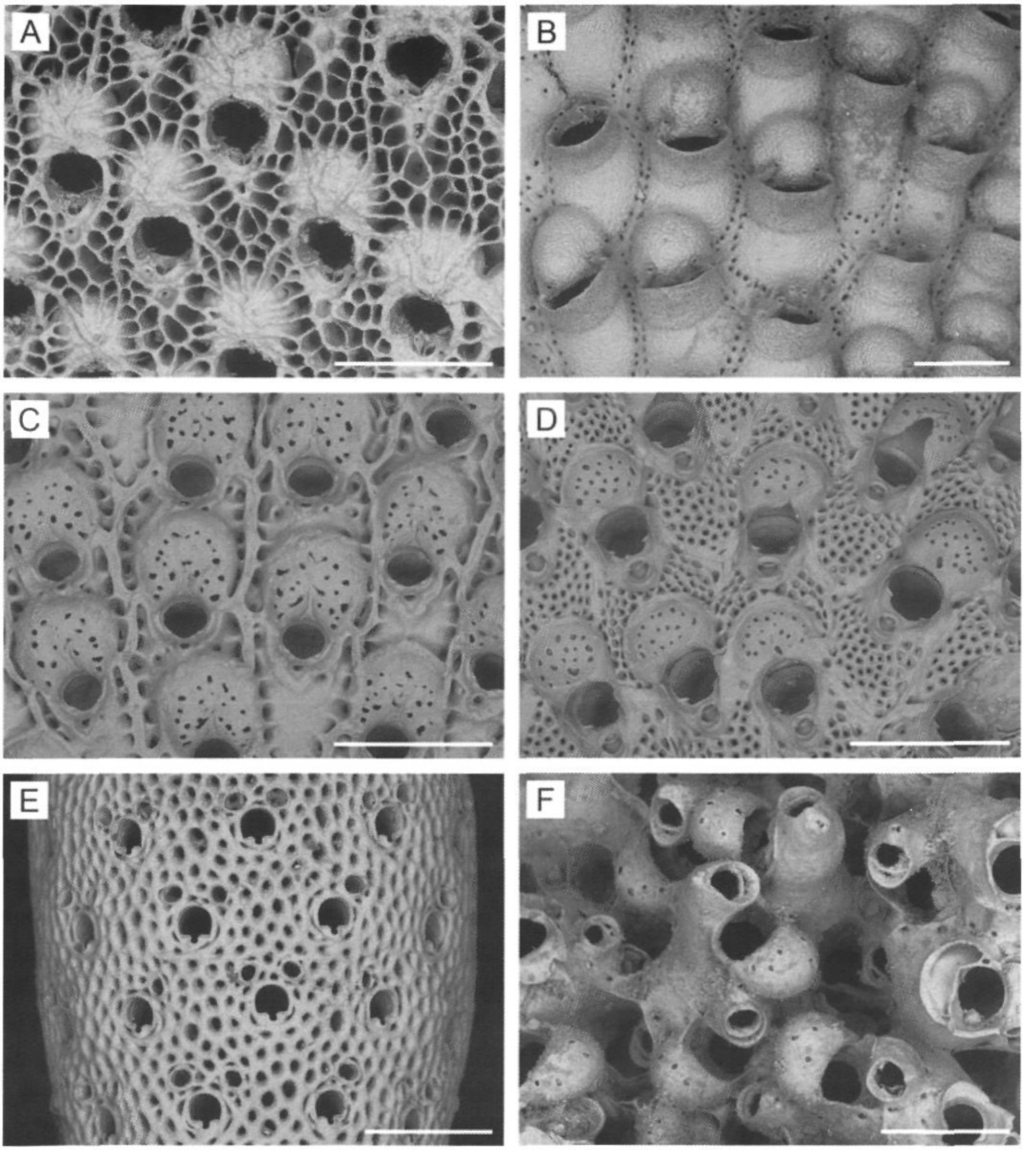


Figure 11. Scanning electron micrographs of specimens in the Kluge Bryozoan Collection. A, Rhamphostomella ussowi, *PSU 810.24. B,* Phylactella labiata, *PSU 810.25. C,* Parkermavella lineata, *PSU 810.26. D,* Schizomavella porifera, *PSU 810.27. E,* Myriapora subgracilis, *PSU 810.28. F,* Cellepora nodulosa, *PSU 810.29. Scale bars: 0.5 mm*

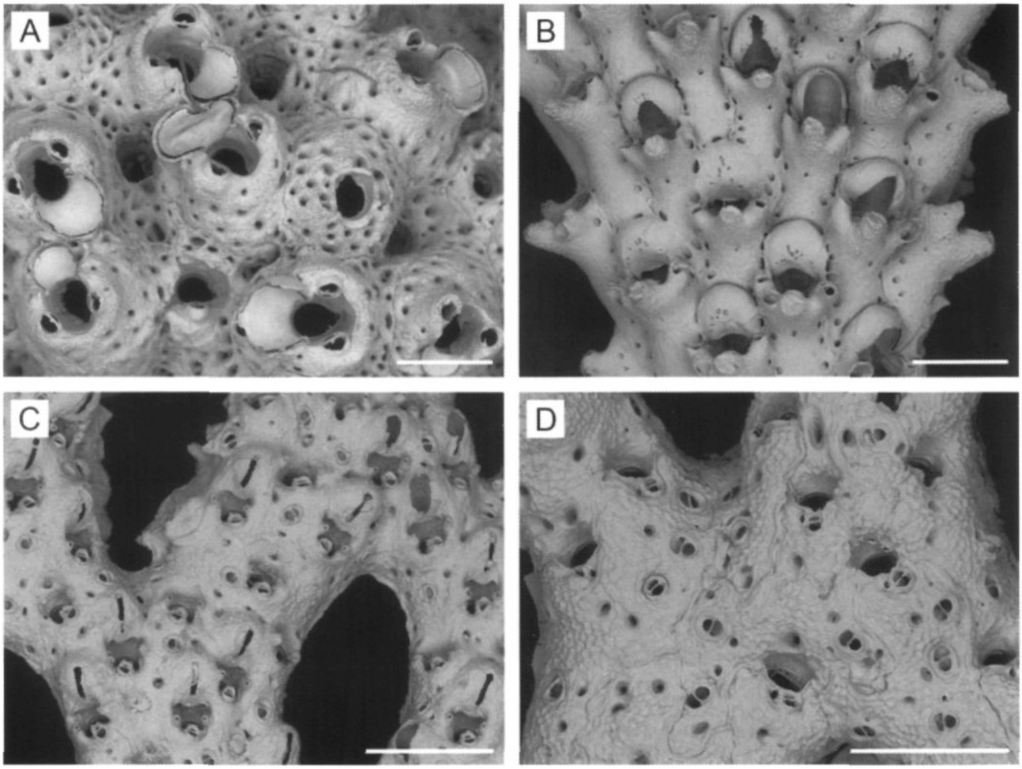


Figure 12. Scanning electron micrographs of specimens in the Kluge Bryozoan Collection. A, Celleporina ventricosa, *PSU 810.30. B,* Palmicellaria tridens, *PSU 810.31. C,* Reteporella beaniana, *PSU 810.32. D,* Reteporella watersi, *PSU 810.33. Scale bars: 0.5 mm*

Derjugin (1915) for Kola Bay, but are widely distributed in the Barents Sea (Kluge, 1962), and except for *R. watersi* occur in the southwestern part (Denisenko, 1990). This strongly suggests that, except for the three bryozoans labeled 'Spitzbergen', the major part of the collection (34 species) was gathered near the *Murmanskaya* BS, either by the station staff or by Kluge himself.

Most of the bryozoans in the Kluge collection in Perm are well-known species widely reported from the Arctic and from numerous Atlantic and Pacific Boreal localities (Osburn, 1950, 1952, 1953; Kluge, 1962; Hayward, 1985; Hayward, Ryland, 1998, 1999; Gontar, Denisenko, 1989). At the same time, roughly a third of these species has never been illustrated by scanning electron microscopy (SEM). To remedy this, I provide SEM images of all species in the newly discovered collection (Figures 7–12). Colonies of cyclostome and cheilostome species were cleaned in sodium hypochlorite solution, rinsed with tap-water and air dried. Dried, uncoated colonies were examined at 15 kV accelerating voltage with a Hitachi TM3000 scanning electron microscope with a back-scattered electron detector. All images were stored electronically as TIFF files at a resolution of 600 pixels in^{-1}. Colonies of species displayed in Museum exhibits were photographed with a Nikon–D100 digital camera at 300 pixels in^{-1} resolution.

The collection of Bryozoa described herein is deposited in the D.M. Fedotov and D.E. Kharitonov Museum of Invertebrate Zoology, Department of Invertebrate Zoology and Aquatic Ecology, Biological Faculty, Perm State National Research University. The collection is registered under inventory number 810, with each species numbered separately (01–33) (Appendix).

6. Conclusions

German Avgustovich Kluge left an impressive scientific heritage, having described over 100 new species, eight new genera, and five new families of bryozoans. In all, he detected nearly 500 bryozoan species (Ushakov, Androsova, 2002) in the Arctic and Far Eastern Russian seas. His taxonomic reference "Bryozoa of the Northern Seas of the USSR" (Kluge, 1962), translated into English in 1975, has been a standard reference book for several generations of bryozoologists. In addition, the approximately 50,000 specimens he identified, which are now housed in the Zoological Institute, Russian Academy of Science, Saint Petersburg, are a primary resource for further research on bryozoans in the Arctic, North Pacific, and several other regions.

It is not surprising that unpublished material has turned up after Kluge's death. Some of his unknown bryozoan illustrations, based on Arctic specimens as far back as 1916, were published for the first time 74 years after Kluge drew them, in a survey of the Arctic bryozoan fauna (Gontar, Denisenko, 1989). Likewise, literally nothing was known about Kluge's material in the Urals, though this material arrived at the Museum of Invertebrate Zoology of Perm State University 94–97 years ago, between 1916 and 1919. After this discovery of his collection, an exhibit of the Arctic heritage of G.A. Kluge will occupy a prominent place in the Museum, and the scanning electron micrographs of bryozoans from Kola Bay and the Barents Sea presented here (Figures 7–12) will supplement the paper Kluge in Derjugin (1915).

7. Acknowledgements

I thank Nina V. Denisenko and Alexei V. Smirnov (Zoological Institute, Russian Academy of Science, Saint Petersburg) for providing biographical references relating to G.A. Kluge and D.M. Fedotov, respectively. Valeriy V. Zhuk (Biological Faculty, Perm State National Research University, Perm) made a photograph entitled "Staff of Department (1922)" publicly available. Mikhail Ya. Lyamin (Biological Faculty, Perm State National Research University, Perm) assisted in photographing material in exhibits. Alexander V. Rzhavsky (A.N.Severtsov Institute of Animal Morphology and Evolution, Russian Academy of Science, Moscow) and Alexei V. Chernyshev (A.V. Zhirmunsky Institute of Marine Biology, Vladivostok) critically read the original manuscript. Matthew H. Dick (Hokkaido University, Sapporo, Japan) edited the manuscript. Patrick N. Wyse Jackson (Trinity College, Dublin, Ireland) kindly invited me to contribute this paper.

References

Arnoldi, K.V., Ghilarov, M.S. and Viktorov, G.A. 1973. Dmitri Mikhailovich Fedotov (1888–1972). *Zoologichesky Zhurnal* 52(2), 300–301 (in Russian).

Beklemishev, V.N. 1959. Dmitri Mikhailovich Fedotov (to the 70th anniversary). *Transactions of the A. N. Severtsov Institute of Animal Morphology* 27, 5–12 (in Russian).

Boguta, K.K. 1976. Scientific activity of D.M. Fedotov (1888–1972). *Transactions of the Leningrad Society of Naturalists* 84(1), 5–9 (in Russian).

Denisenko, N.V. 1990. *Distribution and ecology of bryozoans of the Barents Sea*. Kola Scientific Center Russian Aacdemy of Science, Apatity, 156 pp (in Russian).

Derjugin, K.M. 1915. The Fauna of the Kola Bay and Conditions of its Existence, *Memoires de l'Académie impériale des sciences de Petrograd, séries 8. Western Branch of Academy of Science. Physics–Mathematics Department* 34(1), 1–929 (in Russian).

Fedotov, D.M. 1934. Echinodermata. K. Zittel. Grundüge der Paläontologie (Paläozoologie). Abteilung 1, Invertebrata. Wissenschaftlich-Technischer Staatsverlag für Bergwesen, Geologie und Erdöl, Leningrad, Moskau, Grosny, Novossibirsk, 216–266, 311–552 (in Russian).

Fedotov, D.M. 1951. Phylum Echinodermata, In: Zenkevich, L.A. (ed.), *Handbook on Zoology* 3(2), Invertebrata, 460–591 (in Russian).

Fedotov, D.M. 1966. *Evolution and phylogeny of invertebrate animals*. Nauka, Moscow, 404 pp (in Russian).

Gontar, V.I. and Denisenko, N.V. 1989. Arctic Ocean Bryozoa. In: Herman, Y. (ed.), *The Arctic Seas. Climatology, Oceanography, Geology, and Biology*. Van Nostrand Reinhold Company, New York, 341–371.

Grischenko, A.V. 2012. Museum of Invertebrate Zoology (Museums of the Perm University). *Newspaper of the Perm University* 1800(5), 3 (in Russian).

Hayward, P.J. 1985. Ctenostome bryozoans. Keys and notes for the identification of the species. *Synopses of the British Fauna (New Series)* 33, 1–169.

Hayward, P.J. and Ryland, J.S. 1985. Cyclostome bryozoans. Keys and notes for the identification of the species. *Synopses of the British Fauna (New Series)* 34, 1–147.

Hayward, P.J. and Ryland, J.S. 1998. Cheilostomatous Bryozoa, Part 1, Aeteoidea–Cribrilinoidea. *Synopses of the British Fauna (New Series)* 10, 1–366.

Hayward, P.J. and Ryland, J.S. 1999. Cheilostomatous Bryozoa, Part 2, Hippothooidea–Celleporoidea. *Synopses of the British Fauna (New Series)* 14, 1–416.

Kluge, G.A. 1915. The Bryozoa. In: Derjugin, K.M. (ed.), The Fauna of the Kola Bay and Conditions of its Existence, *Memoires de l'Académie impériale des sciences de Petrograd, séries 8. Western Branch of Academy of Science. Physics–Mathematics Department* 34(1), 376–393 (in Russian).

Kluge, G.A. 1929. Die Bryozoen des Sibirischen Eismeers. *Transactions of the Murmanskaya Biological Station* 3, 1–33.

Kluge, G.A. 1946. New and little-known Bryozoa from the Arctic Ocean. *Reports of the Drifting Expedition of Chief North Sea Routes Department on the Ice-breaker G. Sedov 1937–1940* 3, 194–223.

Kluge, G.A., 1962. Bryozoa of the Northern Seas of the USSR. *Opredeliteli po Faune SSSR* 76, Moscow-Leningrad, 584 pp (in Russian).

Markevitch, A.P. 1959. Phylogenetic researches of D.M. Fedotov. *Transactions of the A.N. Severtsov Institute of Animal Morphology* 27, 13–19 (in Russian).

Osburn, R.C. 1950. Bryozoa of the Pacific Coast of North America. Part 1, Cheilostomata–Anasca. *Allan Hancock Pacific Expeditions* 14, 1–269.

Osburn, R.C. 1952. Bryozoa of the Pacific Coast of North America. Part 2, Cheilostomata–Ascophora. *Allan Hancock Pacific Expeditions* 14, 271–611.

Osburn, R.C. 1953. Bryozoa of the Pacific Coast of North America. Part 3, Cyclostomata, Ctenostomata, Entoprocta and Addenda. *Allan Hancock Pacific Expeditions* 14, 613–841.

Rumyantseva, N.A. 1959. List of scientific publications of Dr D.M. Fedotov. *Transactions of the A. N. Severtsov Institute of Animal Morphology* 27, 20–25 (in Russian).

Smirnov, A.V. 2011. Fedotov Dmitri Mikhailovich. *Biology in Saint-Petersburg. 1703–2008. Encyclopaedic dictionary*. E.I. Kolchinskiy (ed.). Nestor-History, Saint Petersburg, 485–486 (in Russian).

Smitt, F. A. 1879. Recensio animalium Bryozoarum e mari arctico, quae ad paeninsulam Kola, in itinere anno 1877. *Ofversigt Af Kongliga Vetenskaps-Akademiens Forhandlinger* 35 (7), 19–32.

Spencer Jones, M.E., Scholz, J., Grischenko, A.V. and Fujita, T. 2011. Japanese Bryozoans from the Meiji Era at the Natural History Museum, London, Part 1: The Owston and Mitsukuri Collections. pp. 99–118 In: P.N. Wyse Jackson and M.E. Spencer Jones (eds) *Annals of Bryozoology 3: aspects of the history of research on bryozoans*. International Bryozoology Association, Trinity College, Dublin, 234 p.

Svetlov, P.G. 1968. Prof. Dmitri Mikhailovich Fedotov (To the 80th anniversary). *Zoologichesky Zhurnal* 47(10), 1588–1591 (in Russian).

Ushakov, P.V. 1957. German Avgustovich Kluge. Obituary. *Zoologichesky Zhurnal* 36(9), 1433–1435 (in Russian).

Ushakov, P.V. and Androsova, E.I. 2002. German A. Kluge (1871–1956). A profile. *Transactions of the Zoological Institute Russian Academy of Science* 292, 69–76 (in Russian).

Appendix

Kluge Bryozoan Collection in the D.M. Fedotov and D.E. Kharitonov Museum of Invertebrate Zoology, Department of Invertebrate Zoology and Aquatic Ecology, Perm State National Research University.

Registration No. PSU	Revised identification	Kluge's identification	Label details
810.01	*Hornera lichenoides* (L., 1758)	*Hornera lichenoides*	Kola Bay
810.02	*Disporella hispida* (Fleming, 1828)		
807	*Alcyonidium disciforme* Smitt, 1872*	*Alcyonidium disciforme*	Spitzbergen
806	*Alcyonidium gelatinosum* (L., 1767)*	*Alcyonidium gelatinosum*	Spitzbergen
802, 810.03	*Eucratea loricata* (L., 1758)	*Gemellaria loricata*	Barents Sea
810.04	*Callopora craticula* (Alder, 1856)	*Membranipora craticula*	Kola Bay
810.05	*Callopora lineata* (L., 1767)		
810.06	*Cauloramphus cymbaeformis* (Hincks, 1877)	*Membranipora cymbaeformis*	Barents Sea
810.07	*Flustra foliacea* (L., 1758)		
804	*Securiflustra securifrons* (Pallas, 1766)*	*Flustra securifrons*	Barents Sea
810.08	*Terminoflustra membranaceotruncata* (Smitt, 1868)		
810.09	*Dendrobeania fessa* (Kluge, 1955)	*Bugula murrayana v. fruticosa*	
808	*Dendrobeania murrayana* (Johnston, 1847)*	*Bugula murrayana*	Kola Bay
810.10	*Dendrobeania pseudomurrayana* Kluge, 1955		
810.11	*Caberea ellisi* (Fleming, 1818)		
810.12	*Tricellaria gracilis* (Van Beneden, 1848)		
810.13	*Tricellaria ternata* (Ellis, Solander, 1786)	*Menipea ternata*	Barents Sea
810.14	*Cribrilina spitzbergensis* Norman, 1903	*Cribrilina annulata v. spitzbergensis*	Kola Bay
810.15	*Cribrilina watersi* Andersson, 1902	*Cribrilina watersi*	Kola Bay
810.16	*Celleporella hyalina* (L., 1767)		
810.17	*Cystisella saccata* (Busk, 1856)		
810.18	*Porella smitti* Kluge, 1907		
810.19	*Arctonula arctica* (M. Sars, 1851)		
810.20	*Escharella ventricosa* (Hassall, 1842)	*Mucronella ventricosa*	Kola Bay
810.21	*Escharoides bidenkapi* (Kluge, 1946)		
810.22	*Rhamphostomella bilaminata* (Hincks, 1877)		
810.23	*Rhamphostomella costata* Lorenz, 1886		
810.24	*Rhamphostomella ussowi* (Kluge, 1908)		
810.25	*Phylactella labiata* (Boeck in Smitt, 1869)	*Mucronella labiata*	Kola Bay
810.26	*Parkermavella lineata* (Nordgaard, 1896)	*Schizoporella lineata*	Kola Bay
810.27	*Schizomavella porifera* (Smitt, 1868)	*Schizoporella porifera*	Kola Bay
810.28	*Myriapora subgracilis* (d'Orbigny, 1852)	*Myriozoum subgracile*	Spitzbergen
810.29	*Cellepora nodulosa* Lorenz, 1886		
810.30	*Celleporina ventricosa* (Lorenz, 1886)		
810.31	*Palmicellaria tridens* (Busk, 1856)		
810.32	*Reteporella beaniana* (King, 1846)		
810.33	*Reteporella watersi* (Nordgaard, 1907)		

* Displayed only at the Museum exhibition hall

Albert Russell Nichols (1859-1933) and bryozoan research in Ireland during the late 19th and early 20th centuries

Antoinette Kelso and Patrick N. Wyse Jackson
Department of Geology, Trinity College, Dublin 2, Ireland

1. Introduction

Ireland is home to a varied coastline of over 5500km in length. Within this vast coastline is a large number of marine habitat types which makes it the ideal location for a large number of species to live and survive. Bryozoa have been recorded from Ireland since 1755 when John Ellis mentioned he had been sent a specimen of the bryozoan *Bugula avicularia* from Dublin Bay and included it in his book *An essay towards a Natural History of the Corallines*.[1]

Albert Russell Nichols (1859-1933) (Figures 1 and 3) was an English-born naturalist who spent much of his life in Dublin, Ireland. During his career he published just 6 papers on bryozoans, but these are some of the most valuable and comprehensive contributions to Irish Bryozoa records to date. These include his "*Polyzoa* from the coasts of Ireland" published in 1911[2] and the Bryozoa part of the "Clare Island Survey" series of papers published by the Royal Irish Academy published the following year.[3]

This paper will present an account of A.R. Nichols' personal life, professional career and his bryozoological work. Naturalists such as Arthur Hill Hassall, Laura Thornley, J.E. Duerden and Nathanial Colgan also made important contributions to research on Ireland's

Figure 1. Albert Russell Nichols (1859-1933) at opening of the Museum of Science and Art, Kildare Street building in 1890. (Photograph NMINH-PP-777xy © National Museum of Ireland, all rights reserved)

marine bryozoans.[4]

One publication by A.R. Nichols included a list of Bryozoa from many locations around the Irish coast—his was the last national scale comprehensive survey of marine bryozoans from Ireland. Since then other publications have concentrated on specific locations with much work being carried out along the west coast in particular.[5]

2. Personal Biography

Albert Russell Nichols was born in January 1859 in Stowmarket, Suffolk to parents Arthur and Sarah Nichols. His father is listed in the census of England and Wales from 1851-1901 as being an Ironmonger (retired in later years).[6] Albert was christened on the 9th December 1859 in Stowmarket where his family lived on Market Place until they are recorded in the 1881 census as residing at 22 and 23 Nelson Street, Greenwich. Albert's family was small for the time, he had one brother Ernest Russell Nichols who was 2 years his younger and one sister who was 5 years younger. It was interesting to find that as a child Albert Russell was only called 'Albert' in the 1861 Census, on all subsequent censuses from his English addresses he is listed as 'Arthur Russell'. Once he moved to Ireland he is listed as Albert again. Unlike his brother, Albert did not follow in his father's footsteps as an ironmonger, but rather attended university. In January 1878[7] he entered Clare College, Cambridge to study Mathematics, where he gained a Gold Medal and was a Scholar. He graduated B.A. in 1882 with a first class degree in the subject and was ranked 16th Wrangler.[8] In 1902 he took his M.A. from Clare College.

It was at the age of 24 that Albert's life as a Naturalist began. One can only imagine that job opportunities for mathematicians at the time were scarce and this may have prompted his career change. As was the norm at the time, Albert took an examination (on 23rd January 1883) used to determine the most suitable candidate for the appointment of Assistant Naturalist in the Natural History section of the Museum of Science and Art (now the National Museum of Ireland), Dublin.[9] He was ranked first and was offered the position[10] and entered museum service in March 1883.[11] Thus was the beginning of his new life in Dublin where he remained for the rest of his life.

Nine years after arriving in Dublin he married Letitia Anne Perry of Cambridge House, 12 Montpelier Hill, in Matthias Church, Adelaide Road on 20th July 1892.[12] At the time of his marriage Albert was living at 20 Charlemont Place, Dublin[13] which was within walking distance to his place of employment. However, by 1901 the married couple were living in a fashionable southside suburb at 30 Grosvenor Square, Rathmines (Figure 2) with their daughter Beryl (age five) and their two domestic staff.[14]

In May 1905 Albert was promoted to assistant keeper at the museum and remained in this position until August 1921 when at the age of 62 he succeeded Robert Francis Scharff as the Keeper of Natural History (Figure 3). Albert did not remain in this position for a long period as in January 1924 he reached the statutory retirement age of 65 and retired from his position at the museum. Aside from his research on various zoological groups, Nichols "did much work in the classifying and arranging of the invertebrates".[15]

Before his second promotion to Keeper of Natural History Albert Nichols, his family and their general servant were recorded as still living at 30 Grosvenor Square, Rathmines, Dublin[16] in the 1911 census of Ireland. This is the address at which Albert would live out his remaining years. On 21st February 1933 Albert Russell Nichols died at the

Figure 2. 30 Grosvenor Square, Rathmines, Dublin.

Figure 3 (left). A.R. Nichols towards the end of his working life. (Photograph NMINH-PP-741-Nichols © National Museum of Ireland, all rights reserved)
Figure 4 (right). Burial place of A.R. Nichols, his wife and daughter. Section 17, Mount Jerome Cemetery, Harold's Cross, Dublin.

age of 75. He was buried close to his home at Mount Jerome Cemetery, Harold's Cross, Dublin (Figure 4), which was the prominent burial ground at the time of the Protestant population.[17] In his obituary Nichols is described as being very secretive about himself and as always being a perfect gentleman. He was also descried as "his harmless and undisguised curiosity about the doings of others"[18] which sounds like a polite way to say he was unashamedly nosy.

Albert's wife and daughter also lived out there remaining years in the same house in Rathmines. Letitia Anne Nichols died on 7 March 1955, outliving her husband by 22 years. Their daughter, who never married, studied History and Political Science at Trinity College, Dublin.[19] She was later, in 1921, conferred with a doctorate in Canon and Civil Law,[20] and remained closely associated with her alma mater as an active committee member of the TCD Association. She became a noted actress and appeared in a number of radio plays and musical events broadcast by RTE, the Irish national broadcaster between the 1920s and 1940s. From a young age she was interested in animals and in 1909 presented the Royal Zoological Society a rocking horse for the use of the chimpanzees in Dublin Zoo. A contemporary newspaper reported that: "The "Chimps" have not yet become accustomed to the inanimate horse, and look on it with much greater awe than living creatures. The youngest chimpanzee will only *touch* it very gingerly, ..."[21] Much later, in the 1960s she served as a committee member of the St Francis Dispensary, a charity in Dublin that cared for animals.[22] Beryl died in 1976, a spinster who until shortly before her death lived in her family home.

Of Albert's siblings in England and Ireland neither his sister nor brother left children. His sister Emily Grace Nichols lived out her life in Liverpool with their brother Ernest Nichols and died in 1930 as a spinster. Ernest married quite late in life at the age of 65 years to a Roberta Cowie and died at the age of 93, his wife Roberta Nichols died in 1951. There is a possibility of Albert's father Arthur Nichols having 10 siblings, this is still under investigation and not confirmed as of yet.

3. Nichols as a naturalist and bryozoologist

It was not long after his appointment at the museum that Nichols started to produce publications on Ireland's fauna. The earlier years of his career was a time when there was an increased interest in Ireland's flora and fauna due to the recent *Challenger* cruises and Nichols undertook a great deal of his fieldwork during this time. The late 1880s saw the first three marine biology survey cruises conducted by the Royal Irish Academy which were directed by William Spotswood Green[23] with more expeditions to follow by other groups in the 1890s.[24] A number of these expeditions were undertaken by The Flora and Fauna Committee which was established through the efforts of Edward Perceval Wright. In 1886 Nichols took part in a dredging trip on the *Lord Bandon* off southwest Ireland. This trip led to him writing a publication on Hydrozoa in South-West Ireland.[25] In 1895 Nichols took part in a trip to Rockall and from this trip described the molluscs collected around this isolated rock.[26] Nichols continued to publish papers on Ireland's fauna but it wasn't until a year after his promotion to assistant keeper in 1905 that he published a paper describing the occurrence of the bryozoan *Hypophorella expansa* from Ireland.[27] These specimens had been dredged by Alexander Goodman More (1830-1895) from off Broadhaven, Mayo in July, 1873. In this publication Nichols mentions that he had recently started to study Ireland's bryozoans.

During 1906 and 1907 Nichols seemed to be very active in writing up his research, in addition to his papers on Lambay Island (see below) he published on the tufted duck,[28] shrimp,[29] the Canadian crane,[30] and Irish gephyrean worms.[31] During the spring of 1907 the Dublin Marine Biological Committee was established with Nichols as a member of the committee. It regularly reported their findings in the monthly journal *The Irish Naturalist*.[32] The Dublin Marine Biological Committee was one of a number of organisations which Nichols was involved in. He was also elected as a Member of the Royal Irish Academy (RIA). He served as vice-president of the Dublin Naturalists' Field Club in 1908 but did not become President in 1909 as was the normal successional scheme.[33] Between 1910-1912 he was President of Dublin Microscopical Club.[34]

Lambay Island (1907)

During the early 1900s there was also an increased interest in the island biota of Ireland. In an initiative started by Robert Lloyd Praeger, Lambay Island, off the coast of Co. Dublin was targeted and the flora and fauna surveyed, as a result of this survey Nichols published a list of 35 bryozoans which had been collected over 3 days of shore collecting.[35] Each species was accompanied by a short note which may list the location, association with other species or the substrate it was found on. The majority of these specimens are now housed in the Natural History Museum with 22 of the listed samples represented; the whereabouts of the other specimens are unknown to the author at present. Nichols was also responsible for publishing a list of echinoderms from Lambay resulting from the same survey trip.[36]

Clare Island Survey (1912)

Robert Lloyd Praeger was also responsible for organising a biological and scientific survey on Clare Island, Co. Mayo in which Nichols took part from 1909-1911. Praeger had persuaded a large number of naturalists to survey the flora and fauna of both the island and coastal waters and also, the immediate districts on the mainland, and this remains one of the major scientific contributions in twentieth century biological sciences in Ireland.[37] In Nichols' paper on the marine bryozoans (Figure 5) he notes that Clew Bay, Westport Bay and Blacksod Bay were also included.[38] This survey resulted in an enormous amount of papers, with each of the 68 papers dedicated to a different flora or fauna type. Nichols was responsible for the papers on bryozoans (number 53 in the series) and echinoderms (number 57).[39] Specimens collected by Nichols were from both dredged rocks collected from the fisheries research vessel *S.S. Helga* and from shore collecting. He notes that specimens were mainly found on stones and of the sub-order (now order) Cheilostomata. In total Nichols recorded 75 marine Bryozoa from Clare Island with 2 of these being first records for Ireland, *Stomatopora fungia* (now *Tubulipora penicillata*) and *Eucratea chelata* var. *gracilis* (now *Scruparia ambigua*).

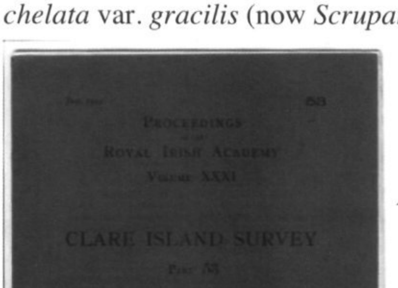


Figure 5 (left). Cover of Nichols' contribution on bryozoans to the Clare Island Survey (1912).

Figure 6 (opposite). Bryozoans collected or examined by A.R. Nichols. These are contained in the collections of the Natural History Museum, Dublin. A. Flustra truncata *(L.)* (= Securiflustra securifrons *(Pallas, 1766)), Portrush, Co. Antrim, collected 1914 (1913.307.22); B.* Beania mirabilis *Johnston, 1840, Greystones, Co. Wicklow, collected 1914 (1914.218.3), and Co. Mayo, collected 1909 (1911.404.12); C.* Turbicellepora avicularis *(Hincks, 1860), Co. Mayo, collected 1886 (1911.404.1). D.* Membranipora lacroixii *(Audouin, 1826)* (= Conopeum reticulum *(L.)) and* Membranipora monostachys *Busk, 1854* (= Electra monostachys *(Busk, 1854)), Greencastle, Co. Donegal, collected 1915 (1913-307); E.* Gemellaria loricata *(L.)* (= Eucratea loricata *(L.)), Greencastle, Co. Donegal, collected 1915 (1909-29).*


Flustra truncata
Portrush April 1914
307. 1913 GRL
NH: 1913.307.22
A
BEANIA MIRABILIS
GREY STONES,
CO. WICKLOW
1914
GRL - NICHOLS A.R.
BEANIA MIRABILIS
COAST OF MAYO
NICHOLS, A.R.
B
1911.404.1
TURBICELLEPORA AVICULARIS
COAST OF MAYO
NICHOLS, A.R.
1886
C
307. 1913
D
G. loricata
Greencastle
GRL
Aug. 1915
29. 1909
E

Handbook to the City of Dublin and the surrounding district (1908)

Nichols contributed a number of sections including that on 'Polyzoa' to a handbook published by the British Association for the Advancement of Science (BAAS) to coincide with the meeting in Dublin in 1908.[40] In the article he noted the contribution that Dr Arthur Hill Hassall made to bryozoan research collected in and around Dublin, and discussed the progression of Bryozoa collections conducted to date by him and others. He also listed species which have been recorded from the Dublin district only. Nichols also contributed articles to a similar BAAS guidebook for the Belfast area.[41]

'Polyzoa from the coasts of Ireland' (1911)

In what is undoubtedly the last most comprehensive survey carried out on Irish bryozoans, Nichols published 'Polyzoa from the coasts of Ireland' in 1911.[42] This publication was based on specimens collected by the Fisheries Branch of the Department of Agriculture and Technical Instruction for Ireland. They were collected off the Irish coasts between 1899 and1907 during both dredging and shore collecting trips. Specimens were collected mainly from encrusted rocks and Nichols notes that more specimens on shells may have increased the species list. The entire species list identified by Nichols totals 101 species with a large percentage of these being found at depths of 50 fathoms (about 90 meters) or more. His paper lists 23 species as first records for Ireland and Nichols provides good location information for each species found and a number of precise species descriptions.

4. Collections

The specimens which were collected or identified by Nichols are now housed mainly at the National History Museum, Dublin (Figure 6). One specimen of *Brettia pellucida* var. *gracilis* that was included in his 1911 publication is currently unlocated in the National History Museum, London and is part of the type material for *Bugulella gracilis* (Nichols, 1911). The majority of the specimens are held in the dry collections with a small number held as wet specimens.

5. Acknowledgements

We thank Nigel Monaghan (National Museum of Ireland, Dublin) for providing photographs from the collections of the National Museum of Ireland. Mary Spencer Jones (Natural History Museum, London) and Sylviane Vaucheret (National Museum of Ireland, Dublin) kindly supplied information on Nichols' collections in the Natural History Museum, Dublin.

Endnotes

1 Ellis, J. 1755. *An essay towards a Natural History of the Corallines*. Printed for the author, London.

2 Nichols, A.R. 1911a. Polyzoa from the coasts of Ireland. *Scientific Investigations Fisheries Branch, Ireland, 1910,* 1: 1-37.

3 Nichols, A.R. 1912a. Clare Island Survey 53: Polyzoa. *Proceedings of the Royal Irish Academy*, 31 (53): 1-14.

4 Wyse Jackson, P.N. 1991. Distribution of Irish marine Bryozoa, together with biographical notes relating to the chief researchers in the group. *Bulletin of the Irish Biogeographical Society* **14** (2), 129-184.

5 See Wyse Jackson, note 4.

6 Census of England and Wales 1851-1901.

7 Venn, J.A. (ed.) 1922-1958. Nichols, Albert Russell. *Alumni Cantabrigienses* (10 volumes). Cambridge University Press.

8 A Wrangler is a student who gained a first-class degree in Mathematics from Cambridge. In any one year the highest ranged student is termed the 'Senior Wrangler' and all other first-class students are ranked consecutively.

9 For background information on the National Museum of Ireland see Crooke, E. 2000. *Politics, archaeology and the creation of a National Museum of Ireland: am expression of National Life*. Irish Academic Press. For the Natural History Museum see O'Riordan, C.E. n.d. *The Natural History Museum Dublin*. The Stationary Office, Dublin.

10 *The Competitor* 1883, p. 253.

11 Nichols' success in this examination is remarkable, as there is no evidence of his having an interest in natural history on graduating from Cambridge. It must be assumed that he used at least a portion of the period between September 1882 and January 1883 studying for this examination. It is unknown if he applied for other positions in other professions at the same time.

12 Information from http://churchrecords.irishgenealogy.ie/churchrecords/details/1092640556371 [accessed: 7.5.2013, and marriage certificate.

13 Information from marriage certificate.

14 Irish census records 1901. 30 Grosvenor Square is a three-story red-brick Victorian house in the north-west corner of the square.

15 Praeger, R. Ll. 1949. *Some Irish Naturalists*. Dundalgan Press, Dundalk, p. 136.

16 See note 10 about the changing numbering scheme of houses on Grosvenor Square.

17 www.igp-web.co

18 Stelfox, A.W. 1933 Albert Russell Nichols, M.A. (Cantab.), M.R.I.A. *Irish Naturalists' Journal* 4: 190-191.

19 *Dublin University Calendar* (1918), p. 28.

20 *Irish Times*, 21 December 1921, p. 6. She was conferred *Doctores in Utroque Jure* (Doctor in Canon and Civil Law)

21 *Sunday Independent*, 31 January 1909, p. 1.

22 *Irish Press*, 9 July 1963, p. 7.

23 Whyte, N. 1999. Science, Colonialism and Ireland. Cork University Press; Moriarty, C. 1995. *The Rev. W.S. Green: explorer and fishery scientist*. Royal Irish Aacdemy, Dublin.

24 See O'Riordan, C.E. 1969. *A catalogue of the collection of Irish marine Crustacea in the*

National Museum of Ireland. Stationary Office, Dublin: ix-x for a summary of these.

25 Nichols, A.R. and Haddon, A.C. 1886. Hydrozoa. *In* Haddon, A.C., 1st Report on the marine fauna of the south-west of Ireland. *Proceedings of the Royal Irish Academy*, 4 (2): 615.

26 Nichols, A.R. 1896. On the mollusca. *In* Notes on Rockall Island and Bank. *Transactions of the Royal Irish Academy*, 31: 77.

27 Nichols, A.R. 1906b. A new Irish Polyzoon *Hypophorella expansa* Ehlers. *Irish Naturalist*, 15: 87.

28 Nichols, A.R. 1907c. Tufted duck breeding on Lough Mask. *Irish Naturalist*, 16: 184.

29 Nichols, A.R. 1907d. The well-shrimp in Co. Clare. *Irish Naturalist*, 16: 208.

30 Nichols, A.R. 1907e. The Canadian crane in Co. Cork. *Irish Naturalist*, 16: 209-211.

31 Nichols, A.R. 1907f. Some Irish gephyrean worms. *Irish Naturalist*, 16: 223.

32 Colgan, N. 1908. Dublin Marine Biological Committee: general account of dredging operations, 1907. With special notes on the Mollusca. *The* Irish Naturalist 17: 105-114.

33 In 1908 for the first time since its establishment in 1886 the Committee of the Dublin Naturalists' Field Club was decided on following an election. However a problem arose in that proper procedures were not followed, and this may have be the reason why Nichols (through no fault of his own) didn't ever serve as President (see Bailey, G.W.D. 1986. History of the Dublin Naturalists' Field Club, pp. 6-29. *Reflections and Recollections*. Dublin Naturalists' Field Club, Dublin).

34 Albert Russell Nichols was first recorded as the president of the Dublin Microscopical Club on 9th November 1911, *Irish Naturalist*, 20(1): 12 and last recorded on 10th April 1912, *Irish Naturalist*, 21(6): 117. This group met monthly during the winter months for "social and microscopic purposes", and was active between 1849 and the mid-1920s (Praeger 1949, see note 15, p. 187).

35 Nichols, A.R. 1907a. Contributions to a natural history of Lambay: Polyzoa. *Irish Naturalist*, 16: 82-83.

36 Nichols, A.R. 1907b. Contributions to a natural history of Lambay: Echinodermata. *Irish Naturalist*, 16: 84-85.

37 Guiry, M.D. 1997. No stone unturned: Robert Lloyd Praeger and the major surveys, pp. 299-307 *In* Wilson Foster, J. (ed.) *Nature in Ireland: a scientific and cultural history*. Lilliput Press, Dublin; Collins, T. 2009. The Clare Island Survey of 1909-1911: participants, papers and progress, pp. 16-19. *In* Jones, R. and Steer, M. (eds) *Darwin, Praeger and the Clare Island Surveys*. Royal Irish Academy, Dublin.

38 Nichols, note 3. In 1915 he published a listing of bryozoans from Blacksod Bay (Nichols, A.R. 1915a. Polyzoa. *In* Farran, G.P. (compiler) Results of a Biological Study of Blacksod Bay, Co. Mayo. *Scientific Investigations Fisheries Branch, Ireland, 1914*, 3: 51).

39 See Nichols, note 3, and Nichols, A.R. 1912b. Clare Island survey 57: Echinodermata. *Proceedings of the Royal Irish Academy*, 31 (57): 1-10. Prior to this James Edwin Duerden had collected bryozoans extensively around Ireland's coasts, but he took up a position in Jamaica in 1894 (see Wyse Jackson and Maderson, this volume) and the group remained largely under-studied until Nichols' interest.

40 Nichols, A.R. 1908a. Molluscoidea: Gephyrea, Brachiopoda, Polyzoa. *In* Cole, G.A.J. and Praeger, R.Ll. (eds) *Handbook to the Dublin District*. Dublin University Press, Dublin, pp. 200-204. Although a contributor to this handbook for the BAAS meeting Nichols did not join the Association nor are any possible scientific contributions to the Dublin meeting recorded in the official report of the meeting, although he may have attended unofficially, and hosted visitors

to the Natural History Museum.

41 Nichols, A.R. 1902. Echinoderma (pp. 231-233), Coelenterata (pp. 233-236), Porifera (pp. 237-238). *In* Bigger, F.J., Praeger, R. Ll. and Vinycomb, J. (eds) *A Guide to Belfast and the counties of Down & Antrim*. M'Caw, Stevenson & Orr, Limited, Belfast.

42 Nichols, note 2.

Appendix 1. Bibliography of Albert Russell Nichols

Nichols, A.R. and Haddon, A.C. 1886. Hydrozoa. *In* Haddon, A.C., 1st Report on the marine fauna of the south-west of Ireland. *Proceedings of the Royal Irish Academy,* 4 (2): 615.

Nichols, A.R. 1893. *Pleurophyllidia loveni* Bergh in Ireland. *Irish Naturalist,* 2: 176

Nichols, A.R. 1895. The stridulation of Corixa. *Irish Naturalist,* 4: 79

Nichols, A.R. 1896. On the mollusca. *In* Notes on Rockall Island and Bank. *Transactions of the Royal Irish Academy*, 31: 77.

Nichols, A.R. 1902. A list of the Echinoderms of Ireland. *Proceedings of the Royal Irish Academy*, 24B: 231-267.

Nichols, A.R. 1900a. A list of the marine Mollusca of Ireland. *Proceedings of the Royal Irish Academy*, 5 (28): 477-662.

Nichols, A.R. 1900b. Review: 'The fauna and flora of Valencia Harbour on the west coast of Ireland'. *Irish Naturalist,* 9: 265

Nichols, A.R. 1902. Echinoderma (pp. 231-233), Coelenterata (pp. 233-236), Porifera (pp. 237-238). *In* Bigger, F.J., Praeger, R. Ll. and Vinycomb, J. (eds) *A Guide to Belfast and the counties of Down & Antrim*. M'Caw, Stevenson & Orr, Limited, Belfast.

Nichols, A.R. 1903. A list of Irish echinoderms. *Proceedings of the Royal Irish Academy*, 24 B (5): 231-267.

Nichols, A.R. 1904a. Exhibits. *Journal of Conchology*, 11: 21.

Nichols, A.R. 1904b. Review: 'Snipe and woodcock' by L.H. De Vismes Shaw. *Irish Naturalist,* 13: 38

Nichols, A.R. 1905a. A peculiar case of necrosis in a lapwing's foot. *Irish Naturalist,* 14: 32-33

Nichols, A.R. 1905b. On some Irish specimens of a large squid, *Sthenoteuthis pteropus* (Steenstrup). *Irish Naturalist,* 14: 54-57

Nichols, A.R. 1906a. Dotterel in Donegal Bay. *Irish Naturalist,* 15: 45

Nichols, A.R. 1906b. A new Irish Polyzoon *Hypophorella expansa* Ehlers. *Irish Naturalist,* 15: 87.

Nichols, A.R. 1906c. Little owl in Ireland. *Irish Naturalist*, 15: 112.

Nichols, A.R. 1907a. Contributions to a natural history of Lambay: Polyzoa. *Irish Naturalist,* 16: 82-83.

Nichols, A.R. 1907b. Contributions to a natural history of Lambay: Echinodermata. *Irish Naturalist,* 16: 84-85.

Nichols, A.R. 1907c. Tufted duck breeding on Lough Mask. *Irish Naturalist,* 16: 184.

Nichols, A.R. 1907d. The well-shrimp in Co. Clare. *Irish Naturalist,* 16: 208.

Nichols, A.R. 1907e. The Canadian crane in Co. Cork. *Irish Naturalist,* 16: 209-211.

Nichols, A.R. 1907f. Some Irish gephyrean worms. *Irish Naturalist,* 16: 223.

Nichols, A.R. 1908a. Molluscoidea: Gephyrea, Brachiopoda, Polyzoa. *In* Cole, G.A.J. and Praeger, R. Ll. (eds) *Handbook to the Dublin District*. Dublin University Press, Dublin, pp. 200-204.

Nichols, A.R. 1908b. Echinodermata. *In* Cole, G.A.J. and Praeger, R. Ll. (eds) *Handbook to the Dublin District*. Dublin University Press, Dublin, pp. 207-209.

Nichols, A.R. 1908c. Admiral Sir F.L. McClintock, K.C.B., F.R.S. *Irish Naturalist,* 17: 42-43.

Nichols, A.R. 1909. Proceedings of Irish Societies: Dublin Microscopical Society. *Irish Naturalist,* 18: 2.

Nichols, A.R. 1910a. Proceedings of Irish Societies: Dublin Microscopical Society. *Irish Naturalist,* 19: 6.

Nichols, A.R. 1910b. The well-shrimp in Co. Westmeath. *Irish Naturalist,* 19: 103.

Nichols, A.R. 1910c. Review: 'A monograph of the British nudibranchiate Mollusca' supplement by C. Eliot. *Irish Naturalist,* 19: 234-236.

Nichols, A.R. 1911a. Polyzoa from the coasts of Ireland. *Scientific Investigations Fisheries Branch, Ireland, 1910,* 1: 1-37.

Nichols, A.R. 1911b. American blue-winged teal in Ireland. *Irish Naturalist,* 20: 16.

Nichols, A.R. 1911c. The Irish dipper, jay and coal titmouse. *Irish Naturalist,* 20: 44-45.

Nichols, A.R. 1911d. Barnacle goose in Co. Wexford. *Irish Naturalist,* 20: 220.

Nichols, A.R. 1912a. Clare Island Survey 53: Polyzoa. *Proceedings of the Royal Irish Academy*, 31 (53): 1-14.

Nichols, A.R. 1912b. Clare Island survey 57: Echinodermata. *Proceedings of the Royal Irish Academy*, 31 (57): 1-10.

Nichols, A.R. 1912c. Little auks in Co. Dublin. *Irish Naturalist,* 21: 63.

Nichols, A.R. 1913a. Common eider duck in Co. Wexford. *Irish Naturalist,* 22: 20.

Nichols, A.R. 1913b. Squacco heron in Co. Mayo. *Irish Naturalist,* 22: 81.

Nichols, A.R. 1914a. Waxwing in Co. Armagh. *Irish Naturalist,* 23: 104.

Nichols, A.R. 1914b. Long-finned tunny on shore of Achill Island, Co. Mayo. *Irish Naturalist,* 23: 227.

Nichols, A.R. 1915a. Polyzoa. *In* Farran, G.P. (compiler) Results of a Biological Study of Blacksod Bay, Co. Mayo. *Scientific Investigations Fisheries Branch, Ireland, 1914,* 3: 51.

Nichols, A.R. 1915b. Floating barnacles on the coast of Antrim. *Irish Naturalist*, 24: 189-190.

Nichols, A.R. 1916a. (Velvet scoter). *Irish Naturalist,* 25: 31.

Nichols, A.R. 1916b. List of the late Robert Warren's more important writings. *Irish Naturalist*, 25: 41-44.

Nichols, A.R. (ed). 1920. *Catalogue of the Birds in the Barrington Collection*. National Museum, Dublin. John Falconer, Dublin.

Ussher, R.J. and Nichols, A.R. 1924. *A list of Irish Birds, showing the species contained in the National Collection*. Second edition. Stationary Office, Dublin.

Colgan, N. (edited and with notes by Nichols, A.R.) 1930. The marine mollusca of the shores and shallow waters of County Dublin. *Proceedings of the Royal Irish Academy*, 39: 391-424.

Appendix 2. Timeline of Albert Russell Nichols' life

January 1859: (0 yrs old) Albert Russell Nichols was born in Stowmarket, Suffolk, England to father Arthur Nichols and mother Sarah.

9 December 1859: (11-12 months old) A.R. Nichols was christened in Stowmarket, Suffolk, England.

January 1878: (19 yrs old) A. R Nichols went to Clare College to study maths.

1882: (23 yrs old) Graduated Clare College with 1st class degree.

23 January 1883; (24 yrs old) Sat examination for appointment to Assistant Naturalist in the Natural History section of the Museum of Science and Art (now National Museum of Ireland).

March 1883: (24 yrs old) Began position in museum.

1886: (27 yrs old) Took part in *Lord Bandon* dredging trip off southwest Ireland (Nichols 1886).

20 July 1892: (33 yrs old) Married Letitia Anne Perry.

1895: (36 yrs old) Trip to Rockall. Described the molluscs in Nichols, 1896.

1896: (37 yrs old) Daughter Beryl Nichols born.

1901: (42 yrs old) 1901 Irish census has Nichols living at 30 Grosvenor Square, Rathmines, Dublin with his wife and child Beryl, along with one nurse and a cook. A visitor Mary Perry (probably his wife's aunt) was also present on the night of the census.

May 1905: (46 yrs old) Promoted to Assistant Keeper.

Easter 1906: (47 yrs old) Spent time on Lambay Island and published lists of bryozoans and echinoderms (Nichols 1907a, b).

1906: (47 yrs old) Nichols publishes note on *Hypophorella expansa*.

1907: (48 yrs old) Dublin Marine Biological Committee established. Nichols was a committee member.

1908: (49 yrs old) Served as Vice-President of the Dublin Naturalists' Field Club.

1908: (49 yrs old) Nichols publishes section on Bryozoa in Dublin Handbook.

1910-1912: (51-53 yrs old) President of Dublin Microscopical Club.

1911: (52 yrs old) 1911 Irish census has Albert, his wife and daughter and one general servant living at 30 Grosvenor Square, Rathmines, Dublin.

1911: (52 yrs old) Clare Island Survey work. Nichols publishes on bryozoans (1912a) and echinoderms (1912b).

1911: (52 yrs old) Irish coastline survey published (Nichols 1911)

1915: (56 yrs old) Blacksod Bay survey published (Nichols 1915)

August 1921: (62 yrs old) Succeeded Robert Francis Scharff as Keeper of Natural History.

29 January 1924: (65 yrs old) Reached statutory retirement age.

21 February 1933: (75 yrs old) A. R. Russell dies and is buried at Mount Jerome Cemetery, Harold's Cross, Dublin.

Things we lost in the fire: the rediscovery of type material from Ehrhard Voigt's early publications (1923–1942) and the bryozoan collection of Hermann Brandes

Silviu O. Martha
Senckenberg Forschungsinstitute und Naturmuseen, Sektion Marine Evertebraten III (Bryozoologie), Senckenberganlage 25, 60325 Frankfurt am Main, Germany

1. Introduction

Professor Ehrhard Voigt (1905–2004) is known to the bryozoan community as one of the most passionate and important researchers in the topic from the 20th century (Figure 1a). He published more than 130 papers on bryozoans during a span of more than 80 years, describing over 500 new species and subspecies, and establishing 79 genera, 4 families, and 2 subgenera. His main research field was the Central European fauna of the Upper Cretaceous and early Palaeogene, and he left behind the world's largest collection of bryozoans from this time span. This represents a unique archive documenting some highlights in the evolutionary history of bryozoans: the early expansion of various types of ascophorines and interior-walled cyclostomes, the increasing importance of encrusting taxa, and the evolutionary crisis at the Cretaceous-Paleogene-boundary, resulting in the final breakdown of the bryozoan-rich carbonate platform.

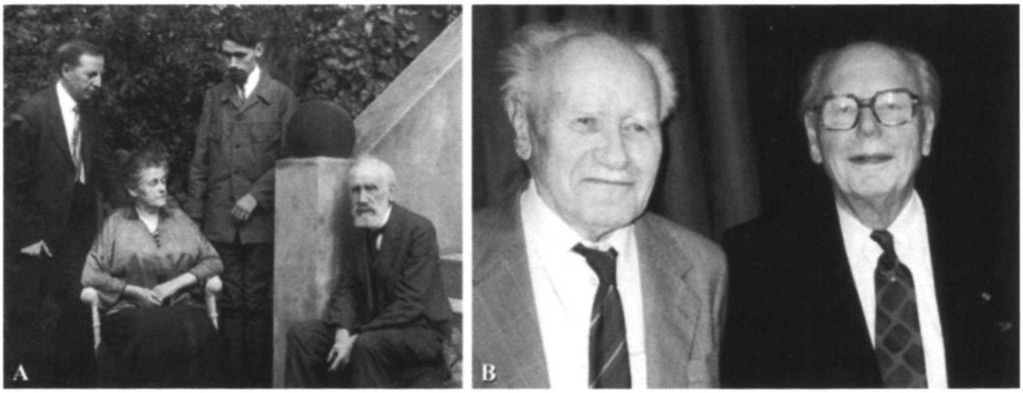


Figure 1. A. The young Ehrhard Voigt with Ray S. Bassler (left) and his parents in Dessau during a visit of Bassler at Voigt in 1928. Modified after Hillmer (2006). B. Two emeriti faculty members of the Institute of Geology and Palaeontology (University of Hamburg), Erhard Voigt and the paleobotanist Wolfgang Hartung (1907-1995), who died just a few months after this photograph being taken, in June 1994. Like Hartung, Voigt was active in academic teaching well beyond retirement age, and was teaching advanced courses of geological mapping. Courtesy of Joachim Scholz.

Hans Adolf Ehrhard Voigt was born on 27 July 1905 in the small town Schönebeck/ Elbe. His parents, Mira Voigt, born Stadelmann (1860–1932) and Adolf Karl Voigt (1863–1932), a chemist, always encouraged their only child towards natural sciences. The young Ehrhard dedicated his interest to geology and palaeontology, and started collecting fossils; bryozoans becoming his special interest after he found many of them in flints in his parents' garden. As a teenager he had already built up a remarkable collection and established connections with many famous bryozoologists of that time. He corresponded regularly and exchanged material with Ray S. Bassler (1878–1961; Figure 1b), Ferdinand Canu (1863–1932), Edward O. Ulrich (1857–1944) and many others.

Voigt started working on several publications on bryozoans from his private collection during his schooldays in Dessau and continued publishing papers during his studies, conducted from 1924 onwards, at the universities of Halle, Munich and Greifswald. He received his Ph.D. in 1929 in Halle working on the lithogenesis of Upper Cretaceous sediments. Voigt stayed on at the University of Halle and worked as an assistant for Johannes Weigelt (1890–1948), helping with the excavations at the fossil site Geiseltal during the 1930s. In that time, he invented a method of lacquer peels. He completed his habilitation dissertation on Eocene fish from the Geiseltal in 1934.

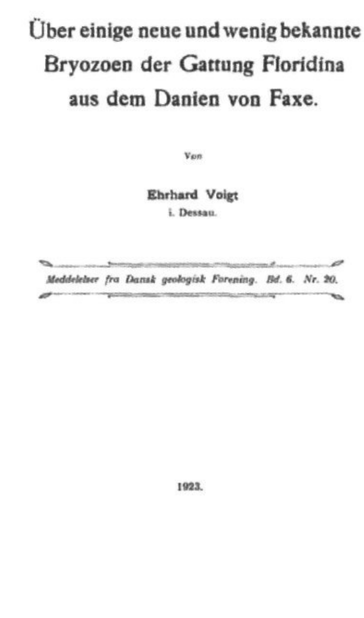
In spring 1939 he joined the staff of the University of Hamburg. After serving in World War II, Voigt became the driving force behind the reconstruction of the *Geologische Staatsinstitut Hamburg* (State Department of Geology Hamburg, GSI) that had been destroyed in 1943. He retired from teaching in 1970, but continued working until his death and most of the publications on bryozoans appeared after his retirement. Ehrhard Voigt died on 22 November 2004 in a hospital in Hamburg following a fall that had caused a hip fracture three weeks earlier. Most parts of his enormous bryozoan collection were relocated in 2005 from Hamburg to Frankfurt. For more detailed biographies on Ehrhard Voigt, see Guha (2005) and Hillmer (2006).

2. Voigt's early publications on bryozoans (1923–1929)

Voigt's early publications on bryozoans can be subdivided into three creative phases: his schooldays comprising five publications in 1923–4, his student days (including his time as Ph.D. student) with eight publications between 1925 and 1930, and the post-student era with just three publications in 1932, 1939, and 1942. Until now it was thought that all of the material examined by Voigt in these works had been destroyed during World War II or lost but, as will be shown later, some material has been recovered.

Voigt's first publication appeared 1923 in the Danish journal *Meddelelser fra Dansk geologisk Forening* (Figure 2). He described five species of the genus *Floridina* Jullien, 1882 from the Danian of Herfølge and Faxe in Denmark, material he received from Bassler and J.P.J. Ravn (1866–1951), and compared it with his own material collected from the white chalk of Rügen and glacial drift deposits from northern Germany. The first new bryozoan species Voigt erected were *F. impar*, *F. trifolium* (put into synonymy with *Tornipora canui* (Brydone, 1906) by Jürgensen 1971), *F. tubulosa* and *F. variabilis* (put into synonymy with *F. pulchella* (Kade, 1852) by Berthelsen 1962).[1] It has to be mentioned that Voigt, like many other authors of that time, did not create holotypes for the new species erected in his pre-World War II publications.

In 1924 four descriptive taxonomic publications on Bryozoa appeared in three issues of the journal *Paläontologische Zeitschrift*. In Voigt (1924b), several cyclostome and cheilostome species he had found in glacial drift deposits of Danian age in his home region (area around Dessau) were described. His other three publications (1924a, c, d) are about material from the Subhercynian Cretaceous Basin and its surroundings in northern Germany. Voigt 1924a was a short description of one ctenostome species,[2] while Voigt 1924c, d is a two-part monograph on the Subhercynian fauna of the Upper Cretaceous. The first part is dedicated to the cyclostomes (Voigt 1924c) and the second part deals with the cheilostomes (Voigt 1924d). The entire monograph comprised 117 species, including 18 new cyclostomes and 28 new cheilostomes. Voigt studied for this monograph his own material, samples from the Brandes Collection in Hoheneggelsen, and loans from the *Preußische Geologische*


Über einige neue und wenig bekannte
Bryozoen der Gattung Floridina
aus dem Danien von Faxe.

Von

Ehrhard Voigt
i. Dessau.

Meddelelser fra Dansk geologisk Forening. Bd. 6. Nr. 20.

1923.

Figure 2. Cover of Voigt's first publication in 1923 on Floridina *from the Danian of Denmark and northern Germany.*

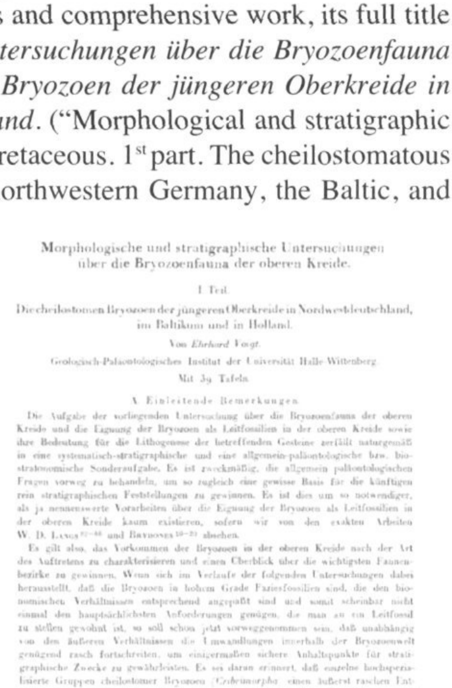
Landesanstalt (PGL; Prussian Geological State Survey) in Berlin. The monograph should originally have contained ten plates but in order to save on printing costs, Voigt was forced to reduce the number of plates to six, so he removed some images and reduced the magnification of the other images. Unfortunately, he could not include images of the newly described cyclostome species *Diastopora cava* in the final version of the monograph, because he received the material for the images too late.[3]

During his freshman year in Halle in 1924, Voigt was one of the founding members of the *Gesellschaft für Geschiebeforschung* ("Society for the research of glacial drifts"), and he contributed several articles to the journal of the society, including also research on bryozoans from glacial drift deposits of his home region (Voigt 1925a, b; 1928a). Some small publications on bryozoan faunas from several regions in northern Germany (Voigt 1929a, b; Hucke & Voigt 1929) and Austria (Voigt 1928b) appeared while Voigt was working on his Ph.D.

3. Voigt's monograph on bryozoans from the Upper Cretaceous and the post-student era (1930–1942)

The last publication of Voigt's student era appeared in 1930 in a Festschrift dedicated to the famous geologist and former teacher of Voigt, Johannes Walther (1860–1937). The monograph (Figure 3) is Voigt's most ambitious and comprehensive work, its full title being *Morphologische und stratigraphische Untersuchungen über die Bryozoenfauna der oberen Kreide. I. Teil. Die cheilostomaten Bryozoen der jüngeren Oberkreide in Nordwestdeutschland, im Baltikum und in Holland*. ("Morphological and stratigraphic researches on the bryozoan fauna of the Upper Cretaceous. 1st part. The cheilostomatous bryozoans of the earlier Upper Cretaceous in northwestern Germany, the Baltic, and Holland").[4]

The main aim of Voigt was to give a complete overview of the bryozoan fauna of the Upper Cretaceous in the examined regions, showing that bryozoans are useful index fossils for the Upper Cretaceous. Many previous authors regarded bryozoans as facies-dependent fossils that are unsuitable for stratigraphical purposes. Voigt ascribed this mainly to insufficient knowledge of the bryozoan fauna to date, and to misidentifications and multiple descriptions of the same species from different regions, due to inaccurate first descriptions and drawings by



Morphologische und stratigraphische Untersuchungen über die Bryozoenfauna der oberen Kreide.

I. Teil.

Die cheilostomen Bryozoen der jüngeren Oberkreide in Nordwestdeutschland, im Baltikum und in Holland.

Von *Ehrhard Voigt.*

Geologisch-Palaeontologisches Institut der Universität Halle-Wittenberg.

Mit 39 Tafeln.

A. Einleitende Bemerkungen.

Die Aufgabe der vorliegenden Untersuchung über die Bryozoenfauna der oberen Kreide und die Eignung der Bryozoen als Leitfossilien in der oberen Kreide sowie ihre Bedeutung für die Lithogenese der betreffenden Gesteine zerfällt naturgemäß in eine systematisch-stratigraphische und eine allgemein-paläontologische bzw. biostratonomische Sonderaufgabe. Es ist zweckmäßig, die allgemein paläontologischen Fragen vorweg zu behandeln, um so zugleich eine gewisse Basis für die künftigen rein stratigraphischen Feststellungen zu gewinnen. Es ist dies um so notwendiger, als ja nennenswerte Vorarbeiten über die Eignung der Bryozoen als Leitfossilien in der oberen Kreide kaum existieren, sofern wir von den exakten Arbeiten W. D. Langs und Brydones absehen.

Es gilt also, das Vorkommen der Bryozoen in der oberen Kreide nach der Art des Auftretens zu charakterisieren und einen Überblick über die wichtigsten Faunenbezirke zu gewinnen. Wenn sich im Verlaufe der folgenden Untersuchungen dabei herausstellt, daß die Bryozoen in hohem Grade Faziesfossilien sind, die den bionomischen Verhältnissen entsprechend angepaßt sind und somit scheinbar nicht einmal den hauptsächlichsten Anforderungen genügen, die man an ein Leitfossil zu stellen gewohnt ist, so soll schon jetzt vorweggenommen sein, daß unabhängig von den äußeren Verhältnissen die Umwandlungen innerhalb der Bryozoenwelt genügend rasch fortschreiten, um einigermaßen sichere Anhaltspunkte für stratigraphische Zwecke zu gewährleisten. Es sei daran erinnert, daß einzelne hochspezialisierte Gruppen cheilostomer Bryozoen (*Cribrimorpha*) einen äußerst raschen Entwicklungsgang eingeschlagen haben, der stratigraphisch noch längst nicht genügend ausgewertet ist. Wenn auch im allgemeinen die durchaus berechtigte Tendenz besteht, die Gliederung mariner Schichten nach Möglichkeit mit Hilfe der Cephalopoden durchzuführen und man sich stets mit Recht vorwiegend der planktonischen Lebewelt für stratigraphische Zwecke bedienen wird, so darf jedoch ebensowenig versäumt werden, auch das sessile Benthos auf seine Eignung zu Gliederungszwecken eingehend zu prüfen, und das um so weniger, als gerade die doch so faziesempfind-

Figure 3. First page of Voigt's 1930 monograph on the cheilostomatous fauna of the Upper Cretaceous in Central Europe.

previous authors. He argued that especially the highly developed and specialized Cheilostomata could be used as stratigraphical tools. He, therefore, provided in his monograph short descriptions and images of all 533 species examined, including 104 new species. The monograph is based mainly on material from Voigt's own collection. A few imaged samples came from other collections, namely the collection of the PGL, the collection of the University of Halle-Wittenberg, and the Brandes Collection. Voigt used in the monograph the classification and terminology of Ferdinand Canu, Ray S. Bassler and William D. Lang (1878–1966). The magnification of the samples (15x) is consistent for Tables 1–37, while the last two plates contain images of some complete bryozoan colonies.

The greatest challenge for Voigt were the membranimorphs, i.e. encrusting Anasca with little or no frontal wall calcification. He classified 128 species, including 43 new species, provisionally within the genus *Membranipora* de Blainville, 1830, but divided them into several groups of similar species in order to create more clarity within this taxon. For example, he created the group of *Membranipora elliptica* (von Hagenow, 1839) on p. 419 including the three species *M. elliptica*, *M. pellicula* Brydone, 1912 and *M. hannoverana* Voigt, 1924d.[5] For some of the species, Voigt indicated a second genus of membranimorph species in brackets, e.g. *M.* (*Callopora*) *polytaxis* Voigt, 1930.[6] The partitioning of the membranimorph species into various genera was just in the early stages of its development in 1930 (and is still in progress). The species with a second genus in brackets are now included within the second genus, or assigned to a different genus altogether.

The full title of the monograph already suggests that a second part was initially intended dealing with the cyclostome fauna. Although Voigt indicated that he was already working on the second part, it remained unfinished and has never been issued. During the 1930s Voigt was mainly occupied with the Geiseltal excavations and worked little on bryozoans. After World War II and the destruction of the material that might have been used for the second part of the monograph, and probably also his notes, Voigt completely abandoned the plan to write this sequel.

Only three further publications on Bryozoa appeared until 1942. In 1932 he authored an article on bryozoans for an encyclopaedia. Voigt showed in 1939 that Dollo's law of irreversibility is valid for bryozoans by examining the spines of several cheilostome taxa and their differentiation in time. The same year Voigt was appointed non-tenured Professor at the University of Hamburg and executive director at the GSI after Roland Brinkmann (1898–1995) had to leave Germany temporarily, due to his political views that were critical of the ruling National Socialists. Voigt and his collection left Halle in springtime.

After his call-up to military service in autumn 1939, Voigt could finish only one more paper on bryozoans that was published in 1942 (the address indicates that Voigt was "currently in battle"). Voigt compared material he received from Bassler with the original material of Reuss (1872). He proved that part of the material described by Reuss (1872), which should have been from the Cenomanian of Dresden-Plauen, is in fact identical with

Danian material from the Vincentown Limesand in New Jersey, USA. As Reuss did not collect the material himself, Voigt concluded that the data on the provenance of the Reuss material must have been wrong as it clearly differs from bryozoan material in Dresden-Plauen of Cenomanian age.

4. Publications by Ehrhard Voigt on bryozoans between 1923–1942

Voigt, E. 1923. Über einige neue und wenig bekannte Bryozoen der Gattung *Floridina* aus dem Danien von Faxe. *Meddelelser fra Dansk geologisk Forening* **6**, 1–9.

Voigt, E. 1924a. Über eine ctenostome Bryozoe aus dem Granulatensenon von Gr. Bülten bei Peine. *Paläontologische Zeitschrift* **6**, 1–2.

Voigt, E. 1924b. Über neue Bryozoen aus Daniengeschieben Anhalts. *Paläontologische Zeitschrift* **6**: 3–13.

Voigt, E. 1924c. Beiträge zur Kenntnis der Bryozoenfauna der subherzynen Kreidemulde. *Paläontologische Zeitschrift* **6**, 93–173.

Voigt, E. 1924d. Beiträge zur Kenntnis der Bryozoenfauna der subherzynen Kreidemulde. (Fortsetzung aus Heft 2). *Paläontologische Zeitschrift* **6**, 191–247.

Voigt, E. 1925a. Über das Vorkommen von Bryozoen in Diluvialgeschieben und die Grundzüge ihrer Systematik. *Zeitschrift für Geschiebeforschung* **1**, 13–28.

Voigt, E. 1925b. Neue cribimorphe Bryozoen aus der Familie der Pelmatoporidae in Kreidegeschieben Anhalts. *Zeitschrift für Geschiebeforschung* **1**, 97–104.

Voigt, E. 1928a. Neue artikulierte cheilostome Bryozoen aus einem Kreidegeschiebe obersenonen Alters von Cöthen in Anhalt. *Zeitschrift für Geschiebeforschung* **4**, 105–114.

Voigt, E 1928b. Bryozoen aus dem Gosauvorkommen am Taubensee bei Kössen in den Nordtiroler Kalkalpen. *Centralblatt für Mineralogie, Geologie und Paläontologie (B)* **7**, 443–448.

Voigt, E. 1929a. Die Bryozoengattung *Diplosolen* in der Schreibkreide von Rügen. *Mitteilungen aus dem Naturwissenschaftlichen Verein für Neu-Vorpommern und Rügen in Greifswald* **52/56**, 1–8.

Voigt, E. 1929b. Über fossile Bryozoen und ihr Vorkommen in heimischen Diluvialgeschieben. *Berichte des Naturwissenschaftlichen Vereines zu Dessau* **1**, 25–26.

Hucke, K. and Voigt, E. 1929. Beiträge zur Kenntnis der Fauna des norddeutschen Septarientones. *Zeitschrift der Deutschen Geologischen Gesellschaft* **81**, 159–168.

Voigt, E. 1930. Morphologische und stratigraphische Untersuchungen über die Bryozoenfauna der oberen Kreide. *Leopoldina: Berichte der Kaiserlich-Deutschen Akademie der Naturforscher zu Halle* **6**, 379–579.

Voigt, E. 1932. Bryozoa (Paläontologie). *Handwörterbuch der Naturwissenschaften* **2** (2nd edition), 280–286.

Voigt, E. 1939. Über die Dornenspezialisation bei cheilostomen Bryozoen und die Nichtumkehrbarkeit der Entwicklung. *Paläontologische Zeitschrift* **21**, 87–107.

Voigt, E. 1942. Kreidebryozoen aus New Jersey (U.S.A.) unter A. E. Reuss' Originalen zu seiner Monographie der Bryozoen und Foraminiferen des Unteren Pläners (1872) in H. B. Geinitz: "Das Elbthalgebirge in Sachsen". *Zeitschrift der Deutschen Geologischen Gesellschaft* **94**, 326–338.

5. Operation Gomorrah and the first years after the war

The loss of the first Voigt Collection goes hand in hand with one of the turning points in World War II. From 24 (Voigt's 38th birthday) to 30 July 1943, the Allies carried out intense air raids codenamed 'Operation Gomorrah' on Hamburg. The northern German city was one of the industrial and military centres of the Third Reich and, therefore a perfect strategic target to weaken the Nazis. The strongest raids during the operation occurred during the night of 27 July. Over 700 aircraft of the Royal Air Force dropped over 2,000 tons of bombs on a small area in the eastern city centre. A heat wave and an extreme drought resulted in the creation of a huge firestorm that lasted several hours and reached temperatures of over 800°C. An area of over 21 km^2 was incinerated, over 16,000 buildings were consumed, and more than 30,000 people died. The GSI, located Lübeckerthor 22 in the district St Georg (Figure 4), was within the area affected by the firestorm. The building and all collections, including the first Voigt Collection, books and documents were completely destroyed (Wüstenhagen *et al.* 1998).

Figure 4. The building of the GSI between 1908 (then: Mineralogisch-Geologisches Institut, *Institute of Mineralogy and Geology) and 1943 on Lübeckerthor 22. Courtesy of the Geologisches Landesamt Hamburg.*

Figure 5. The GSI was lodged in this building (the "toppled commode") on Esplanade 1 after World War II until a new building was constructed in 1960. From Wüstenhagen et al. (1998). Courtesy of the Geologisches Landesamt Hamburg.

Voigt worked as a military geologist from the beginning of World War II, at first on the western front and from 1941 until the end of the war on the eastern front in Czechoslovakia and the Baltic States. He received leave to see the damage caused by the firestorm and returned for a couple of weeks to Hamburg. He could do little, however, and found only a few samples in the ruins that have either been blackened with soot or amalgamated. Voigt soon returned to the eastern front, where he remained until the end of the war. Not even during the harsh times of war did he lose his passion for bryozoans. He used his free time to study the Cenomanian fauna of Predboj while in Czechoslovakia, and collected in 1942/3 several hundred specimens from the Kukersite layers of Ordovician age in Estonia and northwestern Russia. These samples, which became the first samples of the second Voigt Collection, were later studied by Toots (1952a, b). They remained at the University of Hamburg after the relocation of the second Voigt Collection to Frankfurt in 2005.

The Soviet army captured Voigt's Division in 1945, before the end of the war, and

Figure 6. The young Voigt family, Ellinor and Ehrhard Voigt with their three children Irmgard, Wolfgang, and Werner in Hamburg in 1951. Courtesy of Wolfgang Voigt.

Voigt became a prisoner of war in the Soviet Union. When Voigt returned home to Hamburg after one and a half years of captivity in late 1946, his colleagues had already started reconstructing the GSI in a building not affected by the war in the western city centre. The building was situated on Esplanade 1 (Figure 5) and nicknamed "*umgestürzte Kommode*" ("toppled commode"). Soon after his return, Voigt married on 22 May 1947 Ellinor Bucerius (1911–2005), who had lost her first husband Curt Arpe in 1941. Ellinor and Ehrhard's three children were born in 1948 (Werner, linguist) and 1950 (Irmgard, graphic designer, and Wolfgang, architect). The family (Figure 6) lived on the outskirts of Hamburg, but moved into an apartment closer to the institute in 1955.

Voigt put much of his energy and free time during the first years after the war into the reconstruction of the institute and the re-establishment of a new, even larger collection than the one destroyed in 1943. One of Voigt's major interests was the search for material of the species lost in 1943. He was able to recollect material from many of the sites previously studied and also revised several of the 182 new species he had described between 1923 and 1930. One of the greatest successes with regard to compensating for lost material was the purchase of the famous collection of Hermann Brandes (see Section 7).[7] Because the building on Esplanade 1 was too small for the institute and the steadily growing collections, Voigt helped organizing the construction of a new building, von-Melle-Park 11, where the GSI would finally move in 1960.

6. The rediscovery of type material from Voigt's early publications

One of the most important tasks regarding the (second) Voigt Collection is the digitisation of at least the most important parts of the collection[8] and the preparation of a type catalogue including all holotypes and neotypes first described by Voigt and co-authors. This type catalogue will not only include the types now lodged in Frankfurt, but also the ones that remained in Hamburg, lists of the types lost in 1943, and lists of types described by Voigt and co-authors lodged at other institutions. The work will also include images of all of the types not lost. A multi-national team is currently working on the project and taking images of the type material described by Voigt.

During this work, three type specimens from Voigt (1924d) and Voigt (1930) have so far been rediscovered. The first type reappeared while I was searching the Brandes Collection on 20 September 2013. On a handwritten list accompanying the collection, I was surprised to see a note indicating a box that should contain the type specimen of

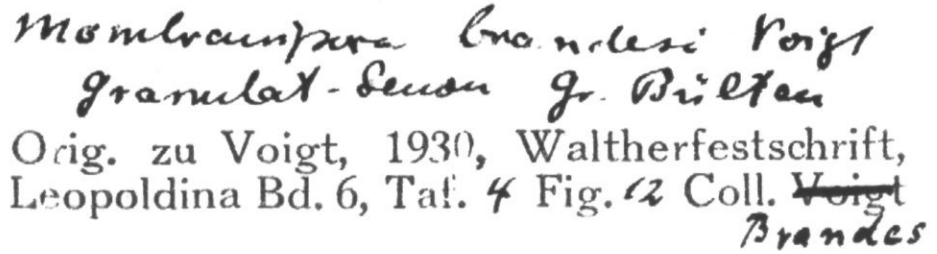


Figure 7. Original label of the holotype of Membranipora brandesi *indicating that it is the original specimen depicted in Voigt (1930).*

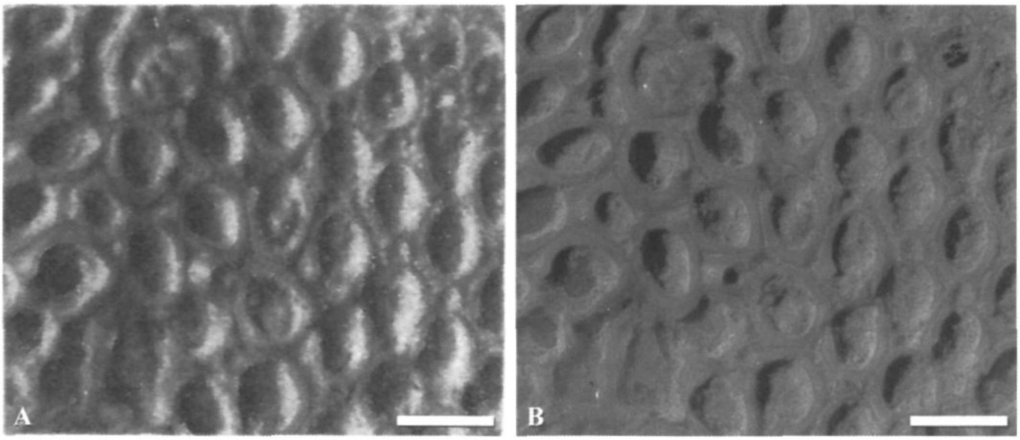


Figure 8. A. Image provided by Voigt (1930) on Pl. 4, Fig. 12 of Membranipora brandesi *from the Late Santonian of Ilsede-Groß Bülten, Lower Saxony, Germany. Scale bar: 500 µm. B. Detail of the specimen of* M. brandesi *from the Brandes Collection showing the same part of the colony. Scale bar: 500 µm.*

Membranipora brandesi Voigt, 1930 (Figure 7). I compared the specimen with the original specimen depicted by Voigt (1930) on Pl. 4, Fig. 12. Without any doubt they are identical (Figure 8). The species encrusts the inner surface of a shell and the type specimen is broken into four fragments, but might have already been broken when Voigt originally described the species. Most of the colony, including the part figured by Voigt, is on one fragment. Voigt included *M. brandesi* in his monograph with 12 other species within the heterogeneous group of the membranimorph bryozoans that do not belong to any of the other groups. As Voigt did not mention any other specimens of this species, the newly discovered specimen is presumed to be the unique holotype of *Membranipora brandesi* Voigt, 1930.

Another two type specimens were rediscovered shortly later at the beginning of November. Angela Ehling from the *Bundesanstalt für Geowissenschaften und Rohstoffe* (BGR; Federal survey for geosciences and resources) in Berlin provided images of all Voigt material included within the original catalogue of the BGR Berlin (Fenner 2006). Among the examined material, one type specimen of *Conopeum congestum* Voigt, 1924d

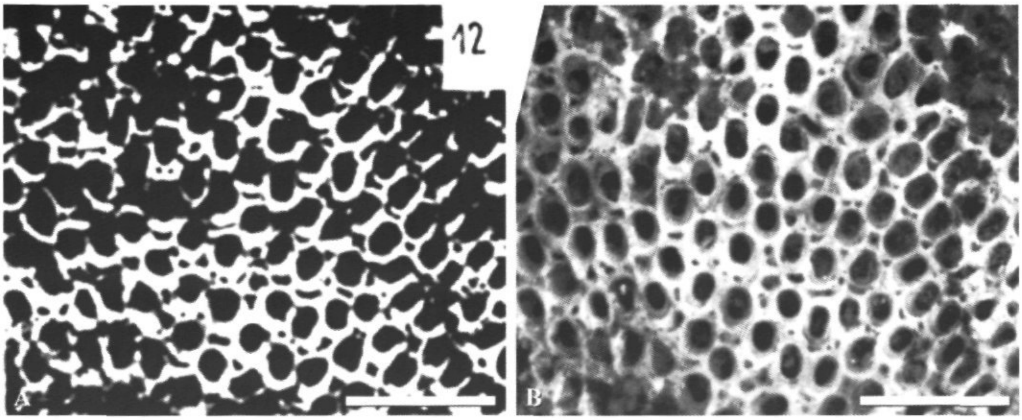


Figure 9. A. Image provided by Voigt (1924d) on Pl. VI, Fig. 12 of Conopeum congestum *from the Santonian of the Salzberg near Quedlinburg, Saxony-Anhalt, Germany. Scale bar: 1 mm. B. Detail of the specimen of* C. congestum *in the collections of the BGR (X 11128) showing the same part of the colony. Scale bar: 1 mm.*

(Figure 9; figured by Voigt on Pl. VI, Fig. 12)[9] and ten specimens of *Ogiva promonturiorum* Voigt, 1924d including two specimens figured by Voigt on Pl. VII, Fig. 23 (Figure 10) were located. These specimens belonged to the PGL material from the Subhercynian Cretaceous Basin and its surroundings. The PGL was dissolved on 1 April 1939 and after a varied history most of the material of the former PGL has belonged to the BGR Berlin since 1990. Another specimen from the PGL material should be an original of *Membraniporidra huckeana* (Voigt, 1924b), which was depicted in Voigt (1930) on Pl. 5, Fig. 6. A comparison of the images showed, however, that these specimens are not

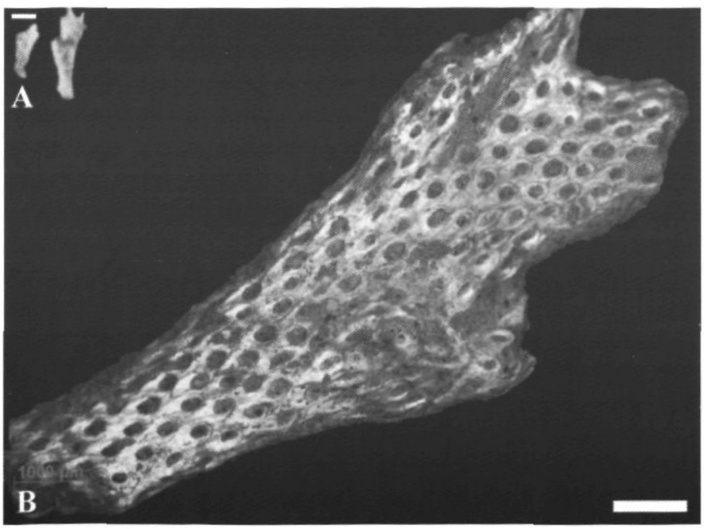


Figure 10. A. Image provided by Voigt (1924d) on Pl. VII, Fig. 23 of Ogiva promonturiorum *showing two specimens from the Santonian of the Salzberg near Quedlinburg, Saxony-Anhalt, Germany, both of which have been recovered. Scale bar: 5 mm. B. One of the specimens in the collections of the BGR (X 11129), which proves from the shape of the colony to be the right specimen imaged on Pl. VII, Fig. 23. Scale bar: 1 mm.*

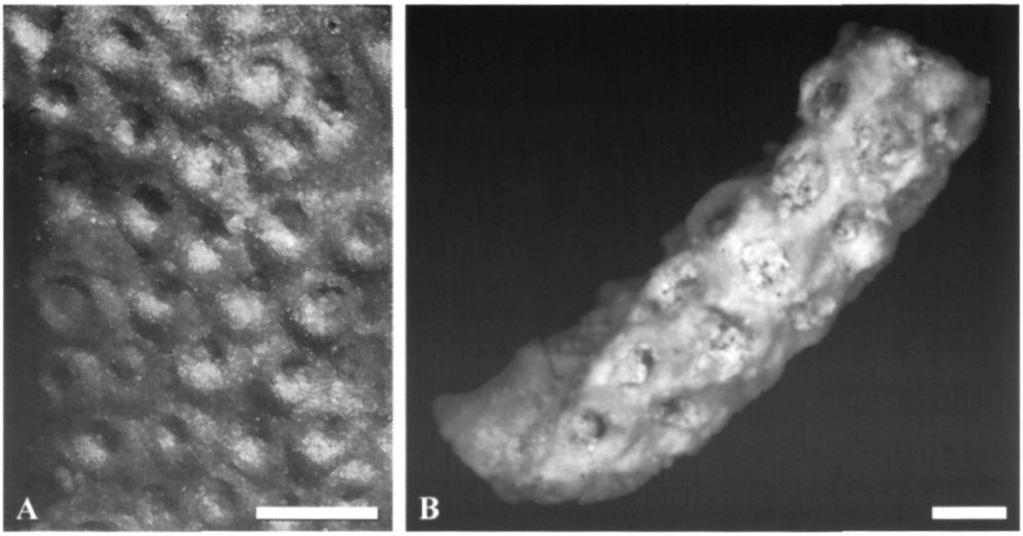


Figure 11. A. Image provided by Voigt (1930) on Pl. 5, Fig. 6 of Membraniporidra huckeana *from a glacial drift deposit of Danian age from Köthen, Saxony-Anhalt, Germany. Scale bar: 500 µm. B. The specimen from the BGR Berlin (X 9454) that should be the original of* M. huckeana *from Voigt (1930) proves to be not identical. Furthermore, Voigt (1930) does not mention that the specimen figured should belong to the PGL collections. Scale bar: 1 mm.*

identical (Figure 11). It remains unclear so far what has happened with the other type material from the PGL. Voigt (1924a, c, d, 1930) provided images for 22 species from PGL material, among which are 13 newly erected species[10] (including the invalid species *Vinella cretacea* Voigt, 1924a).

Voigt (1957) reported that the Marsson Collection of the PGL, which included the material from Marsson (1887), was destroyed in World War II. Fenner (2006), however, indicates 17 samples from Marsson (1887), including also type material for six species, meaning that at least some of the material from that collection could be recovered. Voigt had, therefore, probably been misinformed about the fate of his own material too. Angela Ehling found that part of the collection now at the BGR Berlin was transported to Leningrad (now St Petersburg) after the Second World War, but was recovered several years later. Of course, some losses will have occurred during the relocations. Part of the collections went after the return of the material to the *Museum für Naturkunde* (Museum of natural sciences) in Berlin. So, we have several possible scenarios as to what might have happened to the material of the Marsson Collection and from Voigt (1924a, c, d, 1930), which has not been rediscovered yet. Further research to unravel the fate of the missing material of the PGL is currently in progress. A revision of the rediscovered species so far, including new images of all three species, will be the topic of a separate paper currently in preparation.

7. The bryozoan collection of Hermann Brandes (1855–1940)

The rediscovered type specimen of *M. brandesi* belonged to the bryozoan collection of Hermann Brandes and the species was named in honour of this remarkable man. Although the Brandes Collection (Figure 12) is a very well documented collection containing several thousand specimens of bryozoans from a small region in NW Germany and the island of Rügen, it is relatively unknown among bryozoologists to date. The collection represents a nearly complete fauna of the Cretaceous from a handful of outcrops in the region between Braunschweig, Hildesheim and Peine in Lower Saxony. Most of these outcrops are no longer accessible and have completely been destroyed. Many species, including several of the species erected by Voigt before World War II from this region, are, therefore, only documented in the Brandes Collection. But who was the man behind this collection?

Figure 12. Drawer with specimens from the Brandes Collection in small boxes and a list indicating which specimens are in the boxes at the Senckenberg Institute in Frankfurt.

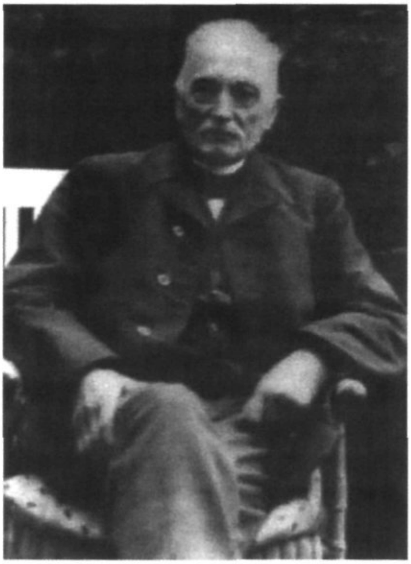


Figure 13. Hermann Brandes in Hoheneggelsen.
Photograph courtesy of the Heimatverein Hoheneggelsen.

Hermann Heinrich Brandes (Figure 13) was born on 31 March 1855 as the second child of Wilhelm Heinrich Brandes and Caroline Wilhelmine Elisabeth Brandes, née Vornkahland. He lived in Mölme, a small village 40 km SE of Hannover. As a young man he suffered from severe typhoid fever for a long time, which forced him to give up his job as an administrator. Brandes appears to have lived on private means thereafter. In 1903 he bought a house in the nearby village of Hoheneggelsen, where he lived until his death. He never married and had no children (Söding 1968).

Brandes had wide interests and the only four publications that can with certainty be assigned to him deal with the cultivation of sugar beet (1884), halophytes (1913), the Upper Jurassic of Hoheneggelsen (1914), and the history of the peasantry in the Hildesheim region (1934). For the latter work he was named honorary citizen of the village Hoheneggelsen. The street around the corner of his house now bears the name of Hermann Brandes. Most relevant for us is his interest in geology and palaeontology. Brandes studied neither geology nor palaeontology at a university, but was self-taught. He examined the geology of his home region and visited every well drilling, house excavation, and other possibility to undertake geological research (Rose 2010). Brandes drew geological profiles and collected all types of fossils, including ammonites, bivalves, brachiopods, bryozoans, cephalopods, foraminiferans, sponges and many others. These he classified by reading books and corresponding with palaeontologists.

Contemporaneous geologists and palaeontologists soon started to visit Brandes to examine his collection. Brandes joined the *Deutsche Geologische Gesellschaft* (DGG, Geological Society of Germany) on 4 December 1889 at the suggestion of three famous German geologists of the time.[11] He also became a member and corresponding member of several other geological societies during the following years. Many researchers admired his collection and also his comprehensive geological knowledge of his home region. Thus, several papers on material from the Brandes Collection appeared during the 1890s to 1930s and many authors not only used fossils from his collection, but also profited from first-hand information provided by Brandes on the geology of the examined outcrops, and included profiles by Brandes in their works. The most comprehensive work on the Brandes Collection appeared in 1920 by Georg Beck and includes many fossil lists. Unfortunately, bryozoans were not considered by Beck.

Voigt first heard of the Brandes Collection and that it contains bryozoans while working on the first part of his 1924 monograph on bryozoans from the Subhercynian Cretaceous Basin, and he was definitely impressed by this "comprehensive collection".[12] He, however, did not include any images of Brandes' material in his 1924 monograph. The only other pre-World War II work of Voigt examining material from the Brandes Collection was his enormous 1930 monograph, and this included three images of Brandes' specimens. The rediscovered type specimen of *M. brandesi* was imaged on Pl. 4, Fig.12, and the type(s) of *Pelmatopora grandiporosa* on Pl. 31, Figs. 13–14, the latter material not having been found as yet.

Voigt was not the first to examine bryozoans in the Brandes Collection. Voigt stated that a person named Hustedt from Berlin had worked on a monograph of the cyclostomes from the Brandes Collection, but died before the publication appeared (Voigt 1924c: p. 94). This was most probably the geography teacher and rector, Wilhelm Hustedt (1860–1907), who worked at a school in Berlin, as he is the only member of the DGG with this name at the beginning of the 20th century. The only other source I could find indicating that a person named Hustedt, a name completely unknown to the bryozoan community, was indeed interested in bryozoans are short reports in a journal on several works dealing with bryozoans in 1905.[13] Brandes must have told Voigt about Hustedt, but it is doubtful whether Voigt ever saw the manuscript of Hustedt's work. Voigt (1924c) dedicated to Hustedt the cyclostome *Fasciculipora hustedti*, stating that Hustedt intended to name it *F. hennigi* according to labels at the PGL.

Hermann Brandes died on 8 December 1940 and was buried in Hoheneggelsen, where the *Heimatverein* (local history club) still takes care of the grave of their honorary citizen. Shortly before his death, he contacted the *Ilseder Hütte* (Iron works of Ilsede) to sell his collection. They first wanted to have a catalogue of the fossils, however, in order to decide whether to buy the collection. Dr Anton Schrammen (1869–1953), a dentist, who published several publications on sponges, offered to produce the requested lists if he could keep the sponges from the collection. Meanwhile, the mineralogist Hermann Rose (1883–1976), born in Hoheneggelsen and a colleague of Voigt, organized that the University of Hamburg should buy the collection to compensate their loss of 1943. In the autumn of 1948 the collection left for Hamburg, where it was lodged in the GSI (Rose 2010).

It took another twenty years before the Brandes Collection, especially the bryozoans, became the subjects of short-lived attention. Several publications by Ferdinand Flor, Gero

Hillmer and Ehrhard Voigt appeared in the years 1968 to 1973 (see list below). The collection, however, soon slid into obscurity again and a comprehensive work on the collection has never been undertaken. Voigt himself became occupied with different projects and collected and described material from new localities, for example the famous Rauen quarry in Mülheim an der Ruhr. This may explain why he probably never discovered that one of the types he had described as a young man was still among the specimens of the Brandes Collection.

Nowadays, most of the Brandes Collection is lodged at the University of Hamburg. Adolf von Koenen (1837–1915), who wrote a monograph on Jurassic ammonites from northern Germany in 1902, took some duplicates of the ammonites from the Brandes Collection to the University of Göttingen. The bryozoan and brachiopod collections were left together and went with most of the Voigt Collection to the Senckenberg Institute in 2005. The samples are lodged in the bryozoology section, sorted by locality and species in small boxes. Lists, probably indicating the specimens in the boxes are attached.

8. Literature describing bryozoans from the Brandes Collection

Flor, F.D. and Hillmer, G. 1970. Rhythmische Wachstumsvorgänge bei *Multicrescis tuberosa* (Roemer, 1839) [Bryoz. Cycl.]. *Paläontologische Zeitschrift* **44**, 171–181.

Hillmer, G. 1968a. Zum systematisch-taxionomischen Wert der Gonozooecien cyclostomer Bryozoen erläutert an ?*Diaperoecia polystoma* (Roemer, 1839). *Paläontologische Zeitschrift* **42**, 186–194.

Hillmer, G. 1968b. Artificial moulds for the studying of the internal structure of paleontological objects. *Atti della Società Italiana di Scienze Naturali e del Museo Civico di Storia Naturale de Milano* **108**, 37–42.

Hillmer, G. 1971. Bryozoen (Cyclostomata) aus dem Unter-Hauterive von Nordwestdeutschland. *Mitteilungen des Geologisch-Paläontologischen Instituts der Universität Hamburg* **40**, 5–106.

Hillmer, G., Voigt, E. and Scholz, J. 1997. Neue fungiforme Bryozoen-Genera (Cyclostomata) aus dem subhercynen Santonium und ihre Ökologie. *Courier Forschungsinstitut Senckenberg* **201**, 201–223.

Voigt, E. 1924c. Beiträge zur Kenntnis der Bryozoenfauna der subherzynen Kreidemulde. *Paläontologische Zeitschrift* **6**, 93–173.

Voigt, E. 1924d. Beiträge zur Kenntnis der Bryozoenfauna der subherzynen Kreidemulde. Zweiter Teil. Cheilostomata. *Paläontologische Zeitschrift* **6**, 191–247.

Voigt, E. 1930. Morphologische und stratigraphische Untersuchungen über die Bryozoenfauna der oberen Kreide. *Leopoldina: Berichte der Kaiserlich-Deutschen Akademie der Naturforscher zu Halle* **6**, 379–579.

Voigt, E. 1968. Eine fossile Art von *Arachnidium* (Bryozoa, Ctenostomata) in der Unteren Kreide Norddeutschlands. *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen* **132**, 87–96.

Voigt, E. 1973. Bryozoen aus dem Santon von Gehrden bei Hannover. I Cyclostomata.

Bericht der Naturhistorischen Gesellschaft Hannover **117**, 111–147.
Voigt, E. and Flor, F.D. 1970. Homöomorphien bei fossilen cyclostomen Bryozoen, dargestellt am Beispiel der Gattung *Spiropora* Lamouroux 1821. *Mitteilungen aus dem Geologisch-Paläontologischen Institut der Universität Hamburg* **39**, 7–96.

9. Acknowledgements

I thank Joachim Scholz from the Senckenberg Institute, Frankfurt for the idea on this paper and for Figure 1B, Brigitte Lotz for technical assistance, and Paul Taylor for valuable comments on the manuscript.

Many people have provided important information for this research, and I thank all of those who contributed to the project (in alphabetical order): Christina Archibald and Harald Braem from the Stadtarchiv (city archive) Hildesheim, Gabriele Binder from the Evangelical-Lutheran Church St Martin in Hoheneggelsen, Angela Ehling from the BGR Berlin, Annette Haupt from the commune Söhlde, Armgard Heine from the Heimatbund Mölme, Gero Hillmer from Hamburg, Manfred Ostwald from the Heimatverein Hoheneggelsen (also for Figure 13), and Renate Taugs from the Geologisches Landesamt Hamburg (also for Figures 4 and 5). For providing the new image of *M. brandesi*, I thank Kei Matsuyama from the Senckenberg am Meer in Wilhelmshaven, and for the images of the PGL originals, I thank Matthias Heldt and Thorsten Ernst from the BGR Berlin. I especially like to thank Wolfgang Voigt from the Deutsches Architekturmuseum, Frankfurt for an enjoyable interview about his father and for Figure 6.

The financial support of the Deutsche Forschungsgemeinschaft (Project SCHO 581/12-1 "Enhancing documentation and digitalization of the Bryozoa collection donated by Professor Voigt (1905-2004) to the Senckenberg Research Institute, Frankfurt am Main, Germany") is gratefully acknowledged.

References

Bassler, R.S. 1935. Bryozoa (Generum et Genotyporum Index et Bibliographia.). *In* W. Quenstedt (ed.) *Fossilium catalogus I: Animalia. Part 67*. W. Junk, Den Haag, 229 pp.
Beck, G. 1920. Tektonische und paläogeographische Untersuchungen im Gebiet zwischen Hildesheim und Braunschweig. *Abhandlungen der Preußischen Geologischen Landesanstalt, Neue Folge* **85**, 1–126.
Berthelsen, O. 1962. Cheilostome bryozoa in the Danian deposits of East Denmark. *Danmarks Geologiske Undersøgelse* **83**, 1–290.
de Blainville, H.M.D. 1830. Zoophytes. *In* G.F. Cuvier (ed.) *Dictionnaire des sciences naturelles, dans lequel on traite méthodiquement des différens êtres de la nature, considérés soit en eux-mêmes, d'après l'état actuel de nos connoissances, soit relativement à l'utilité qu'en peuvent retirer la médecine, l'agriculture, le commerce et les artes. Suivi d'une biographie des plus célèbres naturalistes ... Par plusieurs*

professeurs du Jardin du roi, et des principales écoles de Paris. F.-G. Levrault, Strasbourg, 535–546.

Brandes, H. 1913. Über einen verloren gegangenen Standort von Salzpflanzen. *Jahresbericht des Niedersächsischen Botanischen Vereins* **4**, 17–29.

Brandes, H. 1914. Der obere Jura von Hoheneggelsen. *In* H. Salfeld, Die Gliederung des oberen Jura in Nordwesteuropa von den Schichten mit *Perisphinctes Martelli* Oppel an aufwärts auf Grund von Ammoniten. Mit vergleichend-stratigraphischen Bemerkungen über den oberen Jura Suddeutschlands, der Schweiz, Mittel- und Sudfrankreichs, alpiner Gebiete, Pommerns und Rußlands. *Neues Jahrbuch für Mineralogie, Geologie und Paläontologie, Beilage-Band* **37**, 164–170.

Brandes, H. 1934. *Lose Blätter zur Geschichte des Hildesheimer Bauernstandes*. Westermann, Braunschweig, 228 pp.

Brandes, W. and Brandes, H. 1884. Culturversuche mit Zuckerrüben. *Journal für Landwirthschaft* **23**, 423–494.

Brydone, R.M. 1906. Further notes on the stratigraphy and fauna of the Trimmingham Chalk. *Geological Magazine* (Decade V) **9**, 13–22, 72–78, 124–131 and 289–300.

Brydone, R.M. 1912. Notes on new or imperfectly known Chalk Polyzoa. *Geological Magazine* (Decade V) **3**, 7–8, 145–7, 294–6 and 433–5.

Dana, J.D. 1846. Structure and classification of zoophytes. *United States Exploring Expedition 1838–1842*, **7**, 1–740; Washington, D.C.

Fenner, J. 2006. *Makro- und Megafauna – Originale Geowissenschaftliche Sammlungen der BGR Berlin*. BGR Berlin, 104 pp.; Berlin. [URL: http://www.bgr.bund.de/DE/Themen/Sammlungen-Grundlagen/GG_Sammlungen/Orig_recherche/b_makro_megafauna_originale_recherche.pdf?__blob=publicationFile&v=2]

Guha, A.K. 2005. Prof. Dr. Ehrhard Voigt – The legendary palaeontologist. *Journal of the Palaeontological Society of India* **50**, 183–185.

von Hagenow, F. 1839. Monographie der Rügen'schen Kreideversteinerungen, I. Abtheilung: Phytolithen und Polyparien. *Neues Jahrbuch für Mineralogie, Geognosie, Geologie und Petrefaktenkunde* **7**, 252–296.

Hillmer, G. 2006. Ehrhard Voigt 28 July 1905 – 22 November 2004. *Courier Forschungsinstitut Senckenberg* **257**, 1–6.

Jullien, J. 1882. Note sur une nouvelle division des bryozoaires cheilostomiens. *Bulletin de la Société zoologique de France* **6**, 271–285.

Jürgensen, T. 1971. *Tornipora*, a new cheilostome bryozoan from the Maastrichtian and Danian of Denmark. *Bulletin of the Geological Society of Denmark* **20**, 390–396.

Kade, G. 1852. Die losen Versteinerungen des Schanzenberges bei Meseritz. *Programm des Königlichen Gymnasiums zu Meseritz* **Jg. 1852**, 1–35.

von Könen, A. 1902. *Die Ammonitiden des norddeutschen Neocom (Valanginien, Hauterivien, Barrêmien und Aptien)*. Abhandlungen der Königlich Preussischen Geologischen Landesanstalt und Bergakademie **24**, Berlin, 451 pp.

Marsson, T.F. 1887. Die Bryozoen der weißen Schreibkreide der Insel Rügen. *Palaeontologische Abhandlungen* **4**, 1–112.

d'Orbigny, A. 1846. *Voyage dans l'Amérique méridionale. Zoophytes*. F.-G. Levrault, Strasbourg, 28 pp.

Reuss, A.E. 1872. Die Bryozoen und Foraminiferen des unteren Pläners. *In* H.B. Geinitz (ed.): Das Elbthalgebirge in Sachsen. I. Theil: Der untere Quader. *Palaeontographica* **20**, 95–144.

Roemer, F.A. 1841. *Die Versteinerungen des norddeutschen Kreidegebirges*. Hahn'sche Hofbuchhandlung, Hannover, 145 pp.

Rose, H. 2010. Ereignisse der letzten 100 Jahre in Mölme. A. Hermann Brandes – Laien-Paläontologe und Heimatforscher. *In* H. Schünemann and K. Schünemann (eds): *Von Mulnehêm bis Mölme: Zeitgeschichte einer Siedlung im Hildesheimer Land*. Köhler, Harsum, pp. 234–237.

Söding, A. 1968, October 26. Persönlichkeiten der Heimat. (28. Folge) Hermann Brandes, Geologe und Volkskundler, Hoheneggelsen (1855–1940). *Hildesheimer Allgemeine Zeitung*, Hildesheim, p. 79.

Toots, H. 1952a. Bryozoen des estnischen Kukersits. *Mitteilungen aus dem Geologischen Staatsinstitut in Hamburg* **21**, 113–137.

Toots, H. 1952b. Epökie von Algen (*Microweedia* n. g.) auf Bryozoen des estnischen Kuckersits. *Mitteilungen aus dem Geologischen Staatsinstitut in Hamburg* **21**, 138–141.

Voigt, E. 1926. Berichtigung. *Paläontologische Zeitschrift* **8**, 144.

Voigt, E. 1957. Bryozoen aus dem Kreidetuff von St. Symphorien bei Ciply (Ob. Maastrichtien). *Bulletin de l'Institut royal des Sciences naturelles de Belgique* **33**, 1–48.

Voigt, E. 1979. Vorkommen, Geschichte und Stand der Erforschung der Bryozoen des Kreidesystems in Deutschland und benachbarten Gebieten. *Aspekte der Kreide Europas. IUGS Series A* **6**, 171–210.

Voigt, E. 1989. Beitrag zur Bryozoen-Fauna des sächsischen Cenomaniums. Revision von A. E. Reuss' "Die Bryozoen des unteren Quaders" in H. B. Geinitz' "Das Elbthalgebirge in Sachsen" (1872). Teil I: Cheilostomata. *Abhandlungen des Staatlichen Museums für Mineralogie und Geologie zu Dresden* **36**, 8–87.

Wüstenhagen, K., Ehlers, J., Kausch, F. and Taugs, R. 1998. *Geologisches Landesamt Hamburg – von seiner Geschichte und Entwicklung*. Umweltbehörde Hamburg, Geologisches Landesamt, Hamburg, 22 pp.

Notes

1. The species is mentioned as *Floridina variabilis*, Voigt in Voigt (1923) because Voigt also described it in Voigt 1924b, where it is mentioned as new species. The first issue of the sixth volume of *Paläontologische Zeitschrift* including the papers Voigt 1924a, b was scheduled to appear in 1923 before Voigt's publication on the Danish material, but the issue was delayed until January 1924.
2. Voigt already expressed doubts about the affinity of *Vinella cretacea* to the Ctenostomata the

same year (Voigt 1924d) and regarded the species as possible tangled roots of *Alcyonaria* Dana, 1846.

3. Although Voigt hoped to provide images of the species in a later work, this never happened. The collection of Ehrhard Voigt, however, contains several specimens of *D. cava*, which can be used for a re-examination of the species.
4. By using the German word *Baltikum* ("Baltic"), Voigt was not referring to the states Estonia, Latvia, and Lithuania, which would be the common use of the word, and also not to the whole region around the Baltic Sea, but to Denmark and southern Sweden only.
5. Bassler (1935) designated *Cellopora elliptica* von Hagenow, 1839 as the type species of the genus *Marginaria* Roemer, 1841. Almost sixty years after Voigt established the group of *M. elliptica* in his monograph, he assigned *M. pellicula* and *M. hannoverana* to the genus *Marginaria* (Voigt 1989).
6. Note that the use of parentheses between the generic name and the specific name is now used according to the International Code of Zoological Nomenclature for names of subgenera.
7. Voigt (1979: p. 188) writes: "*Dadurch konnte der Verlust der ersten Sammlung Voigt während des Zweiten Weltkrieges, [...], weitgehend ausgeglichen werden, obwohl die uber 600 verlorenen Typen zur Cheilostomen-Monographie (Voigt 1930) unersetzlich sind.*" ("Thus [the purchase of the Brandes Collection], the loss of the first Voigt Collection during World War II [...] could be largely compensated, although the loss of over 600 types of the Cheilostomata-monograph (Voigt 1930) is irreparable.")
8. The whole collection consists of over 300,000 specimens. The target is to digitize ~40,000 of these specimens, including the *c.* 3,000 types and originals and over 35,000 specimens in Franke cells that have been regarded as very important by Voigt himself.
9. The description to Pl. VI, Fig. 12 uses the name "*Conopeum varians* n. sp." for this species. This has later been withdrawn by Voigt (1926).
10. The 13 species and the material for these species of the PGL that has been imaged by Voigt are as follows (an asterisk indicates that Voigt provided additional images of this species from his own collection in the original publication; for the species of the genus *Fasciculipora* d'Orbigny, 1846, the additional images are drawings): *Conopeum congestum* Voigt , 1924d (Pl. VI, Fig. 12), *Diplosolen germanicus* Voigt, 1924c (Pl. IV, Fig. 21)*, *Elea nodulifera* Voigt, 1924c (Pl. IV, Fig. 9)*, *Escharicellaria polymorpha* Voigt, 1924d (Pl. VIII, Fig. 16)*, *Fasciculipora constricta* Voigt, 1924c (Pl. III, Figs. 9–10)*, *Fasciculipora granulosa* Voigt, 1924c (Pl. III, Fig. 7)*, *Fasciculipora hustedti* Voigt, 1924c (Pl. III, Figs. 3–5)*, *Lichenopora bueltenensis* Voigt, 1924c (Pl. V, Figs. 14–16), *Ogiva promonturiorum* Voigt , 1924d (Pl. VII, Figs. 23–24)*, *Onychocella lamellosa* Voigt, 1924d (Pl. VII, Fig. 7)*, *Onychocella schroederi* Voigt, 1924d (Pl. VII, Figs. 3–5), *Spiropora ingens* Voigt, 1924c (Pl. IV, Fig. 17)*, and *Vinella cretacea* Voigt, 1924a (Fig. 1).
11. In (1889): 2. Protokoll der Dezember-Sitzung. *Zeitschrift der Deutschen Geologischen Gesellschaft*, **41**, 784.
12. Voigt (1924c). On p. 94 he writes: "Zu spät leider ist mir die umfassende Sammlung des Herrn H. Brandes in Hoheneggelsen (Prov. Hannover) bekannt geworden, welche über ein bedeutendes Bryozoenmaterial des nordwestdeutschen Kreidegebietes verfügt, [...]" ("Too late, I became acquainted with the comprehensive collection of Mr. H. Brandes from Hoheneggelsen (Prov. Hannover), which contains important bryozoan material from the northwestern Cretaceous area of Germany, [...]")

13. 9 short summaries of works on bryozoans, especially by Ferdinand Canu, are provided by Hustedt in the journal *Neues Jahrbuch für Mineralogie, Geologie und Paläontologie*, Jahrgang 1905, II. Band on pp. 141–5, 485f. However, the first name of Hustedt is not mentioned.

The earliest colour image of Bryozoa

Xenia Ostrovskaya[1] and Andrew Ostrovsky[2,3]

[1]*Department of Grafics and Printmaking, Faculty of Fine Art, University of Applied Arts, Oskar Kokoschka-Platz 2, 1010-Vienna, Austria*

[2]*Department of Palaeontology, Faculty of Earth Sciences, Geography and Astronomy, Geozentrum, University of Vienna, Althanstrasse 14, A-1090, Vienna, Austria*

[3]*Department of Invertebrate Zoology, Faculty of Biology & Soil Science, St. Petersburg State University, Universitetskaja nab. 7/9, 199034, St. Petersburg, Russia*

1. Introduction: early nature illustration

The passion of biologists for their favorite groups of living organisms is well-known, and this feeling often co-exists with a deep interest in the history of science. It is fascinating to discover which is the first description, or first ever drawing, of a certain animal or plant? As researchers examine early documents and artifacts, more hitherto unknown discoveries are being uncovered.

Naturally, the large vertebrates were the major heroes of the ancient artists, who painted them on the walls of caves. The first invertebrate ever pictured is thought to be a honey bee swarm, whose image adorns a Spanish cave, and dates to 15,000 BC.

Many invertebrates were illustrated by the ancients: scorpions on the Sumerian memorial stellas, dragon-flies and scarab-beetles on the Egyptian pyramids' walls, crabs, octopuses and, again, honey bees on the Ancient Greek coins and vases. This list can be continued. Among dragons and other monsters, invertebrates appeared on the pages of the Medieval bestiaries, and the development of scientific books came next.

2. Early illustrations of bryozoans

Modern-day bryozoologists are fortunately lucky since a reasonable volume of information is known about their pioneers. When Guillaume Rondelet (1507-1566), Professor of Medicine at the University of Montpellier published his famous *Universae*

GVLIELMI
RONDELETII
DOCTORIS MEDICI,
ET MEDICINAE IN SCHOLA
MONSPELIENSI PRO-
FESSORIS RE-
GII

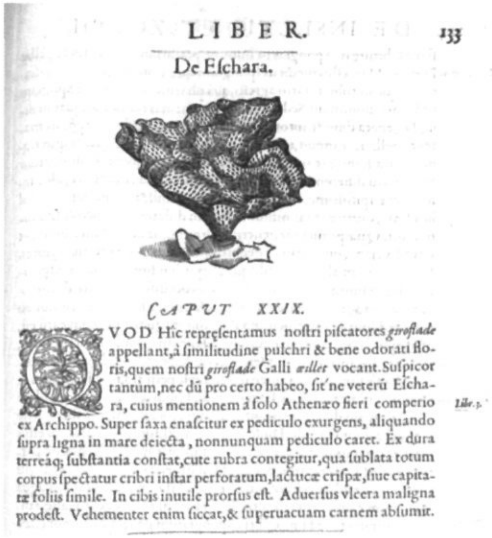
Vniuersæ aquatilium Hiſtoriæ pars altera,
cum veris ipſorum Imaginibus.

His acceſſerunt Indices neceſſarij.

LVGDVNI,
Apud Matthiam Bonhomme.

M. D. L V.

Cum Priuilegio Regis ad duodecim annos.



LIBER. 133

De Eſchara.

CAPVT XXIX.

QVOD Hic repræſentamus noſtri piſcatores *giroflade* appellant, à ſimilitudine pulchri & bene odorati floris, quem noſtri *giroflade* Galli *œillet* vocant. Suſpicor tantùm, nec dũ pro certo habeo, ſit'ne veterũ Eſchara, cuius mentionem à ſolo Athenæo fieri comperio ex Archippo. Super ſaxa enaſcitur ex pediculo exurgens, aliquando ſupra ligna in mare deiecta, nonnunquam pediculo caret. Ex dura terreâq; ſubſtantia conſtat, cute rubra contegitur, qua ſublata totum corpus ſpectatur cribri inſtar perforatum, lactucæ criſpæ, ſiue capitatæ foliis ſimile. In cibis inutile prorſus eſt. Aduerſus vlcera maligna prodeſt. Vehementer enim ſiccat, & ſuperuacuam carnem abſumit. Lib. 3.

Figure 1 (left). Title page of Rondelet (1555).
Figure 2. Woodcut illustration of the cheilostome bryozoan Reteporella *sp. from Rondelet (1555, p. 133)*

aquatilium Historiae pars altera, cum veris ipsorum Imaginibus (*Illustrated Natural History of Aquatic Animals*) in 1555 (Figure 1), he included a woodcut image of the cheilostome bryozoan *Reteporella* sp. (Figure 2). It is in the section "Insectis et Zoophytis" being accompanied by a short description on page 133. The 2nd (French) edition of this wonderful book was published in 1558 as *L'Histoire entiere des poissons* (*Complete History of Fishes*) in which the corresponding description of *Reteporella* was given on page 93 (kindly translated by J.-G. Harmelin):

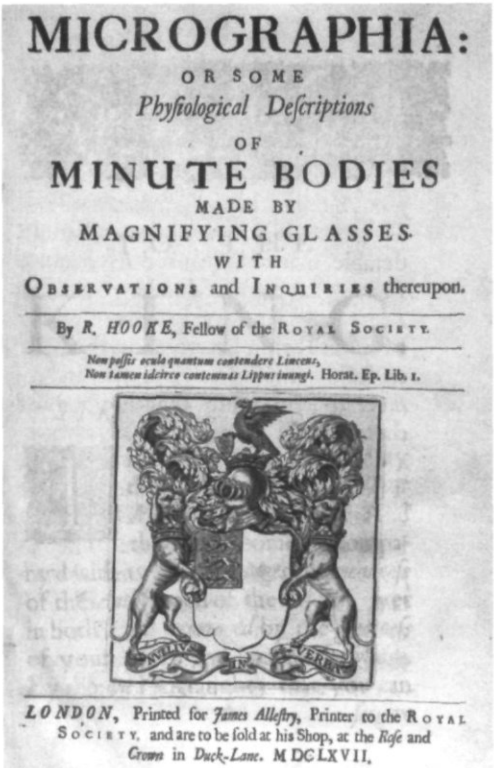
> What is represented, our fishermen name it Giroflade de mer, from its similitude with the beautiful and good smelling flower that we name in our language Giroflade, in French Carnation. I think (but I am not sure) that it is Eschara, named from Archippe in Athena. It grows on rocks, having a tail, sometimes on woods floating at sea, sometimes without a tail. It is made of a hard terrestrial substance, and covered with a red skin which, when removed, it can be seen that this body is pierced as a sieve and contorted as a lettuce.

What is clear from this piece is that (Mediterranean) bryozoans were known since the Ancient Greek times under the name Escharas. The bowl-like shape of some Phidoloporidae resembled the portable hearth for burnt sacrifice that stood on graves in Ancient Greece and these were called Eschara. The same name was used for the sacrificial brazier-like stone altars in Roman times (P. Bock, personal communication, 2013).

What should also be stressed is that Rondelet introduced numerous Latin names for animals (both generic and specific), later used by Linnaeus, and often employed binary nomenclature (for example, distinguishing *Pinna magna* and *Pinna parua*) (two centuries before Linnaeus). Unfortunately, he did not employ such a nomenclatural scheme for the bryozoan described and illustrated.

In 1599 images of three more Mediterranean bryozoans under the names *Retepora, Frondipora* (both with a subtitle Eschara marina) (p, 722) and Poro Cervino (p. 721) were published by Ferrante Imperato (1550-1609), the Naples naturalist, in his multivolume work *Historia Naturale* (Figure 3). The 2nd edition appeared in 1672. Creator of one of the first "Museo" or Cabinet of curiosities in Europe, Imperato published nine volumes of his *Historia* on alchemy and 19 more on mining, minerals, "marine productions" and

Figure 3. Top-left: Title page of Imperato (1599) (top-left) with his illustrations of Poro cervino (bottom-left), Retepora *(top-right) and* Frondipora *(bottom-right).*



MICROGRAPHIA:
OR SOME
Physiological Descriptions
OF
MINUTE BODIES
MADE BY
MAGNIFYING GLASSES.
WITH
OBSERVATIONS and INQUIRIES thereupon.

By *R. HOOKE*, Fellow of the ROYAL SOCIETY.

Non possis oculo quantum contendere Linceus,
Non tamen idcirco contemnas Lippus inungi. Horat. Ep. Lib. 1.

LONDON, Printed for *James Allestry*, Printer to the ROYAL SOCIETY, and are to be sold at his Shop, at the *Rose* and *Crown* in *Duck-Lane*. M DC LXVII.

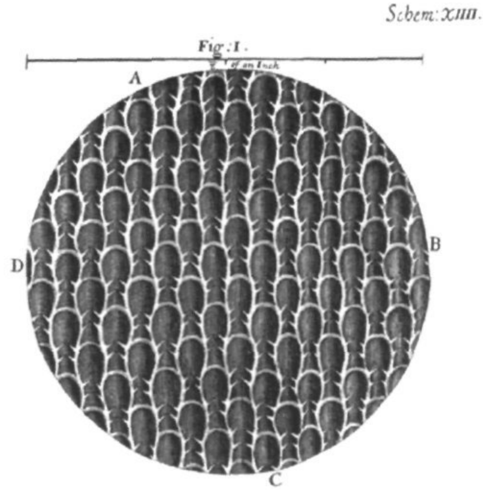


Figure 4. Title page of Hooke (1665) (left) with his illustration of the microscopic structure of the bryozoan Flustra foliacea *(above).*

MÉMOIRES
POUR L'HISTOIRE
DES POLYPES.

PREMIER MÉMOIRE.

Où l'on décrit les Polypes, leur Forme, leurs Mouvemens, & une partie de ce qu'on a pu découvrir sur leur Structure.

DES Faits aussi singuliers, aussi contraires aux idées généralement reçues sur la nature des Animaux, que le sont ceux que m'a fait voir l'Insecte dont je vais donner l'Histoire, demandent, pour être admis, les preuves les plus évidentes. Il est arrivé plus d'une fois, que la précipitation, & l'amour

A du

Figure 5. Title page of Trembley (1744) (right) with his illustration of the structure of the freshwater bryozoan Lophopus crystallinus *(above).*

plants. Bryozoan images and short notes about them appeared in the 27th volume together with corals, sponges and algae. The quality of the images is very high, and one is able to recognize *Reteporella*, *Frondipora verrucosa* and *Adeonella calveti* in them. It also seems that *Frondipora* may be the oldest currently accepted bryozoan name.

Other early depictions of Bryozoa are the schematic image of *Flustra foliacea* that appeared in 1665 in the famous *Micrographia* of Robert Hooke (Figure 4), the illustration by Antoni van Leeuwenhoek (1694) of what was later recognized as *Conopeum reticulum* (Cadée 2002), and very detailed picture of the living colony of *Lophopus crystallinus* by Abraham Trembley (1744) (Figure 5) (Cadée 2002). Noticeably, the depiction of *Lophopus* is the first ever image of the freshwater bryozoan and, also, the first ever image of the living feeding bryozoan.

All these images were black and white engravings, and it was John Ellis whose fascinating depictions of Corallines (Ellis 1755; French and Dutch editions 1756; German edition 1767) were thought to be the first to be coloured (using a watercolour wash on lithographs) (Figure 6). It has recently come to light, however, that an earlier artist, working two centuries before Ellis, had executed colour images of bryozoans.

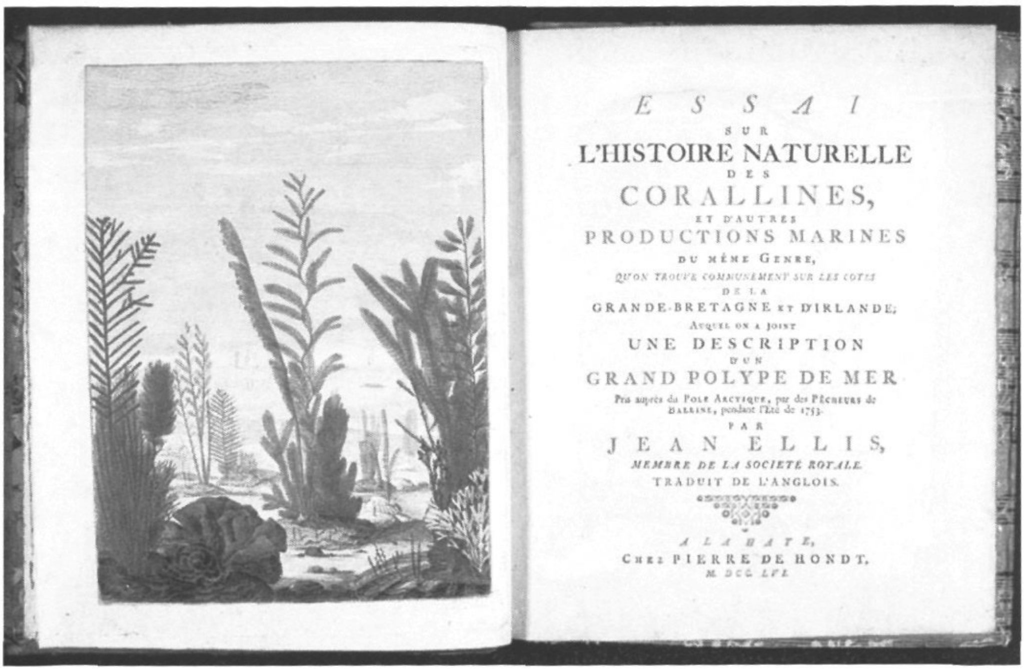


Figure 6. Title page of Ellis (1756) showing the hand-coloured frontispiece illustrating various bryozoans and hydroids

3. Giorgio Liberale's paintings of Ferdinand II's natural history collection

Animalistic painting has always been one of the chief interests of the authors of this paper, so a visit to an exhibition devoted to it that happened to be mounted in Vienna was, naturally, visited. Moreover, "Cabinets of curiosities" are definitely a recent focus for the contemporary art community, as highlighted at the last Biennale in Venice, "The encyclopedic palace". That is where scientific and artistic approaches meet nowadays. The exhibition *Fish, Birds, and Reptiles - Masterpieces from the Imperial Collections* took place in the Stateroom of the Austrian National Library, and a well-produced catalogue (Weiler 2011) accompanied it. We decided to buy a catalogue as a Christmas present for one of us. At home, leafing through it, we unexpectedly discovered an image of Bryozoa, coloured, like all the other images in the book. The story behind is as follows.

The Italian artist Giorgio Liberale (1527-ca 1580) from Udine, being at the court of Ferdinand II, Archduke of Austria, was asked to produce an album of animalistic paintings. The Archduke had a University education and patronized the arts and science. He also had assembled a large collection of curiosities, with a special emphasis on paintings of people with interesting deformities—this collection remains as the Chamber of Art and Curiosities at the Ambras Castle in Tyrol, near Innsbruck.

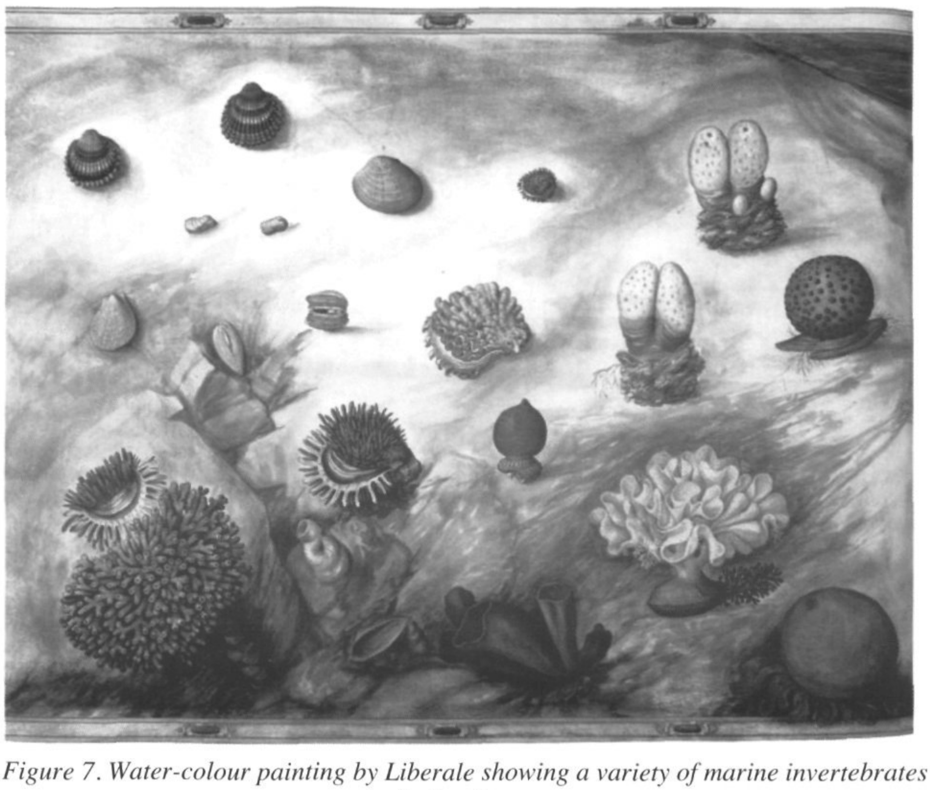


Figure 7. Water-colour painting by Liberale showing a variety of marine invertebrates including Bryozoa

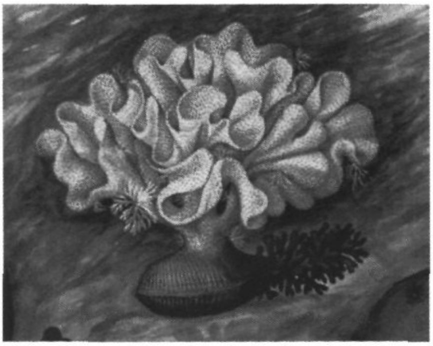


Figure 8. Detail of Figure 7 showing reteporellid colony with small white crisiids attached.

Liberale was already experienced in such work, having already sketched in pencil more than a thousand images of plants that were used by Meyerpeck for the xylographic (woodcut) illustrations for the translation of Dioscoride's famous 1st-century herbal, *Materia medica*. This important volume was translated into Italian and considerably added to by Pier Andrea Mattioli who was a personal physician of the Archduke.

In the course of several years' work for Ferdinand II, 100 parchment sheets (64 x 86 cm) with wonderful watercolour pictures on both sides were prepared. There are more than 1100 images. While many land insects were depicted, most animals were aquatic, including a sperm whale, a dolphin, a seal (eating grapes), a crocodile (naturally, with human bones nearby) and various fishes. Fish and marine invertebrates were from the Adriatic Sea whose coastline (being depicted in the background) and landscapes are easily recognizable.

The quality of the images varies, but generally it is rather high. It was clearly an attempt to combine an artistic and documentary approach but this was not always successful. Most invertebrates, however, were painted very well (Figure 7). It is especially interesting that Liberale pictured not only large invertebrates like crabs, lobsters, cephalopods, jelly-fishes and large gastropod shells, but virtually everything including caterpillars, millipeds, moths and their pupae, as well as tube-worms, corals, ascdians, sponges and bryozoans.

Turning pages, we have found our old friend – Rondelet's Eschara or Imperato's Retepora. The exact period during which the water colour images were painted can be accurately determined. It is mentioned in the catalogue that Liberale started his work in 1562 (Weiler 2011). Another indicator is the 20 May, 1569 the date Liberale's parchments were mentioned in the inventory of the Archduke library. Thus, his is the earliest image of living bryozoans, and is significant in that it shows their original colouration and that they were pictured close to the sea shore. Liberale also figured three tiny crisiid colonies attached to the reteporellid colony (Figure 8). Thus, he was also the first who produced an image of a cyclostome bryozoan. Other invertebrates depicted on the same sheet also have natural coloration, suggesting that all of them had been recently collected. These colour images post-date, by only ten years Rondelet's publication of the Eschara woodcut image.

4. Conclusion

The recently restored collection of Liberale's paintings is kept in Tyrol. The large exhibition of 2011-2012 in Vienna was not able to exhibit all the images, but thanks to Christina Weiler, who prepared a wonderful illustrated catalogue that contains many, but not all of the original paintings, such that the first colour bryozoan images, were published. Ultimately we need to be grateful to both Giorgio Liberale and Ferdinand II, whose curiosity and love of nature resulted in a wonderful collection of paintings that included an image of our favourite animals.

References

Cadée, G. 2002. Early bryozoan studies in the Netherlands. *In* P.N. Wyse Jackson and M.E. Spencer Jones (eds), *Annals of Bryozoology*. International Bryozoology Association, Dublin, pp. 31–43.

Ellis, J. 1755. *An essay towards a natural history of the corallines, and other marine productions of the like kind, commonly found on the coasts of Great Britain and Ireland*. A. Millar, London.

Ellis, J. 1756. *Essai sur l'histoire naturelle des corallines, et d'autres productions marines du même genre, qu'on trouve communément sur les cotes de la Grande-Bretagne et d'Irlande*. La Haye, Pierre de Hondt.

Hooke, R. 1665. *Micrographia: or, Some physiological descriptions of minute bodies made by magnifying glasses. With observations and enquiries thereupon* London, J. Martyn and J. Allestry.

Imperato, F. 1599. *Dell'Historia Naturale di Ferrante Imperato Napolitano. Libri XXVIII. Nella Quale Ordinatamente si Tratta della Diversa Condition di Miniere et Pietre. Con alcune historie di Plante, & Animali; sin'hora non date in luce. Con Privilegio*. Costantino Vitale nella Stamperia a Porta Reale, Napoli.

Imperato, F. 1672. *Historia naturale nella quale ordinatamente si tratta della diversa condition di minere, pietre pretiose, & altre curiosità. Con varie historie di piante, animali, sin'hora non date in luce*. Venice, Presso Combi & la Noù.

Rondelet, G. 1555. *Universæ aquatilium historiæ pars altera, cum veris ipsorum imaginibus*. Lyon, Mathias Bonhomme.

Rondelet, G. 1558. *L'histoire entiere des poissons, Composée premierement en Latin par maistre Guilaume Rondelet Docteur regent en Medecine de l'université de Mompelier. Maintenant traduites en François sans auoir rien omis estant necessaire à l'intelligence de l'icelle. Auec leur poutraits au naïf*. (2 volumes). Lyon, Mace Bonhomme.

Trembley, A. 1744. *Mémoires pour servir à l'histoire d'un genre de polypes d'eau douce: à bras en forme de cornes*. Leiden, Jean et Herman Verbeek

Weiler, C. 2011. *Von Fischen, Vögeln und Reptilien - Meisterwerke aus den kaiserlichen Sammlungen*. Vienna, Kremayr and Scheriau.

Benjamin Harrison Grave: American Marine Invertebrate Zoologist

Mary A.B. Sears and Robert M. Woollacott
Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts, USA

1. Introduction

Benjamin Harrison Grave (1878-1949) (Figure 1) was an American zoologist and educator. A native of Indiana, he left the family farm for graduate study in zoology at Johns Hopkins University and went on to a distinguished career in teaching and research. He published 23 articles on marine invertebrates that included observations on 20 species ranging over 7 phyla. These studies focused primarily on anatomy, gamete and fertilization biology, embryology, and general aspects of life history. He is best known for his articles on the marine invertebrates in the vicinity of Woods Hole, Massachusetts, and Beaufort, North Carolina. His teaching career (1904-1942) encompassed a broad range of biological topics, in the laboratory and in the field, primarily addressed to undergraduates. He was a life-long Quaker known for his passion for justice and love of nature.

2. Origins and Early Years

Benjamin Harrison Grave was born on December 5, 1878, in Monrovia, Indiana, the second son of Thomas Clarkson Grave (1840-1924) and Anna Hubbard Grave (1848-1908).[1] Benjamin Grave's life came to a close in January 1949 only 40 km from Monrovia in Indianapolis, Indiana, from complications following a fall. Though his career and

Figure 1. B.H. Grave at the microscope, 1926 (Courtesy of the Marine Biological Laboratory Archives, http://hpsrepository.asu.edu/handle/10776/2870)

education would lead him across the United States, the greater part of his years were spent within 200 km of Monrovia.

Grave was a "birth-right Quaker", meaning that he was born into a family who belonged to the Society of Friends, commonly known as the Quakers. Benjamin's father was descended from Thomas Grave, an English Quaker who emigrated and settled in New Castle County, Delaware, in 1691.[2] Both the Grave and Hubbard families moved from Pennsylvania to Indiana in the early nineteenth century, part of a "great migration" of Quakers to what is now the American mid-west.[3]

Benjamin's great-grandparents, Enos (ca. 1771-1842) and Elizabeth Jones Grave (1775-ca. 1860), reached Indiana in 1816, settling in Wayne County, Indiana, north of Richmond, and joining the Whitewater Monthly Meeting.[4] Benjamin's grandfather, David Isaac Grave (1803-1864), was born in Brownsville, Pennsylvania. After moving west with his family, he became a coverlet weaver, inventing his own jacquard loom.[5] Some of his work survives in the collection of the Art Institute of Chicago.[6] After both David Isaac and his wife, Elizabeth Hartley Grave, were dismissed from the Whitewater Monthly Meeting for nonconformity,[7] they and their children moved to Monrovia, Indiana, in 1850. David's son, Thomas Clarkson Grave, remained in Monrovia as a farmer, married Anna Hubbard in 1868, and raised his family there.[8]

Monrovia, a farming community in central Indiana, began as an enclave of Friends, and the West Union Friends Meeting, established in 1832, was the center of the Monrovia community. The Meetinghouse was the town's first religious building and school. Both of Benjamin Grave's parents, and all four of his grandparents, are buried in the West Union Cemetery adjacent to the meetinghouse. West Union Friends Meeting is still active; it is affiliated with the Friends United Meeting, which is headquartered in Richmond,

Figure 2. Joseph Moore (Courtesy of Earlham College Archives)

Indiana.[9]

Benjamin Grave left Monrovia to attend Friends Central Academy in Plainfield, Indiana, from 1895-1898. He then earned a B.S. degree in Biology from Earlham College in Richmond, Indiana, a Quaker-affiliated college. It is possible, perhaps likely, that he did not interact with non-Quakers until he had graduated from college.

Benjamin Harrison Grave grew up with three brothers: Caswell (1870-1944), Thomas Hubbard (1880-1961), and Everette Floyd, known as Floyd (1885-1951). All were well educated for their day, completing B.S. degrees: Caswell graduated from Earlham College in 1895, Benjamin in 1903, and Thomas in 1906; Floyd graduated from Carleton College in Northfield, Minnesota, in 1908. Caswell and Benjamin went on to complete Ph.D.'s and pursue careers as invertebrate zoologists, Floyd became a medical doctor. Only Thomas stayed in agriculture, becoming a rancher in Gresham, Oregon.[10]

3. College and Graduate Study

Grave was a student at Earlham College, Richmond, Indiana, for five years, graduating with a B.S. degree in 1903. He followed a broad liberal arts program with in-depth study in biology, and other courses including geology, physics, chemistry, history, and French and German languages.[11] His scientific influences at Earlham were Professor David Worth Dennis (1849-1916),[12] who taught biology and chemistry, and Professor Joseph Moore (1832-1905) (Figure 2),[13] who taught biology and geology. Grave was heavily involved with college athletics, competing on behalf of Earlham on their track, baseball, and football teams (Figure 3). He held the Indiana state record for the quarter mile for three years.[14] During his student years in Richmond, Grave met his future wife Lucile H. Moore (1879-1968), Earlham class of 1902 and daughter of Joseph Moore. Benjamin's younger brother Thomas was also on campus then, graduating with the class of 1906.

After graduating from Earlham College in 1903, Grave started graduate study in biology at Johns Hopkins University, completing his Ph.D. there in 1910. It was anything

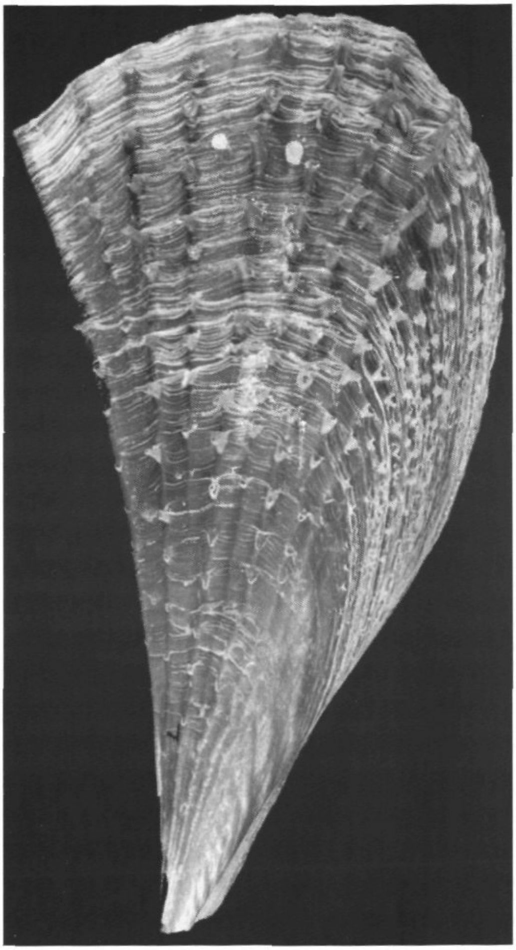
Figure 3. B.H. Grave, student athlete (Courtesy of Earlham College Archives)

but a direct path from start to finish, however. In his initial application to Johns Hopkins, he stated that he would like to study both botany and zoology.[15] After the 1903-1904 academic year, he spent the summer at the Biological Laboratory at Cold Spring Harbor, New York, which was then affiliated with the Brooklyn Institute of Arts and Sciences. Grave studied both comparative anatomy (principally of invertebrates) there, under Henry Sherring Pratt, and botany with Forrest Shreve of Johns Hopkins.[16] In the fall of 1904, instead of returning to Johns Hopkins, Grave left for Carleton College in Northfield, Minnesota, where his brother Floyd was a student. During the summer of 1905, he studied at the University of Chicago, enrolling in four courses: three in botany and one in biblical history (The History of the Priest System, offered by the Department of Semitic Languages and Literatures). He earned credit for his work in Elementary Plant Physiology and General Morphology of Spermatophytes, but did not complete Methods in Plant Histology.[17] For Grave, the highlight of the summer was studying with Professor John Merle Coulter, his instructor in the spermatophytes course.[18]

Grave completed a Master of Science degree in Botany at Carleton in 1906, with a thesis on *Lilium tigrinum*.[19] In the spring of 1906, he reapplied to continue his studies at Johns Hopkins and was readmitted.[20] Having resumed his studies at Johns Hopkins, he also was a member of the track team there in the 1906-07 academic year.[21]

Grave's dissertation[22] was an anatomical study of the bivalve mollusk, *Atrina rigida* (Lightfoot, 1786), a member of the Pinnidae (Figure 4). According to Grave, the species ranged in distribution in the western Atlantic from northern regions of South America to Cape Hatteras in North Carolina. The largest specimen found by Grave was 14 x 9 x 3 inches. Individuals live in shallow water and are occasionally exposed at low tide. They burrow in the soft substrate, anterior end pointed downward, and attach to solid objects using an extensive byssus apparatus. *Atrina rigida* is a species that was of economic consequence in the nineteenth and early twentieth centuries. It has a large posterior adductor muscle that is edible. Grave estimated that about 20% of specimens he examined contained black pearls; when present, Grave found as many as 10 pearls in a single

Figure 4. Left valve of Atrina rigida *(MCZ Mollusk Collection Lot 216963)*



specimen. Finally, the byssus, being well developed, was used in manufacturing articles such as shawls, waistcoats, gloves, caps, and purses.

Its common abundance, lack of prior study, and economic utility provided the rationale for a baseline study of the anatomy of this species and made for an excellent dissertation subject in Grave's era. Grave credits William Keith Brooks (1848-1908) (Figure 5) with the suggestion he pursue this topic. Brooks was professor of biology at Johns Hopkins University from 1891-1908.[23] His journey into marine biology began with studying under Louis Agassiz and spending two summers (1873 and 1874) at the Penikese Island laboratory in Buzzards Bay, Massachusetts. In 1875, Brooks investigated the embryology of salps at Alexander Agassiz's laboratory in Newport, Rhode Island. Brooks received his doctoral degree from Harvard University in 1875. At Johns Hopkins University, Brooks founded the Chesapeake Zoology Laboratory in 1878, which he directed for many years. Although Brooks published extensively on a wide diversity of marine invertebrates, it was the oyster that most captured his zeal. His commitment to farming over fishing placed him in the middle of a major controversy in the Chesapeake community.[24] To this end, Brooks published in 1891 a popular book on oysters and the prospects of culturing to restore the oyster industry in Maryland.[25] A second edition was published in 1905. Brooks's legacy in biology extends well beyond his own researches as he mentored some students who went on to become among the most influential biologists of their day including: E. G. Conklin, R. C. Harrison, T. H. Morgan, and E. B. Wilson.[26]

Although Brooks is credited with steering Grave toward the study on *Atrina rigida* he died in 1908 and Grave's dissertation was not published until 1911. The research was supervised by Professor Ethan Allen Andrews (1859-1956) (Figure 6). Andrews had been an undergraduate at Yale and graduate student at Johns Hopkins.[27] He received his Ph.D. in 1887 with a dissertation on polychaete annelids of Beaufort, North Carolina.[28] Andrews

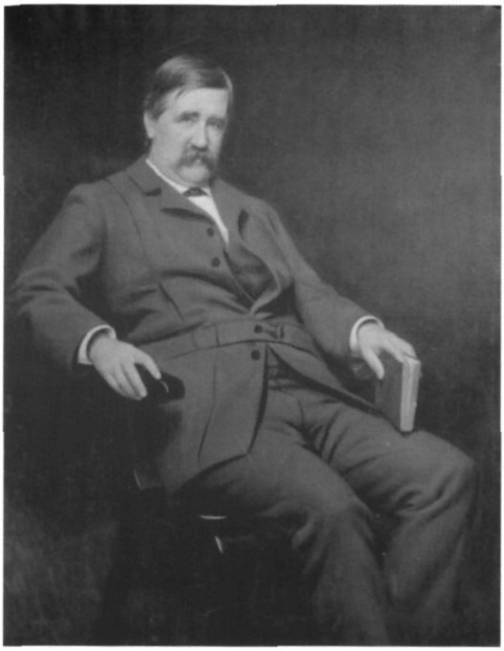


Figure 5. William Keith Brooks (courtesy of Ferdinand Hamburger Archives, Sheridan Libraries, Johns Hopkins University)

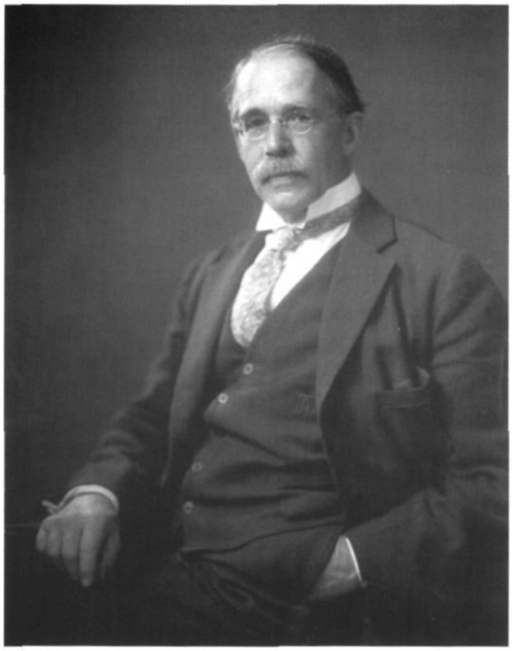


Figure 6. Ethan Allen Andrews (courtesy of Ferdinand Hamburger Archives, Sheridan Libraries, Johns Hopkins University)

joined the faculty at Johns Hopkins in 1887 and became a full professor in 1908.[29] Andrews, like Brooks, had broad interests and published numerous papers over a range of organisms, including protozoans (especially folliculinids), numerous invertebrates, insects, and several papers on vertebrates, including one on a whale skeleton. Unfortunately, we found no further information about his relationship with Grave.

Grave's dissertation in its published form is less than 30 pages in length and includes 14 figures and 3 plates (Figure 7). The text is subdivided into parts based on bivalve anatomy. There is a brief introduction and also a brief 10-part summary at the conclusion of the text.

As neither of the authors is schooled in bivalve anatomy, we inquired of Brian Morton, Professor emeritus of Marine Ecology of The University of Hong Kong. Professor Morton is officially retired, but continues research in ecology and conservation and now lives in the United Kingdom. He built a prominent career in marine biology in Asia and is widely known for his efforts in marine conservation. Professor Morton is also acknowledged for his pioneering and ongoing work in bivalve anatomy. Professor Morton kindly read the published version of Grave's dissertation and offers the following comments:[30]

> "For its time, it is a remarkable piece of work in terms of the detailed understanding of the species' anatomy but also with regard to its skillful interpretation in the accompanying illustrations, which, in the absence of any evidence to the contrary, I assume Grave undertook.

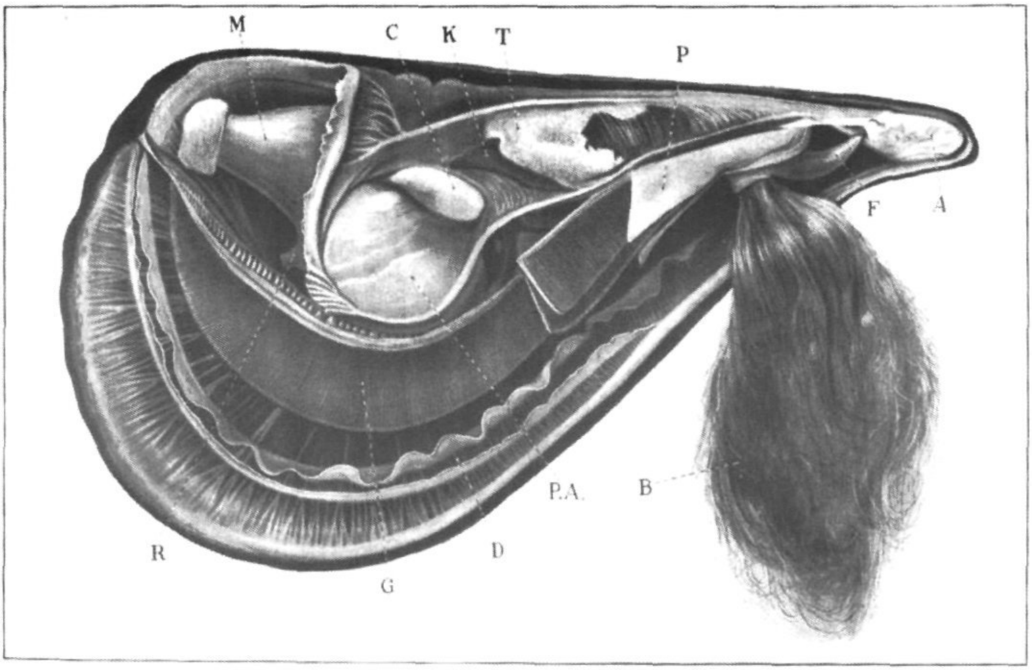


Figure 7. Atrina rigida *(from B.H. Grave 1911,* Bulletin of the Bureau of Fisheries *29: 409-439, plate XLVIII fig. 16.)*

In fact, there are few people alive today who would match the quality of such anatomical drawings."

"All in all, I would say that Grave was way ahead of his contemporaries in terms not only of his understanding of bivalve anatomy, but also the quality of the anatomical illustrations created and his interpretations of them".

Finally, Professor Morton led us to a landmark paper by C.M. Yonge on a species in the related genus *Pinna*. In this work, C. M. Yonge credits Grave for important initial observations on anatomy in species of the family Pinnidae and is able to confirm some of Grave's findings.[31] First and most significant is Grave's observation that the mantle lobes are free from the shell and that this feature makes repair of damage to the shell possible. As the shells of these bivalves are easily damaged, this adaptation to facilitate repair has major consequences for the ecology of individuals and health of populations. Second, the large portion of the shell that is exposed to seawater is made of the outer prismatic layer that is secreted by the outer lobe of the mantle and not the inner nacreous layer. Third, Yonge reports the organs in the visceral mass in *P. carnea* are similar to those found by Grave in *A. rigida*. Fourth, Yonge found in the case of *P. carnea* that individuals who come loose from the sediment are unable to re-establish themselves. Grave observed a similar inability in *A. rigida* unless specimens became partially re-embedded anterior end downward in the sediment.

4. Teaching Career

Benjamin Grave was a dedicated educator who, over the course of his career, taught undergraduates at six colleges and universities and the Marine Biological Laboratory, Woods Hole, Massachusetts. In chronological order, he was on the faculty of: Carleton College (1904-1906), Earlham College (1908-1909), the University of Wyoming (1910-1913), Knox College (1913-1920), Wabash College (1920-28), and DePauw University (1928-42). Few details have been preserved, but it is clear that he had experience with a wide range of biological topics, in the field and the laboratory.

His earliest known teaching appointment was at Carleton College in Northfield, Minnesota, as Instructor in Biology. In the two years he spent there, he taught Invertebrate Zoology, Botany, and Plant Physiology and Anatomy. Professor Franz Exner praised his work in Biology and added that Grave also assisted the laboratory sections of Elementary Chemistry. Both Exner and his colleague Professor Lucian W. Chaney wrote glowing recommendations to Johns Hopkins University president Ira Remsen.[32] Grave was well-liked and respected at Carleton, and they would have preferred to retain him, but they endorsed his returning to complete his doctoral studies.

Grave left Johns Hopkins for a second time for the 1908-09 academic year, returning to Earlham College. When Professor David W. Dennis, the head of the biology department, went on leave suddenly, Grave left Baltimore for Richmond, Indiana, to teach Comparative Anatomy and Plant Evolution and manage the laboratories. In the 1909 yearbook, *The Sargasso*, the students praised alumnus and now Assistant Professor Grave. They good-naturedly recalled his frugality and his chapel address opposing "Wishy Washy Sentimentalism."[33] It is likely that Dennis had recommended the choice of Grave for that year. In 1906, he had written "I have known him and his family for a long time and would underwrite for Ben whatever he desires. He would not want what he could not do."[34]

Following graduation from Johns Hopkins University, Grave taught biology at the University of Wyoming, Laramie, Wyoming, from 1910-1913. Laramie was an isolated community in the early twentieth century, 80 km from the state capital of Cheyenne, over 1700 km from Grave's family and friends in Indiana, and over 2700 km from Baltimore and the Atlantic coast. No detailed records of Grave's teaching were preserved, but a few fragments document his time there. In October 1912, professor of botany Aven Nelson wrote that Professor Grave would produce an article on leaf miners,[35] but this entomological paper was never published. A cicada collected by Grave in Laramie is mentioned in the type description of *Okanagana gibbera* in 1927. [36] The only works that Grave produced while at Wyoming were on the avifauna of Wyoming, in collaboration with Ernest P. Walker.[37] The 1913 yearbook, *The Wyo*, includes Benjamin H. Grave, Ph.D, Professor of Zoology, and Ernest P. Walker is recorded as a member of the sophomore class.[38] Both Grave and Walker left Wyoming after the spring semester of 1913: Grave to do summer research at the Marine Biological Laboratory at Woods Hole, Massachusetts, and Walker to take a position as warden and inspector for the U.S. Bureau of Fisheries in Alaska.

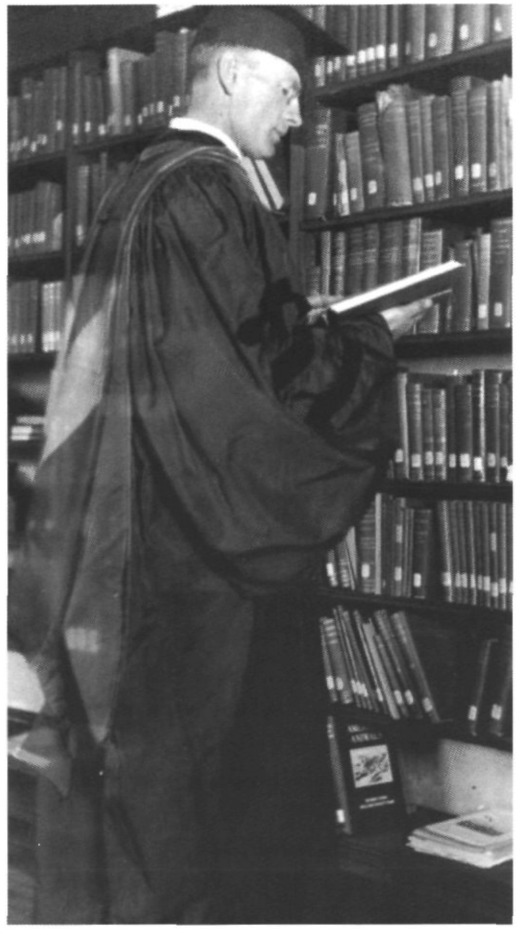


Figure 8. B.H. Grave in the Science Math Center Library, Knox College (Courtesy of Knox College Archives)

Grave was appointed Professor of Biology at Knox College, Galesburg, Illinois, in 1913 replacing Professor Herbert V. Neal.[39] Knox College, a liberal arts college in the midwestern region of the United States, seemed a more congenial environment for Grave. Founded by a group of missionaries led by the Reverend George Washington Gale, it has been known for the moral character of its students and faculty. In October 1858, future president Abraham Lincoln debated Stephen A. Douglas on the Knox College campus. In the spring of 1914, the students described Grave thus: "Although a newcomer, Dr. Grave is no longer a stranger. He has gained the friendship and esteem of the college as a whole thru his versatile knowledge of human nature and his thoroughness in his courses." The student authors also observed that "that laugh of Professor Grave's: it's the best one in school." [40] Only one year after arriving at Knox, Grave published his *Laboratory Guide for a Course in Invertebrate Zoology* (Appendix 1), almost certainly to fulfill the needs of his own classroom. In addition to teaching, Grave was also responsible for curating the Albert Hurd Museum.[41] A natural history museum with over 20,000 specimens in the early twentieth century, the Hurd is now a teaching collection of approximately 1300 vertebrate specimens.[42] A notable milestone during Grave's tenure at Knox was his marriage to Earlham College alumna Lucile H. Moore (Figure 9), known as Lucy, on 14 September 1915. In 1920, Ben and Lucy Grave left Knox College to return home to Indiana.

Grave served on the faculty at Wabash College, Crawfordsville, Indiana, from 1920-1928.[43] Wabash College is an independent liberal arts college for men, founded by Presbyterians. Grave had a productive tenure at Wabash, with a devoted following of students. He was an energetic and athletic presence on campus who always walked or bicycled between his home and campus.[44] He took students with him to the Marine Biological Laboratory, Woods Hole, Massachusetts, for many summers (Figure 11),

Figure 9 (left). Lucile Moore Grave (Courtesy of Earlham College Archives)
Figure 10 (right). Ben Grave (Courtesy of Earlham College Archives)

including Joseph F. Oliphant (1906-1986).[45] Another distinguished student of Grave's was Willis H. Johnson (1902-1994), who went on to earn a Ph.D. at the University of Chicago and became the Head of the Biological Sciences Department at Wabash. Grave's faculty colleague Fergus Ormes recalled Grave as a somewhat controversial figure. Although the better students were devoted to him, the poor to average students found him "tough and unreasonable." He had a tendency to be perfectionistic, and was a formidable opponent when conflicts arose at faculty meetings. According to Ormes, Grave was adept both at laboratory work and in taking students out into the field, with memorable dinners around the campfire. Another of Grave's responsibilities at Wabash was curating the

Hovey Museum, the college's natural history museum, which had been established by botanist John Merle Coulter when he was on the faculty there.[46] Grave took a leave of absence in 1926-1927 to conduct research at Yale University as a Seessel Fellow. The following year was his last at Wabash, as he accepted an offer to head the Zoology Department at nearby DePauw University.

Grave spent the remainder of his professional career on the faculty of DePauw University in Greencastle, Indiana, approximately 50 km to the south of Crawfordsville, and only 35 km from his hometown of Monrovia. DePauw University, a coeducational liberal arts institution affiliated with the United Methodist Church, grew rapidly during the 1920s under President Lemuel H. Murlin. Grave was hired to bolster DePauw's teaching faculty, in order to serve a larger student population.[47] He was the head of the Zoology Department from 1928-1940, and continued to teach until 1942, when he transitioned to emeritus status due to health issues. Grave led the Zoology Department through its evolution in the 1930s - its move out of Middle College and into temporary quarters in the Science Annex, a frame building nicknamed "Termite Hall,"[48] and then into Harrison Hall in September 1940, newly opened and built on the site of Middle College, providing expanded space for the Zoology, Botany, Geology and Psychology departments.[49] Few details of his teaching at DePauw were preserved, but a 1933 article in the campus newspaper, *The DePauw*, gives a vivid glimpse. The Monday December 13th article related that Grave, having suffered a stroke the previous Friday, was at Indianapolis Methodist Hospital, where he was "directing his classes from the bedside."[50] A remarkable number of his students who majored in zoology, approximately 85 percent, went on to advanced study in zoology, medicine, or related subjects.[51] The class of 1941 described an active "Dr. Grave" as a naturalist who loved to "roam in the woods" and remarked on his many years of summer research at the Marine Biological Biology at Woods Hole.[52]

Grave took groups of as many as six students from DePauw to Woods Hole each summer in the 1930s, typically for the invertebrate zoology and embryology courses.[53] Zoology student Jay Smith spoke at the Evening Lectures at Woods Hole with Grave in 1935 on "Sex Inversion in *Teredo [navalis]* and its Relation to Sex Ratios".[54] Smith and Grave coauthored an article on that topic which was published in 1936 (Appendix 1). DePauw University did not have a natural history museum, but Grave continued collecting nevertheless. In 1931, he donated 5 specimens of salamanders, collected in Putnam County, Indiana, to the Field Museum in Chicago.[55]

Grave taught embryology at the Marine Biological Laboratory from 1919-1936, a period spanning his tenure at Knox, Wabash, and DePauw. As mentioned above, he brought many of his undergraduate zoology students to Woods Hole with him for the summer, a great opportunity for undergraduates from the Midwest.[56] Grave and his students thrived in association with other students and faculty from around the United States, including Grave's older brother Caswell, who was also an instructor and investigator there. Three students' work was of a caliber that led to collaboration on publications: Ralph C. Downing (Wabash), Joseph F. Oliphant (Wabash), and Jay Smith (DePauw). It is thus not surprising that Professor and Mrs Grave designated part of their estate as a

Figure 11. B.H. Grave at Woods Hole, Massachusetts, 1921 (Courtesy of Marine Biological Laboratory Archives, http://hpsrepository.mbl.edu/handle/10776/2433)

scholarship fund for students at Knox, Wabash, and DePauw to study marine biology, with preference given for those attending the Marine Biological Laboratory.[57]

Throughout his career, Grave was active in professional associations. He was a member of the American Society of Zoologists, the Indiana Academy of Science, where he served as chair of the Zoology Section, and the American Association for the Advancement of Science, becoming a Fellow of the AAAS in 1915.[58] At Wabash College, he chaired the committee for relations with the National Education Association, a labor organization for teachers and professors in the United States.[59]

5. Research and the Marine Biological Laboratory

We have already considered Grave's dissertation research on anatomy of the marine bivalve mollusk *Atrina rigida*, a species of commercial importance at the time of his investigations. Though his study reports in considerable detail about the species, for whatever reason, it has not been often cited in subsequent years. Leading specialists in bivalve anatomy and functional morphology, however, hold the work in high regard.

For the invertebrate biologist, likely the most surprising works in Grave's oeuvre are his collaborative study with Ernest Pillsbury Walker[60] (Figure 12) on the effects of land use change on avian species richness in Wyoming[61] and his related single-authored publication regarding the influence of agricultural development on bird fauna[62] that summarizes major ideas underpinning this survey. The Grave and Walker paper includes a discussion of how the conversion of prairie to agricultural land and the increasing human population associated with the establishment of farming affected species composition and

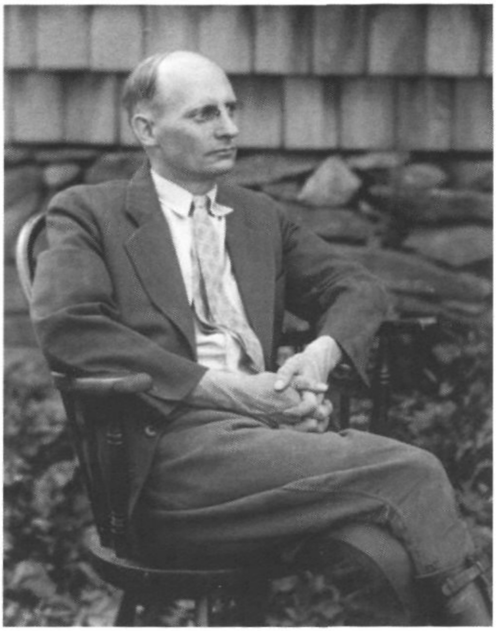


Figure 12. Ernest Pillsbury Walker (Smithsonian Institution Archives. Image 94-515)

richness of bird species. The survey also contains a list of all known species of birds to be found in Wyoming, new records for the state, and new breeding records. The study was conducted under auspices of the Department of Zoology at the University of Wyoming. Walker spent two summers in the field making personal observations. Data were acquired from previous collectors, most importantly W. C. Knight's study published in 1902.[63] Inquiries were made of residents about their observations and impressions of species identities and abundances before and after the introduction of significant agricultural development. Results indicated that certain species increased in number (Robin, Meadow Lark, Crow, Dove, Brewer's Blackbird and Cowbird). Some species described as rare by W. C. Knight were considered common by 1913. Finally, 45 species were found new to the state since the 1902 survey. Grave and Walker attributed the increase in number of species to agricultural growing of grain that provided seeds as food, tree plantings associated with towns and farm buildings creating new habitat that is rare, or mostly absent, in the prairie ecosystem, and irrigation for growing of crops providing an increase in sources of water. On the converse side, the authors report a subjective consensus among those interviewed that game birds were less abundant, presumably attributable to greater hunting pressure brought on by the increase in human population associated with agriculture. Grave and Walker emphasize the positive role of birds as predators on insects, many species of which are harmful to agriculture. Additionally, seed-eating birds were noted to have a beneficial effect in reducing weed populations and, concomitantly, a deleterious one in consumption of agriculturally important seed.

Grave and Walker conclude with several basic recommendations. First, they considered existing state laws concerning protection of species sufficient in coverage and that little could be gained by adding further legislation. Compliance with these regulations, however, they point out is critical to achieving the intended goals of any laws. Finally, the authors suggest that attracting birds to home settings would be fostered by planting trees for shelter, providing ample water and food, and by not maintaining cats as pets. Clearly, the vision of Grave and Walker that more species of birds present regardless of their origin is desirable stands at odds with today's conservation efforts to limit habitat destruction and introduction of alien species brought about through land use changes and their consequent effects.

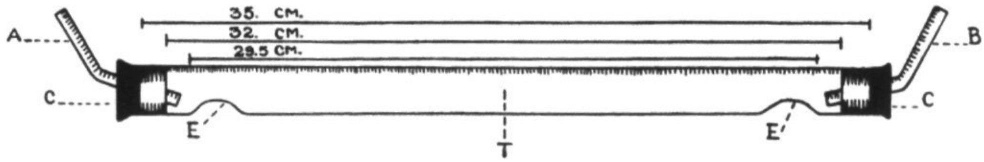


Fig. 1 *E*, **elevation in floor of tube;** *T*, **experimental tube, 2 cm. in diameter and 29½ cm. long;** *A*, **feed tube through which sperm were introduced;** *B*, **feed tube through which eggs were introduced;** *C*, **cork stoppers.**

Figure 13. Sperm tube apparatus (from B.H. Grave and R.C. Downing, 1928. Journal of Experimental Zoology ***51****(3), 384)*

The major body of Grave's scholarly output focused on diverse aspects of the biology of marine invertebrates, particularly from the region of Woods Hole, Massachusetts. These studies range over 20 species in 7 phyla (Appendix 2). Such taxonomic breadth is a credit to Grave's broad interests and apparent fascination with natural history. Not only was Grave able to successfully conduct research using diverse fauna, he also investigated a broad array of problems in life history biology, including: anatomy, life cycles, spawning, egg longevity and fertilization capability, sperm longevity and fertilization capability, protandric hermaphroditism, and culture techniques.

Grave enjoyed "tinkering" and creating novel apparatuses and clever experimental designs to test some of his ideas. Most interesting is the device designed to test sperm swimming speed and swimming distance (Figure 13). Grave and his student Ralph C. Downing[64] set out to improve on the experimental design created earlier by the Scottish naturalist James Fairlie Gemmill to test gamete viability.[65] Gemmill was concerned about the accuracy of sperm locomotion measurements using dishes with a large air-water surface area because of factors such as air currents on the water surface creating mixing that would result in passive dispersal of sperm rather than translocation by active swimming. In an attempt to avoid this pitfall, Gemmill employed narrow cross-section tubes of varying lengths as a more accurate way of determining sperm swimming speed. Unfortunately, the narrow diameter tubes accentuated boundary effects on sperm movement thus making Gemmill cautious of these data as well. Grave and Downing's apparatus was designed to overcome or at least minimize these limitations. The design was based around a tube-like chamber and introducing unfertilized eggs at one end of the chamber and sperm at the opposite end. Hillocks were placed near the end of tubes but distal to where gametes were introduced, creating shallow wells in order to reduce passive dispersal of gametes. Gametes were introduced into the wells. Time from introduction of sperm to observable fertilization of eggs at the opposite end of the tube, as evidenced by a cortical reaction having taken place in the eggs, was then measured and converted to swimming speed. Grave and Downing attempted to avoid wall effects by increasing the diameter of the chamber over the sizes used by Gemmill. By the use of carmine particles, the authors tested for currents that might result in passive transport of gametes. They found that eggs sank to the bottom and did not cross the hillock and they reported no evidence of sperm passively diffusing across the hillock at the other end of the chamber. In 1934 Grave modified the design even further and devised a way to submerge the tube to eliminate any effects of air currents on water mixing within the tube.[66] Considering that Grave had no special understanding of fluid dynamics, he did an admirable job of thinking through potential problems in design.

Grave published two journal articles on bryozoans[67] and one chapter in a multi-authored volume on culture methods.[68] These studies focused primarily on *Bugula simplex* (as *B. flabellata*).[69] Included in the paper are some data on *B. turrita* also from the Woods Hole region.

The most cited of all Grave's output is his 1930 paper in *Biological Bulletin* on the natural history of *B. simplex* (as *B. flabellata*) with comments on *B. turrita*.[70] This broad-based descriptive account includes information on reproductive season, larval release and behavior, settlement and metamorphosis. Grave carefully notes comparisons of his findings with those of previous workers, primarily in France and Germany. Again, Grave reveals his fascination with experimental design. By manipulation of the light regime, Grave documents that release of larvae from parental colonies is a light-triggered event. He examined phototactic responses at different stages of larval life by shifting the source of light using a mirror, and documented that larvae settle away from the direction of incident illumination. In important ways, this paper set the stage for a large body of subsequent work that remains ongoing a century later. But Grave's study is not without some oversights. For example, in his analysis of morphogenetic movements in the rearrangement of tissues during metamorphosis, Grave does not mention the involution of the corona and uplift of the walls of the metasomal (internal) sac in establishment of the lateral aspects of the ancestrual body wall. Though a critical step in metamorphosis, it would have been a difficult one to observe in conventional light microscopy of the day.

One fascinating aspect of Grave's 1930 study has been overlooked by subsequent investigators. Grave reported that *Bugula turrita* occurs in Vineyard Sound, but not Eel Pond and *B. simplex* [as B. *flabellata*] was found in Eel Pond, but not Vineyard Sound. Yet the two bodies of water communicate freely. When Grave reciprocally transplanted colonies of these species, they did not survive and, instead, died within months to a year. Grave proposed that the inability to survive might have been attributable to different properties of water flow between Vineyard Sound and Eel Pond, with the latter being more sheltered. Grave pointed to similar differences in occurrence of species of hydroids between the two localities. In their manual on culture methods,[71] Costello and Henley reported in 1971 the same distributions of *B. simplex* (as *B. flabellata*) and *B. turrita*. When *B. turrita* became successfully established in Eel Pond is undocumented. This species remains at the present time a conspicuous member of the Eel Pond fouling community.

Thus we come full circle in one arena of Grave's research agenda: from non-native birds entering Wyoming due to conversion of prairie to agricultural use to his failed transplantation attempts involving species of *Bugula* in the Woods Hole region. Although his point of view is quite different from the modern conservationists, he provides some good historical data and insights on the contemporary thought of his day.

Osburn[72] stated explicitly in his 1910 monograph on bryozoans of the Woods Hole region that a third congener, *B. stolonifera* (as *B. avicularia*)[73] was not present in any collection from the Woods Hole area. Rogick, however, while not including *B. stolonifera* (as *B. avicularia*) in her 1964 key to bryozoans of Woods Hole,[74] does provide a figure of this species. She may have chosen this action because *B. stolonifera* might have been present, but was sufficiently rare in occurrence to not merit inclusion in the key. Gooch and Schopf (1970)[75] employed specimens of *Schizoporella errata* from Eel Pond and Green Pond along with *B. stolonifera* collected in Eel Pond for their pioneering study of population genetics of marine bryozoans. They do not mention, however, the history of *B. stolonifera* in the context of *B. avicularia* in Eel Pond. Karl Kaufmann's 1971 study of *avicularia* was based on *B. simplex* and *B. stolonifera* from Eel Pond.[76] Again, no mention of the history of *B. stolonifera* was included. Finally, *B. stolonifera*, *B. simplex* and *B. turrita* were reported to co-exist in Eel Pond by 1982.[77] The arborescent cheilostome fauna occurring in Eel Pond continues undergoing change to the present day.[78]

The 1933 article by Grave[79] on life history parameters of some Eel Pond invertebrates covers a 10-year survey of rates of growth, time of sexual maturity, and duration of life. This study focuses on *Obelia commissuralis*, *Balanus eberneus*, *Hydroides hexagonus*, and *Botryllus gouldii*. Only brief mention is made of *Bugula simplex* (as *B. flabellata*). Grave amends several quite minor points mentioned in his major 1930 paper. These changes include the observation that the first avicularium develops in colonies of four autozoids rather than later as noted in 1930; at the eight autozoid stage avicularia are present on the second, third, and fourth autozoids; and the everted metasomal (= internal) sac becomes branching and stolon-like in form rather than disc-like as stated in 1930. Comment on this article is included here only for purposes of thoroughness of coverage of Grave's observations on bryozoans.

Finally, Grave contributed a chapter on culture methods for *Bugula simplex* (as *B. flabellata*) and *B. turrita* to a multi-authored volume on culture techniques of invertebrates.[80] This chapter and five additional ones Grave authored on different species of invertebrates are products of his many years of engagement with the natural history of marine invertebrates at Woods Hole. Most of these likely derive in large measure from his extensive teaching experience at the Marine Biological Laboratory mentioned in previously in Section 4.

6. Personal Life and Later Years

Grave had an active personal life, enjoying outdoor activities and cultural events. Until his health declined, he was known for taking long walks, especially "moonlight walks" with his wife. While at Wabash College, Ben and Lucy socialized with other faculty couples, reading plays aloud at each other's homes.[81] They both enjoyed listening to music, especially Beethoven. Cleveland P. Hickman, a zoology colleague from DePauw University, wrote: "By nature he was sympathetic and generous and every worthy cause received willing support in his hands. Nothing afforded him greater enjoyment than the study of nature in all of its aspects and he developed an aesthetic appreciation of outdoor beauty".[82] His colleague Will E. Edington remembered Grave as "deeply interested in spiritual values and the problems of human welfare and ... a bitter foe of intolerance or tyranny in any form either on or off the campus."[83]

Grave's unpublished work *The Destiny of Man* (Appendix 1) consists of a set of five essays that are works of encouragement, with themes of progress, spirituality, and optimism. They appear to be addresses to undergraduates and may well have been notes from which he spoke: typewritten pages with hand-drawn illustrations, as well as corrections and additions in handwriting. Grave introduces three scholarly figures with differing points of view: Jacques Loeb (1859-1924) with a mechanistic view of science and the world, Herbert Spencer Jennings (1868-1947) emphasizing experimentation and experience, and Quaker theologian and educator Rufus Jones (1863-1948) on mysticism and spirituality. When discussing Loeb and tropism, Grave includes examples of the behavior of *Bugula* larvae. Throughout, Grave expresses his own deeply ingrained faith and his appreciation of beauty in nature. Because of references to popular American sports figure Red Grange, and the statesmen Aristide Briand and Gustave Streseman (Nobel Peace Prize laureates in 1926), it was likely written in the mid-1920s for the Wabash College students.

Although Quakers have historically been pacifists, some, including members of the Grave family, have served in the military, especially when issues of justice were at stake. Ben's father, Thomas Clarkson Grave, served in the Union Army, Indiana 33rd Infantry Regiment, during the United States Civil War.[84] Ben's younger brother Floyd commanded a medical laboratory in France attached to the 90th division of the American Expeditionary Forces in World War I.[85] Caswell and Caswell's son Thomas also served in World War I with the Chemical Warfare Service in Washington, DC.[86] Ben and his younger brother Thomas registered for both World War I and World War II, as was required, but were not drafted for service. Ben's draft registration cards reveal his physical description, not available from other sources. In 1918, the registration card reflected a man in his prime: a professor at Knox College, Galesburg, Illinois, height of 5'11'' (180cm) and weight of 160 lbs (72 kg), with blue eyes and brown hair. Twenty four years later, in 1942, he was retired in Greencastle, Indiana, still at the same height but only 127 lbs (58 kg).[87]

Although the distinctive traditional dress and speech of the Quakers diminished in use in the nineteenth and early twentieth centuries,[88] a remnant of the tradition is found in letters among the Grave and Moore families. While they used standard American grammar in business communications, Ben and Lucy used the traditional "thee" and "thy" forms when writing to family members. Ben's letter to Lucy in December 1924 contains this usage and reveals much of his life at that time: he expresses his devotion to Lucy, shares remembrances of his father who had passed away earlier that year, and also discusses plans for his research on invertebrates. Letters from Lucy underscore what others observed of her: a great appreciation of beauty, a quick wit, absolute devotion to her husband, and a warm and diplomatic manner.[89]

Figure 14. Caswell Grave (Courtesy of the Marine Biological Laboratory Archives, http://hpsrepository.mbl.edu/handle/10776/2868).

Figure 15. B.H. Grave ca. 1935 (Courtesy of DePauw University Archives and Special Collections)

Family relationships were important to both Ben and Lucy Grave. Both were from close-knit, devout Quaker families who vigorously encouraged education. With the exception of three years in Wyoming, Ben lived with or near relatives for the rest of his life. In addition to their association with Earlham College noted above, all four of the Grave brothers attended Johns Hopkins University,[90] first Caswell (Figure 14) and then various combinations of the brothers, depending on the year, living with Caswell and his wife Josephine (d. 1951) in Baltimore while Caswell was on the faculty there.[91] After his marriage to Lucy Moore in 1915, Grave maintained ties with both his own family and the Moores. Because they were both Earlham alumni, Ben and Lucy's holiday visits to Mrs. Moore, Ben's visiting lectures, etc., were chronicled in the Earlham campus newspaper.[92] Every summer from 1919-1936, Ben and his brother Caswell were both in residence at Woods Hole with their families.[93] Caswell's son Thomas Brooks Grave, was also a fixture at Woods Hole, serving as the "Person in Charge" of the Chemical Room at the Marine Biological Laboratory from 1920-25.[94] Lucy maintained close ties with her mother, Mary Thorne Moore (1847-1925) and siblings, Anna M. Cadbury (1873-1932), Grace E. Moore (1876-1953), and Willard E. Moore (b. 1884). Her sister Grace remained at the home where they had grown up, on the Earlham Campus, where Lucy would join her after Ben's death in 1949. The Moore family home at 430 College Avenue, which they called Twin Willows, is now the Marketing and Communications Office at Earlham College.

Grave's health declined in the 1930s. He suffered a stroke in 1933[95] and a severe case of shingles in 1936.[96] He retired for health reasons in 1942, and was cared for by Lucy at their home in Greencastle, Indiana, until his last days. Colleagues from Wabash and DePauw visited him at home after his retirement, and remarked on Lucy's dedication.[97]

Benjamin Grave passed away on Monday, 24 January 1949, at Central Hospital, Indianapolis, Indiana, from complications following a fall and broken hip.[98] Faculty colleagues joined with friends and neighbors at a Quaker style memorial service held at the Graves' home on Friday, 28 January. Clyde E. Wildman (1889-1955), then President of DePauw University and an ordained Methodist minister, led the service.[99] Grave was remembered as a beloved colleague and mentor, his life and career characterized by "simplicity, sterling integrity and fearless defense of what he believed to be right and true."[100] He is buried in Earlham Cemetery, Richmond, Indiana, next to his wife (Figure 16) and in close proximity to Joseph and Mary Thorne Moore.[101]

Figure 16. Gravestone of B.H. Grave, Earlham Cemetery, Richmond, Indiana, 29 May 2013 (Courtesy of Friends Collection, Earlham College)

7. Acknowledgements

The authors are grateful to Brian Morton and John Ryland for generously sharing of their insights about Grave's dissertation and the taxonomic status of *Bugula* spp. in Eel Pond, respectively.

We also wish to thank and acknowledge help given by the following: Anne Thomason, Amy Bryant, Prof. Thomas Hamm and Mary Louise Reynolds from Earlham College, Richmond, Indiana; James Stimpert, Johns Hopkins University Archives; Wesley Wilson, DePauw University Archives, Greencastle, Indiana; Elizabeth Swift, Wabash College, Crawfordsville, Indiana; Judith Winston, Virginia Museum of Natural History; Cleveland Hickman, Jr., Washington and Lee University, Lexington, Virginia; Thomas Whittaker and Timika Hoffman-Zoller, University of Chicago; Tad Bennicoff, Smithsonian Institution, Washington, DC; Prof. Jim Mountjoy and Mary McAndrew, Knox College, Galesburg, Illinois; Eric Hillemann, Carleton College Archives, Northfield, Minnesota; Clare Clark, Cold Spring Harbor Laboratory Archives, Cold Spring Harbor, New York; Diane Rielinger, Marine Biological Laboratory Archives, Woods Hole, Massachusetts; Adam Baldinger, Collin Johnson, Murat Recevik, Constance Rinaldo, Museum of Comparative Zoology, Harvard University. Special thanks go to Helene Ferranti of the Museum of Comparative Zoology for her diligent and exacting work on the manuscript.

Finally, we thank the co-editors of this volume, Patrick Wyse Jackson (Trinity College, Dublin, Ireland) and Mary Spencer Jones (Natural History Museum, London, UK), for inviting the submission of this paper, for their encouragement and their critical editing.

Notes

1 Dates for Thomas Clarkson Grave and Elizabeth Hubbard Grave from gravestones in West Union Cemetery, Monrovia, Indiana.

2 *Biographical and Genealogical History of the State of Delaware*, vol. 1, J.M. Runk, Chambersburg, PA, 1899, 473.

3 Hubbard family information confirmed in: United States of America, Bureau of the Census. *Seventh Census of the United States, 1850*. Census Place: Monroe, Morgan, Indiana. Micropublication roll M432_162, page 129A, image 264.

4 *Thomas Graves, Quaker of Newcastle Co., Delaware and His Descendants*, http://www.gravesfa.org/gen085.htm, accessed 3 October 2013.

5 P. Montgomery, *Indiana Coverlet Weavers and their Coverlets*, Hoosier Heritage Press, Indianapolis, 1974, 56.

6 D.I. Grave, "Coverlet", 1838, Art Institute of Chicago catalog, http://www.artic.edu/aic/collections/artwork/72456, accessed 3 October 2013.

7 The Society of Friends is organized into groups called "meetings". The term meeting is used for congregational units as well as larger groups. A yearly meeting is a larger group of people than a monthly meeting, for example, and would be composed of several monthly meetings. These meetings maintained strict codes of conduct in the 19th century, including dress and speech and prohibiting activities such as dancing or drinking alcohol. David Isaac Grave was cited by Whitewater Monthly meeting for being lax in disciplining his children amongst other

offenses.

8 T.C. Grave family information confirmed in: United States of America, Bureau of the Census, *Tenth Census of the United States, 1880*, Census Place: Monroe, Morgan, Indiana, Enumeration District: 263. Micropublication roll 301, Film 1254301, page 41B, image 0086.

9 F.A. Battey and F.W. Teeple, *Counties of Morgan, Monroe and Brown, Indiana: Historical and Biographical*, F.A. Battey & Co., Chicago (1884) 126-129; Current information for West Union Friends Meeting at http://www.fwccamericas.org/MeetingSearch.aspx?n=West+Union+Friends+Meeting; Friends United Meeting information http:/fum.org/.

10 W. Norman Brown, *Johns Hopkins Half-Century Directory: A Catalogue of the Trustees, Faculty, Holders of Honorary Degrees, and Students, Graduates and Non-graduates 1876-1926*, Johns Hopkins University, Baltimore (1926) 137.

11 Anne Thomason, Earlham College Archives, personal communication, 20 August 2013.

12 David Worth Dennis (1849-1916) was a member of the science faculty at Earlham College from 1884 to 1916, and a friend and mentor to Benjamin Grave. He received his A.B. degree at Earlham College in 1873 and his Ph.D. in Geology from Syracuse University in 1899 (*Alumni Record and General Catalog of Syracuse University,* F. Smalley (ed.), Syracuse, N.Y. (1889) 599, 653). In the course of his career, D.W. Dennis taught chemistry, biology and geology at Earlham College, serving as the head of the Biology Department for many years. ('David W. Dennis, A.B., A.M., Ph.D.' *Biographical and Genealogical History of Wayne, Fayette, Union and Franklin Counties, Indiana*, Lewis, Chicago (1899) 17-19.) He was also an Orthodox Quaker minister.

His son, William Cullen Dennis (1878-1962) was the president of Earlham College from 1929 to 1946. (Dennis Family Papers, 1867-1988, Friends Collection, Earlham College Archives, https://archives.earlham.edu/?p=collections/findingaid&id=49, accessed 17 October 2013.) The younger Dennis was a close friend of Ben and Lucy Grave, and Lucy's sister Grace (letter from W.C. Davis to B.H. Grave, 21 December 1936, Earlham College Archives).

13 Joseph Moore (1832-1905) was a major figure in science and education in 19th century Indiana. He studied at Friends Boarding School (which would become Earlham College in 1859), Richmond, Indiana, then began teaching there in 1853. Moore was a student at Harvard University from 1859-1861, receiving the S.B. degree from Harvard's Lawrence Scientific School in 1861. At Harvard, he was a student of Louis Agassiz, Asa Gray, and Jeffries Wyman, and was influenced by each. He developed a neo-Lamarckian theory of evolution which was consistent with his Quaker beliefs, and is believed to be the first educator to teach about evolution in Indiana. (W. Cooper, 'Joseph Moore: Quaker Evolutionist', *Indiana Magazine of History* 72 (2) (1976) 123-137.)

Moore returned to Indiana in 1861 to serve on the faculty of Earlham College. He was president of Earlham College from 1868-1883, then in 1883 moved to North Carolina where he taught and served as principal at New Garden Boarding School, which is now Guilford College. He returned to Earlham in 1888 to teach botany and geology. He started the natural history museum at Earlham College as a teaching collection in 1853, and continued to collect specimens and develop the museum over the next several decades. ('Joseph Moore, M.A.' *Biographical and Genealogical History of Wayne, Fayette, Union and Franklin Counties, Indiana*, vol. 1, Lewis, Chicago (1899) 190-192.) It was re-named the Joseph Moore Museum in 1905, and is currently a resource for the Earlham community and the general public.

In addition to his academic leadership, Moore was also a respected religious figure, recorded as a minister by the Society of Friends in 1865. Following the U.S. Civil War, he led efforts to assist Quakers in North Carolina. ('Joseph Moore' http://www.earlham.edu/about/

campus-history/presidential-gallery/joseph-moore/, accessed 21 May 2013.)

14 "Benjamin H. Grave", *Wabash Bulletin* 19 (4) (1920) 8-9.

15 Application for Admission, Johns Hopkins University, Benjamin Harrison Grave, 1 October 1903, section VI, student files, Johns Hopkins University Archives.

16 'The Biological Laboratory 15th Season', *Sixteenth Yearbook of the Brooklyn Institute of Arts and Sciences* (1904) 198-202.

17 Transcript for Benjamin Harrison Grave, University of Chicago, Summer 1905, Office of the University Registrar. Additional information supplied by Timika Hoffman-Zoller, Office of the Registrar, personal communication 22 July 2013.

18 B.H. Grave to I. Remsen, 5 April 1906, student files, Johns Hopkins University Archives.

19 *The Carletonian*, June 11, 1906 as communicated by Eric Hillemann, Carleton College Archivist, personal communication 13 September 2012.

20 B.H. Grave to I. Remsen, note 18.

21 'Win Relay by Foot: Georgetown Runners', *Washington Post*, 10 March (1907) S1. Grave finished second in the 440 yard open-handicap race, a track and field event held at Georgetown University on 9 March 1907. Johns Hopkins University won the Hickman and White Trophy for the institution with the greatest number of total points.

22 B.H. Grave, 'Anatomy and physiology of the wing-shell *Atrina rigida*', *Bulletin of the Bureau of Fisheries* 29 (1911) 409-439, pls. XLVIII-L. [Published version]

23 E.G. Conklin, '*William Keith Brooks 1848–1908*', National Academy of Sciences, Washington, D. C. (1913) 88 pp.

24 M. W. Fincham, 'The oyster dreams of W. K. Brooks: Could science save a seafood industry?' *Chesapeake Quarterly*, Maryland Sea Grant, April 2013, http://ww2.mdsg.umd.edu/CQ/V12N1/main3/, accessed 18 October 2013.

25 W. K. Brooks, *The Oyster*, The Johns Hopkins Press, Baltimore, Maryland (1891) 230 pp.

26 D. M. McCullough, 'W. K. Brooks's role in the history of American biology', *Journal of the History of Biology* 2 (2) (1969) 411-438.

27 *American Men of Science*, 3rd edition, J. M. Cattell and D.R. Brimhall (eds.) Science Press, Garrison, NY (1921) 15.

28 E.A. Andrews, 'Report upon the Annelida Polychaeta of Beaufort, North Carolina', *Proceedings of the U.S. National Museum* 14 (852) (1891) 277-302.

29 *American Men of Science*, 3rd edition, J. M. Cattell and D.R. Brimhall, eds. Science Press, Garrison, NY(1921) 15.

30 Personal communication from Brian Morton to Robert Woollacott dated 30 June 2013.

31 C. M. Yonge, 'Form and habitat in *Pinna carnea* Gmelin', *Philosophical Transactions of the Royal Society* 237 (648) (1953) 335-374.

32 L.W. Chaney to I. Remsen, 5 April 1906; F.F. Exner to I. Remsen, 4 April 1906, student files, Johns Hopkins University Archives.

33 *The Earlham Sargasso of 1909*, 2 (1909) 53, 58.

34 D.W. Dennis to I. Remsen, 22 May 1906, student files, Johns Hopkins University Archives.

35 A. Nelson, 1912, 'Horticultural Column', *Wyoming Farm Bulletin* 2 (4) (1912) p. 223.

36 W.T. Davis, 'New cicadas from the western United States with notes on several other species', *Journal of the New York Entomological Society* 35 (1927) 373-386.

37 Ernest Pillsbury Walker (1891-1969), subsequent to his study at the University of Wyoming, became the most prominent mammalogist of the twentieth century. His three-volume treatise *Mammals of the World* stands as a monument to his scholarship and devotion to mammals and their conservation. Walker was born in Missouri and completed his formal education at the

University of Wyoming, never earning the Ph.D. He moved immediately after his stay at Wyoming to the Territory of Alaska where he worked for the U. S. Bureau of Fisheries. He later spent time in government service with the U.S. Biological Survey in California and Arizona and then returned to Alaska. In 1930, he was appointed assistant director of the Smithsonian Institution's National Zoological Park in Washington, D. C. where he would remain for the duration of his career. Walker officially retired in 1956, but stayed on at the zoo where he began the daunting process of assembling *Mammals of the World*, a massive work that was published in 1964. This treatise reported on 1044 known genera of recent mammals (R.H. Manville, 'Mammals in review', *Science* 146 (3649) (1964) 1285-1286).

38 *The Wyo*, 5 (1913) 17, 48.

39 'Among the Faculty', *American Educational Review* 34 (12) (1913) 621.

40 *1915 Gale: the Knox College Annual*, Galesburg, IL, 25 (1914) np.

41 'Educational Directory 1916-17', *U.S. Dept. of the Interior, Bureau of Education Bulletin* 43 (1917) 140.

42 F.J.H. Merrill, 'Natural History Museums of the United States and Canada', *Bulletin New York State Museum* 62 (1903) 41; James Mountjoy, Knox College, personal communication, 31 July 2013.

43 W.E. Edington, 'Benjamin Harrison Grave', *Proceedings of the Indiana Academy of Science* 59 (1950) 1-2.

44 Fergus Ormes was a colleague and neighbor of Grave's who was on the faculty at Wabash College from 1921-1958. He taught economics and was the College Comptroller from 1929-1958. His notes on Grave were written after he attended Grave's memorial service, and are part of a large collection of Ormes' observations of his contemporaries. F. Ormes, Personal Papers, 28 January 1949, Robert T. Ramsay, Jr. Archival Center at Wabash College.

45 After graduating from Wabash College, Joseph Oliphant (1906-1986) pursued graduate study at Johns Hopkins University. He earned the Ph.D. in Biology in 1935, with a dissertation 'The effect of chemicals and temperature on reversal in ciliary action in *Paramecium*', *Physiological Zoology* 11 (1) (1938) 19-30. He taught in the Department of Biological Sciences at Stanford University from 1938-1978.

46 The natural history collection at Wabash was based on donated specimens organized by Edmund O. Hovey (1801-1877), a founder of the college who taught geology and chemistry. Botany professor John Merle Coulter, who was at Wabash from 1879-1891, moved, organized and developed the collection, naming it in honor of Hovey in 1881. In Grave's era, the museum occupied four rooms in South Hall and the major categories collected were fossil vertebrates, crinoids, rocks and minerals, and Native American items. The museum collections were dispersed in 1950, with the fossils going to the Chicago Museum of Natural History (Field Museum) and botanical specimens to the Brooklyn Botanical Garden. (*Handbook of American Museums*, The American Association of Museums, Washington DC (1932) 152; Elizabeth Swift, Wabash Archives, personal communication, 27 August 2013; *Museum Work* 8 (5) (1926) 135.

47 C.J. Phillips et al., 'DePauw between the Wars' chap. 3 in S.Y. Loong (ed.), *DePauw University Pictorial History*, E-history edition, (2003) p. 3 http://my.depauw.edu/library/archives/ehistory/index.htm, accessed 10 October 2013.

48 Cleveland P. Hickman, Jr., personal communication, 25 September 2013.

49 C.J. Phillips et al., note 47, p. 9.

50 'Prof. B.H. Grave Suddenly Stricken', *The DePauw* 33 (37) (1933) 1.

51 W. E. Edington, note 43.

52 *Mirage Yearbook*, DePauw University, Greencastle, Indiana (1941) 30.
53 C.P. Hickman, 'Benjamin Harrison Grave', *Anatomical Record* 106 (3) (1950) 438-439.
54 'The Marine Biological Laboratory thirty-eighth report for the year 1935...' *Biological Bulletin* 71 (1) (1936) 31.
55 *Field Museum News* 2 (1) (1931) 2. According to the specimen catalog of the Field Museum, the species donated were *Eurycea cirrigera, E. longicauda, Plethodon cinereus, P. dorsalis*, and *P. glutinosus*, all collected by Grave in Putnam County, Indiana, in 1930. http://fieldmuseum.org/explore/department/zoology/amphibians-and-reptiles/collections, accessed 9 July 2013.
56 'Annual Report of the Marine Biological Laboratory...' *Biological Bulletin (1920-1940)*. Each report includes names of students who attended MBL with Grave, identified by name and college. More information and class lists are available at http://history.archives.mbl.edu/courses.
57 Lucy Moore Grave Bequest, *2013-2014, Wabash College Academic Bulletin*, (2013) 224.
58 W.E. Edington, note 43.
59 'B.H. Grave Heads Committee', *Wabash Bulletin* 25 (4) (1928) 1.
60 note 37.
61 B.H. Grave and E.P. Walker, 'Wyoming birds and their value to agriculture', *University of Wyoming Bulletin* 12(6) (1916a) 1-137; B.H. Grave and E.P. Walker, *The Birds of Wyoming with an explanation of recent changes in their distribution, economic aspects also considered*, University of Wyoming, Laramie, Wyoming, 1913 [1916b] 137 pp. [1913 is printed on the cover, but an author's note from 1916 states that printing was delayed and post-1913 data added. Grave preferred this title over the edition published as a *University of Wyoming Bulletin*.]
62 B.H. Grove [sic], 'The influence of the development of agriculture in Wyoming upon the bird fauna', *The American Naturalist* 47 (557) (1913) 311-313.
63 W.C. Knight, *The Birds of Wyoming*, Wyoming Experiment Station, Laramie, Wyoming (1902).
64 B.H. Grave and R.C. Downing, 'The longevity and swimming ability of spermatozoa', *Journal of Experimental Zoology* 51 (3) (1928) 383-388.
65 J.F. Gemmill, 'On the vitality of the ova and spermatozoa of certain animals', *Journal of Anatomy and Physiology* 34 (2) (1900) 163-181.
66 B.H. Grave 'Further studies on the longevity and swimming ability of spermatozoa', *Biological Bulletin* 67(3) (1934) 513-518.
67 B.H. Grave, 'The natural history of *Bugula flabellata* at Woods Hole, Massachusetts, including the behaviour and attachment of the larva', *Journal of Morphology* 49 (2) 1930 355-384; B.H. Grave, 'Rate of growth, age at sexual maturity, and duration of life of certain sessile organisms, at Woods Hole, Massachusetts', *Biological Bulletin* 65 (3) (1933) 375-386. [Life history of B. flabellata on p. 384.]
68 B.H. Grave, '*Bugula flabellata* and *B. turrita*', in P.S. Galtsoff et al.(eds.), *Culture Methods for Invertebrate Animals*, Comstock, Ithaca, NY (1937) 178-179.
69 J.S. Ryland and P.J. Hayward, *Marine Flora and Fauna of the Northeastern United States. Erect Bryozoa*, NOAA Technical Report, NMF 99 (1977) 1-47.
70 B.H. Grave, 'The natural history of *Bugula flabellata* at Woods Hole, Massachusetts, including the behaviour and attachment of the larva', *Journal of Morphology* 49 (2) (1930) 355-384.
71 D.P. Costello and C. Henley, *Methods for Obtaining and Handling Marine Eggs and Embryos*, 2nd ed., Marine Biological Laboratory, Woods Hole, Massachusetts (1971) 247 pp.

72 R.C. Osburn, 'The Bryozoa of the Woods Hole region', *Bulletin of the Bureau of Fisheries* 30 (1912) 203-266.

73 It appears there is no single publication that explicitly deals with *Bugula avicularia* being incorrectly identified in material from Eel Pond and that the true identity of these specimens is *B. stolonifera*. Maturo (F.J.S. Maturo Jr., 'Bryozoa of the southeast coast of the United States: Bugulidae and Beaniidae (Cheilostomata: Anasca)' *Bulletin of Marine Science* 16(3) (1966) 556-583) states that *B. avicularia* reported to occur along the east coast of North America is likely *B. stolonifera*, but he makes no specific mention of material in Eel Pond. Maturo points out that Verrill, however, reported *B. avicularia* (USNM 4981) from "Ram Island Ledge" which Maturo suggests is Great Harbor, Woods Hole. Maturo, however, refers these specimens to *B. fulva*. That *B. avicularia* and *B. stolonifera* are, in fact, distinct species is made quite clear by Ryland (1960) – see Table 2, page 99 for comparisons of closely related species (J.S. Ryland, 'The British species of *Bugula* (Polyzoa)' *Proceedings of the Zoological Society of London* 134 (1960) 5-105.

74 M.D. Rogick, 'Phylum Ectoprocta', in R.I. Smith (ed.), *Keys to the Marine Invertebrates of the Woods Hole Region*, Contribution No. 11, Systematics-Ecology Program, Marine Biological Laboratory, Woods Hole, Massachusetts (1964) 165-187.

75 J.L. Gooch and T.J.M. Schopf, 'Population genetics of marine species of the phylum Ectoprocta', *Biological Bulletin* (2) (1970) 138-156.

76 K.W. Kaufmann, 'The form and function of the avicularia of *Bugula* (Phylum Ectoprocta)', *Postella* 151 (1971) 1-26.

77 M.S. Brancato and R. M. Woollacott (1982). The effect of microbial films on larval settlement in three species of *Bugula* (Bryozoa). *Marine Biology* 71(1) 51-56.

78 Since the establishment of *Bugula simplex, B. stolonifera*, and *B. turrita* in Eel Pond, a fourth, *B. neritina,* has appeared (C.H. Johnson, personal observation). This cosmopolitan species is a common component of fouling communities in tropical and subtropical waters worldwide. Though abundant and well-established south of Massachusetts, *B. neritina* has been sighted only occasionally in Massachusetts (J.E. Winston and P.J. Hayward, 'The Marine Bryozoans of the Northeast Coast of the United States: Maine to Virginia', Memoir 11, Virginia Museum of Natural History, Martinsville, VA. (2012) 180 pp.)

In an important study published in 2003 by McGovern and Hellberg (T. M. McGovern and M.E. Hellberg, 'Cryptic species, cryptic endosymbionts, and geographical variation in chemical defenses in the bryozoan *Bugula neritina*', *Molecular Ecology* 12 (5) (2003): 1207-1215) on cryptic species of *B. neritina*, the authors utilized material collected from Connecticut to Louisiana. The outgroups for their molecular analyses, *B. stolonifera* and *B. turrita* were collected from Woods Hole. Had *B. neritina* been obtainable at Woods Hole, the authors would have likely reported its presence and included genetic analysis of such specimens in their study as it would have extended the distribution range used in their investigation. Consequently, we place the time of introduction of *B. neritina* after 2003 and by August 2007, when it was first observed by C. H. Johnson (C. H. Johnson, personal observation). Since 2007, *B. neritina* has become a stable member of the Eel Pond fouling community (C. H. Johnson, personal observation).

No studies to date have focused on explanations for the northward dispersal of the species beyond Cape Hatteras. The common occurrence of this species south of Massachusetts and the large amount of small boat traffic, especially recreational, passing along the eastern seaboard suggest that specimens of *B. neritina* would have dispersed north on occasion as mentioned by

Winston and Hayward, but failed to become permanent residents until sometime in the last decade. One possible explanation for why the environment is now suitable for stable colonization by *B. neritina* in Massachusetts may be linked with the change in coastal water temperatures over the past decade. Long term records of sea surface temperature taken at Woods Hole document an upward trend beginning around 1960 (S. W. Nixon, S. Granger, B. A. Buckley, M. Lamont and B. Rowell, 'A one hundred and seventeen year coastal water temperature record from Woods Hole, Massachusetts', *Estuaries* 27 (3) (2004) 397-404). By 2007, it is possible that the local water temperature at Woods Hole reached a level suitable for establishment of *B. neritina*.

In a study covering the period of 2006 to 2012 of fouling bryozoans in Eel Pond and adjacent regions, Johnson and colleagues (C.H. Johnson, J.E. Winston, and R.M. Woollacott, 'Western Atlantic introduction and persistence of the marine bryozoan *Tricellaria inopinata*', *Aquatic Invasions* 7 (3) (2012) 295-303) found in a collection from September 2010 another arborescent bryozoan, *Tricellaria inopinata*. This species is common in European waters, but had not previously been reported from the western Atlantic. Specimens were not present in any preceding survey and specifically not in July of that year. Those individuals that over-wintered began regrowth late in May 2011 and began reproduction in early June. From the 2011 season to the present, *T. inopinata* remains the dominant erect bryozoan in this fouling community. Three factors apparently contribute to its success in the Eel Pond fouling community: *T. inopinata* begins reproduction earlier than the former dominant species, *B. stolonifera,* and thereby gains an advantage in colonizing space available early in the season; *T. inopinata* settles on and overgrows resident species; larvae of other species do not settle on colonies of *T. inopinata*.

79 B.H. Grave, 'Rate of growth, age at sexual maturity, and duration of life of certain sessile organisms, at Woods Hole, Massachusetts', *Biological Bulletin* 65 (3) (1933) 375-386 [Life history of *B. flabellata* on p. 384].

80 B.H. Grave, '*Bugula flabellata* and *B. turrita*', in P.S. Galtsoff et al.(eds.), *Culture Methods for Invertebrate Animals*, Comstock, Ithaca, NY (1937) 178-179.

81 F. Ormes, note 44.

82 C.P. Hickman, note 53.

83 W.E. Edington, note 43.

84 'Clark Grave', *American Civil War Soldiers*, online database by Historical Data Systems, Kingston, MA, found through http://Ancestry.com, accessed 10 October 2012.

85 *The Minnesota Alumni Weekly* 19 (1) 29 September (1919) 39; 'Field Operations', *The Medical Department of the United States Army in the World War*, 8 (1925) 466-468.

86 Caswell was a captain in the Chemical Warfare Service, Trench Warfare Branch Design Section, Washington, DC. Thomas Brooks Grave held the rank of private in the Chemical Warfare Service. *Maryland in the World War 1917-1919*, 1, Maryland War Records Commission, Baltimore (1933) 792.

87 U.S. Selective Service System, 'Benjamin Harrison Grave', World War I Draft Registration Cards 1917-1918, Illinois, Knox County, Draft Board 2, 12 September 1918; U.S. Selective Service System, 'Benjamin Harrison Grave', Selective Service Registration Cards World War II, Fourth Registration, Indiana, Putnam County, 27 April 1942.

88 Hamm, Thomas D., 1988, *The Transformation of American Quakerism: Orthodox Friends, 1800-1907*, Bloomington, Indiana University Press, 261 pp.

89 B.H. Grave to L. Grave, 28 December 1924, Letters between Lucy, Grace, Willard, Anna and

Mary Thorne Moore, 1893-1954, Moore and Grave family correspondence, Earlham College Archives.

90 Caswell Ph.D. in Zoology 1899, Benjamin Ph.D. in Zoology 1910, Thomas H. enrolled 1905-06 (no degree), Floyd MD 1914. W. Norman Brown, 1926, note 10.

91 In the 1910 census, Caswell is listed as the head of household, with his wife Josephine, their son Thomas B., and Caswell's brothers Benjamin and Thomas H. Grave residing together. *Thirteenth Census of the United States, 1910*, Baltimore Ward 13, Baltimore (Independent City), Maryland; Roll: T624_557, pg: 3B, Enumeration District 0197.

92 *Earlham Press*, Richmond, Indiana, 14 June 1916 p. 4; ibid, 6 January 1917 p .4; ibid 26 April 1919 p. 3; ibid 8 January 1921 p. 3; ibid 3 December 1923 p. 3; ibid 2 June 1931 p. 3; ibid 9 May 1933 p. 1.

93 After graduating from Earlham College in 1895, Caswell Grave entered graduate school at Johns Hopkins University where he came under the mentorship of W. K. Brooks, who was to later influence Caswell's brother Benjamin in selection of the latter's dissertation topic. Caswell Grave's dissertation concerned the larval development of a brittle star and was accepted in typescript form on May 10, 1899 (W.K. Brooks and C. Grave, '*Ophiura brevispina*.', in *Memoirs of the National Academy of Sciences*, Vol. VIII, Fourth Memoir, Government Printing Office, 1899 [Introductory note by W. K. Brooks: "As my name appears upon the title-page of this memoir, it is proper for me to state that my share in the work has been that of the instructor under whose direction the work has been done. The discovery that this ophiuran is of peculiar interest and that it is unusually favorable for the study of the problems of the morphology of Echinoderms, was made by Dr. Grave; and the results which are here detailed are his work."]). Caswell Grave remained on the faculty of Johns Hopkins University until 1919 when he moved to Washington University in St. Louis, Missouri, where he would spend the remainder of his career. While at Washington University he is credited with building the biology department to one of the most influential of its time in the country. He spent summer holidays at U. S. Commission of Fish and Fisheries laboratories, first at Woods Hole, Massachusetts, and later at Beaufort, North Carolina. He was director of the Beaufort lab from 1902 – 1906. While at Beaufort, Grave became interested in the biology of oysters and from 1906 to 1912 was shellfish commissioner for the State of Maryland. Caswell Grave devoted many summers to the Marine Biological Laboratory at Woods Hole as an instructor, investigator and trustee and later at the Carnegie Laboratory at the Dry Tortugas in Florida. In this latter stage of his career Grave became interested in the study of ascidians, focused especially on the initiation of metamorphosis of the ascidian tadpole larva (S.O. Mast, 'Caswell Grave January 24, 1870-January 8, 1944', *Science* 99 (2566) (1944): 174-175).

94 O.S. Strong, 'The Chemical Room: its Past and Present', *The Collecting Net* 2 (4) 1927, 4-5. T.B. Grave graduated from Johns Hopkins University with a Ph.D. in Chemistry in 1923.

95 *The DePauw*, note 50.

96 L. Grave to Mrs Packard, October 1936; W.C. Dennis to B.H. Grave, 21 December 1936, Moore and Grave family correspondence, Earlham College Archives.

97 C.P. Hickman, Jr., note 48; F. Ormes, note 44.

98 Certificate of Death of Benjamin H. Graves [sic], Marion County Health Department, Indianapolis, Indiana.

99 F. Ormes, note 44.

100 W.E. Edington, note 43.

101 Mary Louise Reynolds, personal communication, 29 May 2013.

Appendix 1. Publications of Benjamin Harrison Grave

Publications (Excluding Abstracts)

B.H. Grave, 1942. The sexual cycle of the shipworm, *Teredo navalis*. *Biological Bulletin* **82**(3), 438-445.

B.H. Grave, 1937a. *Bugula flabellata* and *B. turrita*, pp. 178-179. *In* P.S.Galtsoff et al.(eds.) *Culture Methods for Invertebrate Animals*. Comstock, Ithaca, NY.

B.H. Grave, 1937b. *Nereis limbata*, pp. 182-184. *In* P.S.Galtsoff et al.(eds.) *Culture Methods for Invertebrate Animals*. Comstock, Ithaca, NY.

B.H. Grave, 1937c. *Hydroides hexagonus*, pp. 185-187. *In* P.S.Galtsoff et al.(eds.) *Culture Methods for Invertebrate Animals*. Comstock, Ithaca, NY.

B.H. Grave, 1937d. *Chaetopleura apiculata*, pp. 519-520. *In* P.S.Galtsoff et al.(eds.) *Culture Methods for Invertebrate Animals*. Comstock, Ithaca, NY.

B.H. Grave, 1937e. *Cumingia tellinoides*, pp. 543-545. *In* P.S.Galtsoff et al.(eds.) *Culture Methods for Invertebrate Animals*. Comstock, Ithaca, NY.

B.H. Grave, 1937f. Rearing *Teredo navalis*, pp. 545-546. *In* P.S.Galtsoff et al.(eds.) *Culture Methods for Invertebrate Animals*. Comstock, Ithaca, NY.

B.H. Grave and J. Smith, 1936. Sex inversion in *Teredo navalis* and its relation to sex ratios. *Biological Bulletin* **70**(2), 332-343.

B.H. Grave, 1934. Further studies on the longevity and swimming ability of spermatozoa. *Biological Bulletin* **67**(3), 513-518.

B.H. Grave, 1933. Rate of growth, age at sexual maturity, and duration of life of certain sessile organisms, at Woods Hole, Massachusetts. *Biological Bulletin* **65**(3), 375-386. [Life history of *B. flabellata* on pg. 384]

B.H. Grave, 1932. Embryology and life history of *Chaetopleura apiculata*. *Journal of Morphology* **54**(1), 153-160.

B.H. Grave, 1931. The Amphibia of Montgomery County, Indiana. *Proceedings of the Indiana Academy of Science* **40**, 339.

B.H. Grave, 1930. The natural history of *Bugula flabellata* at Woods Hole, Massachusetts, including the behaviour and attachment of the larva. *Journal of Morphology* **49**(2), 355-384.

B.H. Grave and J.F. Oliphant, 1930. The longevity of unfertilized gametes. *Biological Bulletin* **59**(2), 233-239.

B.H. Grave, 1928a. Natural history of shipworm, *Teredo navalis*, at Woods Hole. *Biological Bulletin* **55**(4), 260-282.

B.H. Grave, 1928b. Vitality of the gametes of *Cumingia tellinoides*. *Biological Bulletin* **54**(5), 351-362.

B.H. Grave and R.C. Downing, 1928. The longevity and swimming ability of spermatozoa. *Journal of Experimental Zoology* **51**(3), 383-388.

B.H. Grave, 1927a. An analysis of the spawning habits and spawning stimuli of *Cumingia* *tellinoides*. *Biological Bulletin* **52**(6), 418-435.

B.H. Grave, 1927b. The natural history of *Cumingia tellinoides*. *Biological Bulletin* **53**(3), 208-219.

B.H. Grave, 1922. An analysis of the spawning habits and spawning stimuli of *Chaetopleura apiculata* (Say). *Biological Bulletin* **42**(5), 234-256.

B.H. Grave, 1917. *Zeugophora scutellaris* (Suffr.). *Journal of Morphology* **30**(1), 245-259.

B.H. Grave and E.P. Walker, 1916a. Wyoming birds and their value to agriculture. *University of Wyoming Bulletin* **12**(6), 1-137.

B.H. Grave and E.P. Walker, 1913 [1916b]. *The Birds of Wyoming with an explanation of recent changes in their distribution, economic aspects also considered*. University of Wyoming, Laramie, Wyoming, 137 p. [1913 is printed on the cover, but an author's note from 1916 states that printing was delayed and post-1913 data added. Grave preferred this title over the edition published as a University of Wyoming Bulletin.]

B.H. Grave, 1914. *Laboratory Guide for a Course in Invertebrate Zoology*. Cadmus Press, Galesburg, Illinois. 113 p.

B.H. Grave, 1913. The influence of the development of agriculture in Wyoming upon the bird fauna. *American Naturalist* **47**(557), 311-313. [Author's name misprinted as B.H. Grove.]

B.H. Grave, 1912. The otocyst of the Pinnidae. *Biological Bulletin* **24**(1), 14-17.

B.H. Grave, 1911. Anatomy and physiology of the wing-shell *Atrina rigida*. *Bulletin of the Bureau of Fisheries* **29**, 409-439, pls. XLVIII-L. [Published version of Grave's Ph.D. dissertation]

B.H. Grave, 1909a. *Pinna seminuda*. *Johns Hopkins University Circulars* **6**, 46-51.

B.H. Grave, 1909b. Some observations on the habits of *Pecten dislocatus*. *Biological Bulletin* **16**(5), 259-264.

Abstracts

B.H. Grave, 1942. The sexual cycle in *Teredo navalis*. *Proceedings of the Indiana Academy of Science* **51**, 265.

B.H. Grave, 1932. Further studies on the longevity and swimming ability of spermatozoa. *Anatomical Record* **54**(3, Supplement), 24.

B.H. Grave, 1929a. Behavior of the larva of *Bugula flabellata*. *Anatomical Record* **44**(3), 198.

B.H. Grave, 1929b. Periodicity in spawning by *Cumingia tellinoides*. *Anatomical Record* **44**(3), 198.

B.H. Grave and J.F. Oliphant, 1929. The longevity of unfertilized gametes. *Anatomical Record* **44**(3), 199. [Oliphant's initials are misprinted as J.K. Oliphant in the original.]

B.H. Grave, 1924. Rate of growth and age of sexual maturity of certain sessile organisms. *Anatomical Record* **29**(2), 90.

Unpublished Works

B.H. Grave, 1910. Anatomy and physiology of *Atrina (Pinna) rigida* (Dillwyn). 67 p. [Typescript of Ph.D. dissertation, Johns Hopkins University.]

B.H. Grave, 1906. The Development of the Microspore and Megaspore in *Lilium tigrinum*. [M.S. thesis, Carleton College.]

B.H. Grave, n.d. The Destiny of Man. 49 p. [Incomplete draft document. Typescript donated to Earlham College Archives by Bartram Cadbury (Grave's nephew), 1997.]

Appendix 2. Marine invertebrate species published on by Benjamin Harrison Grave

Journal articles and contributions to an edited volume, but excluding published abstracts. No attempt has been made in compiling this list to update the taxonomic status of the species studied by Grave.

Annelida - Polychaeta
Chaetopleura apiculata 1922, 1932, 1937
Hydroides hexagonus 1930, 1933, 1937
Nereis limbata 1937

Arthropoda - Crustacea
Balanus eberneus 1933

Bryozoa - Gymnolaemata
Bugula flabellata 1930, 1933, 1937
Bugula turrita 1930, 1937

Chordata - Urochordata - Ascidiacea
Botryllus gouldii 1933
Molgula manhattensis 1933

Cnidaria - Hydrozoa
Campanularia calceolifera 1933
Campanularia flexuosa 1933
Gonothyrea loveni 1933
Obelia commissuralis 1933

Echinodermata- Echinoidea
Arbacia punctulata 1928, 1934

Mollusca – Bivalvia

Atrina rigida 1911, 1912
Cumingia tellinoides 1927a, 1927b, 1928, 1928b, 1933, 1934, 1937
Pecten dislocatus 1909
Pinna nobilis 1912
Pinna seminuda 1909a
Pinna sp. (unidentified small red *Pinna* from Jamaica)
Teredo navalis 1928a, 1933, 1936. 1937, 1942

Cleaning and conservation of fossil bryozoan cavity slides of the William Dickson Lang Collection at the Natural History Museum, London

Consuelo Sendino
Department of Earth Sciences, Natural History Museum, London SW7 5BD, UK

1. Introduction

The Natural History Museum, London, holds one of most significant collections of fossil bryozoans, collected by William Dickson Lang (1878-1966), who was one of the most important proponents of the theory of orthogenesis[1] and a Keeper of the Department of Geology at the British Museum (Natural History). There are more than 2,800 specimens in cavity slides that date from the first half of the 20th century and include numerous type and figured Cretaceous cribrimorphs. The material is important in illustrating Lang's ideas about the orthogenetic[2] evolution of this group of cheilostomes. 86% of the specimens are types (1210), figured (297), described or only cited in the 131 publications of Lang. It is therefore one of the most important bryozoan fossil slide collections of published specimens. 86% of his specimens originate from England, 12% are from Europe and 2% are from USA (see Figure 9).

Lang's slide collection comprises small fragments of colonies mounted in wooden cavity slides and stained with blue paint. This paint forms a thick coating on the surfaces of the colonies, obscuring details vital to the identification of the bryozoans. The paint was originally applied to emphasize morphological features, such as spines and pores, which are difficult to see in these very white specimens from the Chalk. Unfortunately, when coated specimens are studied using a scanning electron microscope spots of paint pigment

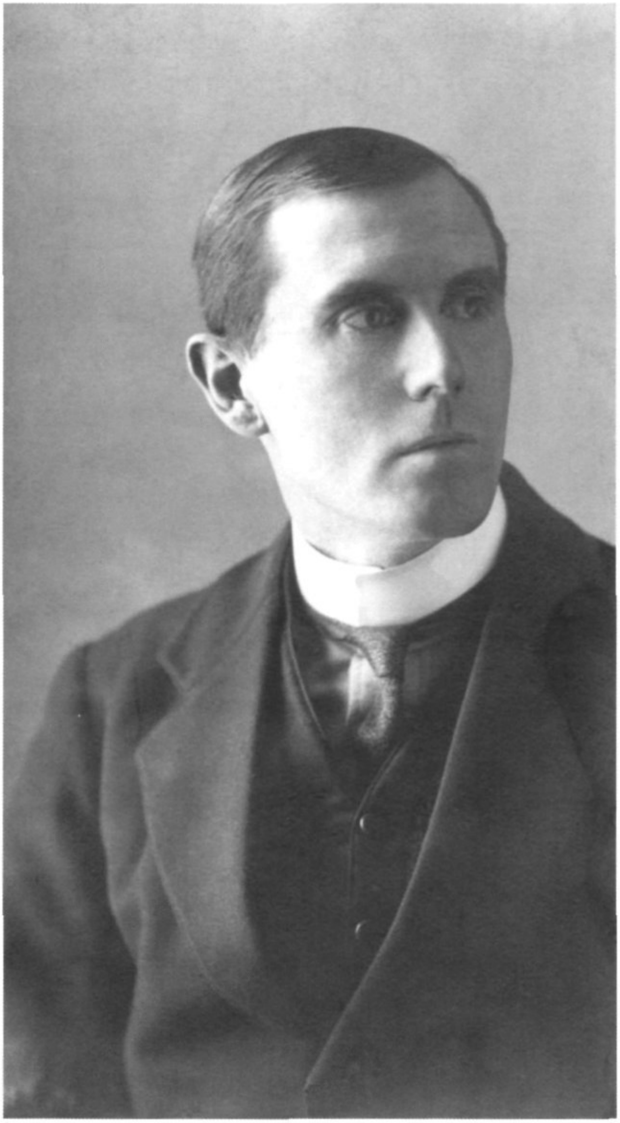


Figure 1 William Dickinson Lang (1878-1966). NHM photograph. Archive reference PH/10/13.

dominate the images. Preliminary cleaning experiments have been undertaken using ultrasonic treatment in water, and with the addition of bleach or Quaternary-O. Dramatic results were obtained in all cases with the skeletal features of the bryozoans becoming clear for the first time.

2. William Dickson Lang (1878-1966)

William Dickson Lang[3] (Figure 1) was born on 29th December 1878 in the Indian Punjab, where his father Edward Tickell Lang was working as a civil engineer, engaged in the construction of the Jumna Canal. His family moved to England when he was one year old. In 1894 he began his education[4] at Christ's Hospital School in Hertford, moving to Harrow School in Harrow in north west London. In 1898 he went up to Pembroke College, Cambridge, where he read Natural Sciences. He was awarded the degree of Bachelor of Arts in Part I in 1901 and Part II in 1902, receiving the degree of Master of Arts in 1903.[5]

While he was still studying, he began working for the Department of Geology of the British Museum (Natural History) on 1st October 1902 as an assistant[6] in charge of the Protozoa, Coelenterates, Sponges and Polyzoa collections. During the First World War he worked in the Department of Entomology curating mosquitos.[7] A year later, he gained his Ph.D. from Cambridge University and returned to work in the Department of Geology where he became Assistant Keeper in 1921, Deputy Keeper in 1927 and Keeper in 1928, a post that he held until his retirement in 1938.

During his life he researched a wide variety of subjects[8] varying from mosquitos, corals and bryozoans to geology, and he published innumerable papers. E.I. White (1966) cited 131 publications by W.D. Lang. His first articles on bryozoans[9] date from 1904 and are on Cretaceous cyclostomes and cheilostomes, concentrating largely on cribrimorph cheilostomes and he went on to propose the orthogenesis theory (Figures 2-5). He described this as:

> The study of development stages focused attention on the modifications in time of single characters, and showed how a character, independently in different lineages, continually appeared to run through a similar course of development, and often to continue this course until it became so exaggerated as to threaten the organism's existence.[10]

Lang was a member of the Council of the Geological Society from 1923 to 1926 and was awarded the Lyell Medal of the Geological Society of London in 1928. In 1929 he was elected Fellow of the Royal Society.

After his retirement at the age of 60, he lived in Charmouth, Dorset, where he continued his studies on natural history. Until his death on 3rd March 1966 at the age of 87, the majority of his time was devoted to the study of the local geology.[11]

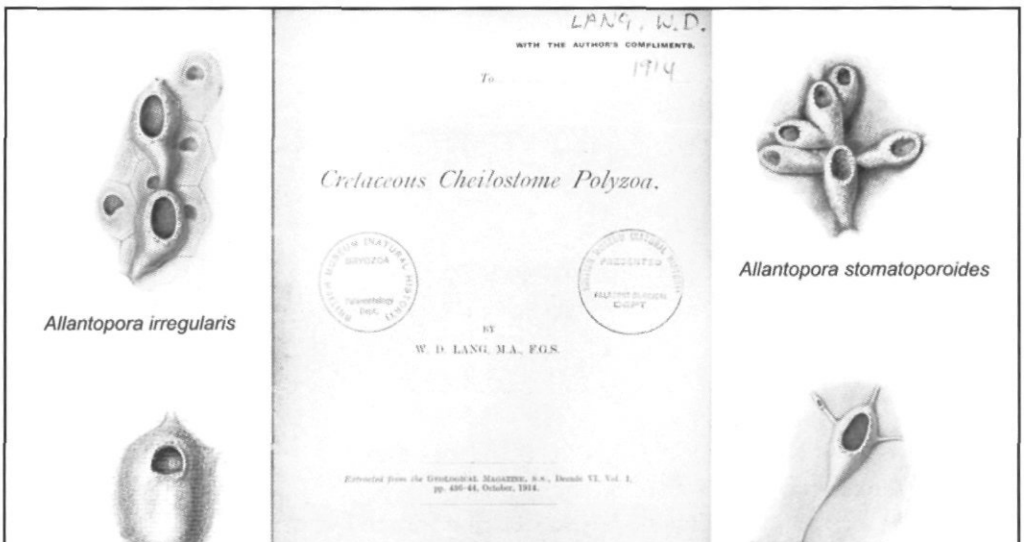
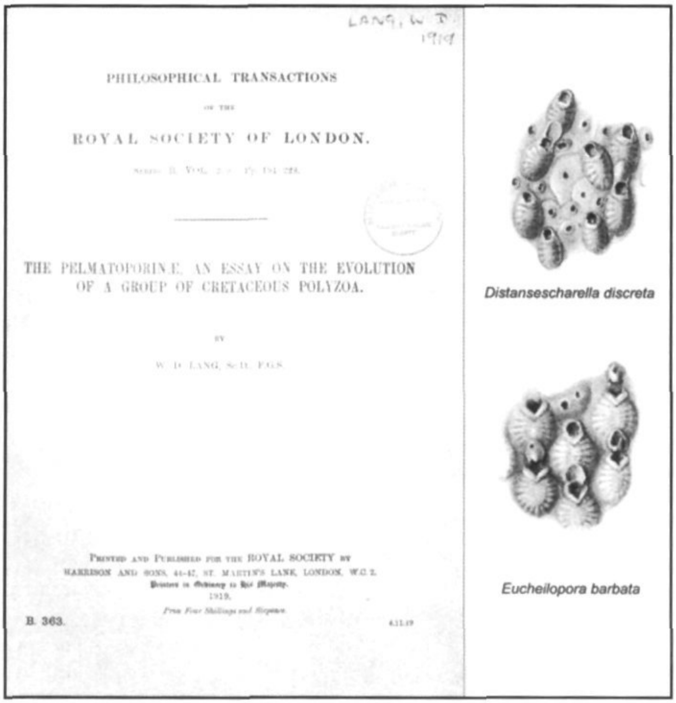


Figure 2. Monograph with Cretaceous cheilostomes described by Lang in 1914.



PHILOSOPHICAL TRANSACTIONS

OF THE

ROYAL SOCIETY OF LONDON.

THE PELMATOPORINÆ, AN ESSAY ON THE EVOLUTION OF A GROUP OF CRETACEOUS POLYZOA.

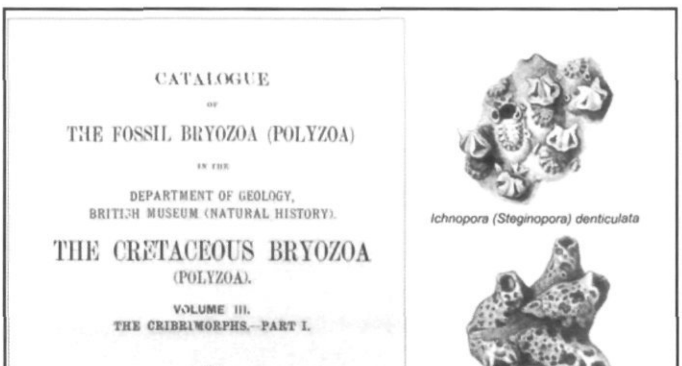
BY

W. D. LANG, Sc.D., F.G.S.

Printed and Published for the ROYAL SOCIETY by HARRISON AND SONS, 44-47, ST. MARTIN'S LANE, LONDON, W.C. 2.
Printers in Ordinary to His Majesty.
1919.

B. 363.

Figure 3. Monograph with Cretaceous cheilostomes described by Lang in 1919.



CATALOGUE

OF

THE FOSSIL BRYOZOA (POLYZOA)

IN THE

DEPARTMENT OF GEOLOGY,
BRITISH MUSEUM (NATURAL HISTORY).

THE CRETACEOUS BRYOZOA (POLYZOA).

VOLUME III.
THE CRIBRIMORPHS.—PART I.

BY

W. D. LANG, Sc.D., F.G.S.

WITH EIGHT PLATES.

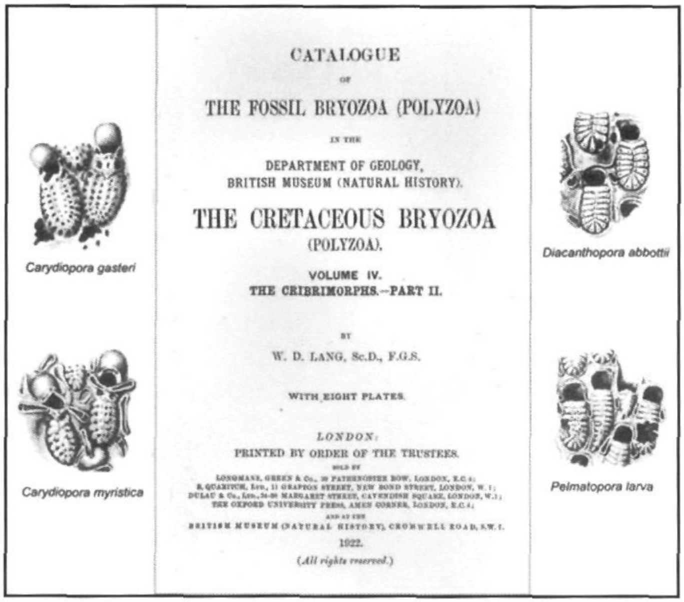
LONDON:
PRINTED BY ORDER OF THE TRUSTEES.

1921.

(All rights reserved.)

Figure 4. Monograph with Cretaceous cheilostomes described by Lang in 1921.

Figure 5. Monograph with Cretaceous cheilostomes described by Lang in 1922.

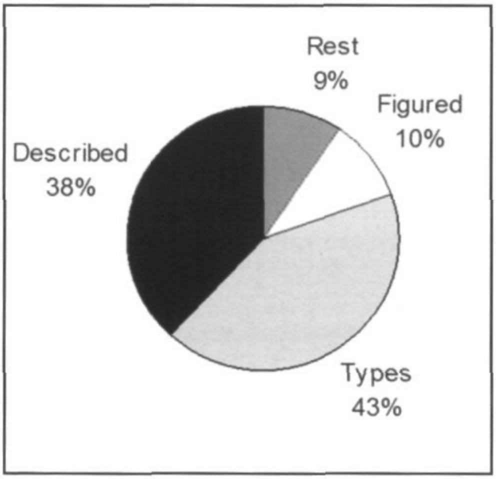


CATALOGUE
OF
THE FOSSIL BRYOZOA (POLYZOA)
IN THE
DEPARTMENT OF GEOLOGY,
BRITISH MUSEUM (NATURAL HISTORY).
THE CRETACEOUS BRYOZOA
(POLYZOA).
VOLUME IV.
THE CRIBRIMORPHS.—PART II.
BY
W. D. LANG, Sc.D., F.G.S.
WITH EIGHT PLATES.
LONDON:
PRINTED BY ORDER OF THE TRUSTEES.
1922.
(All rights reserved.)

Figure 6. Trays from the wooden cavity slide cabinets at the NHM, London, where the Lang Collection is kept.

3. Fossil Bryozoan Collection of W.D. Lang

The Lang Collection is housed at the NHM, London, and includes 2866 specimens catalogued, mostly published and preserved in cavity slides (Figure 6). There are 216 different species that belong to 88 genera, being 43% of types, 10% figured specimens and 38% cited (Figure 7). 86% are from England (Sussex 927; Surrey 585; Cambridgeshire 189; Norfolk 141; etc.) (Figure 8), 5% from Germany, 3% from France, 2% from the USA and also Denmark, 1% from Holland and Bohemia as well and a very small proportion from Sweden and Russia (Figure 9).



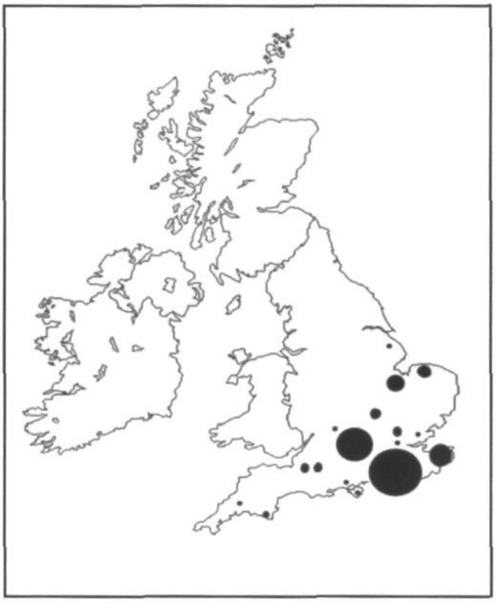


Figure 7 (above). Percentage of types, figured and cited specimens of the Lang Collection. Figure 8 (right). Geographical distribution in UK after abundance of the Lang Collection.

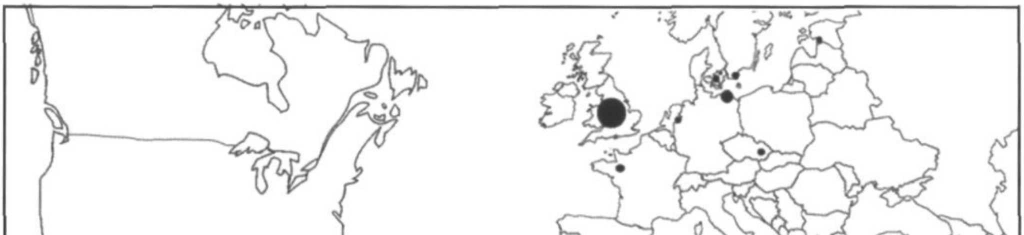


Figure 9. Geographical distribution in the world after abundance of the Lang Collection.

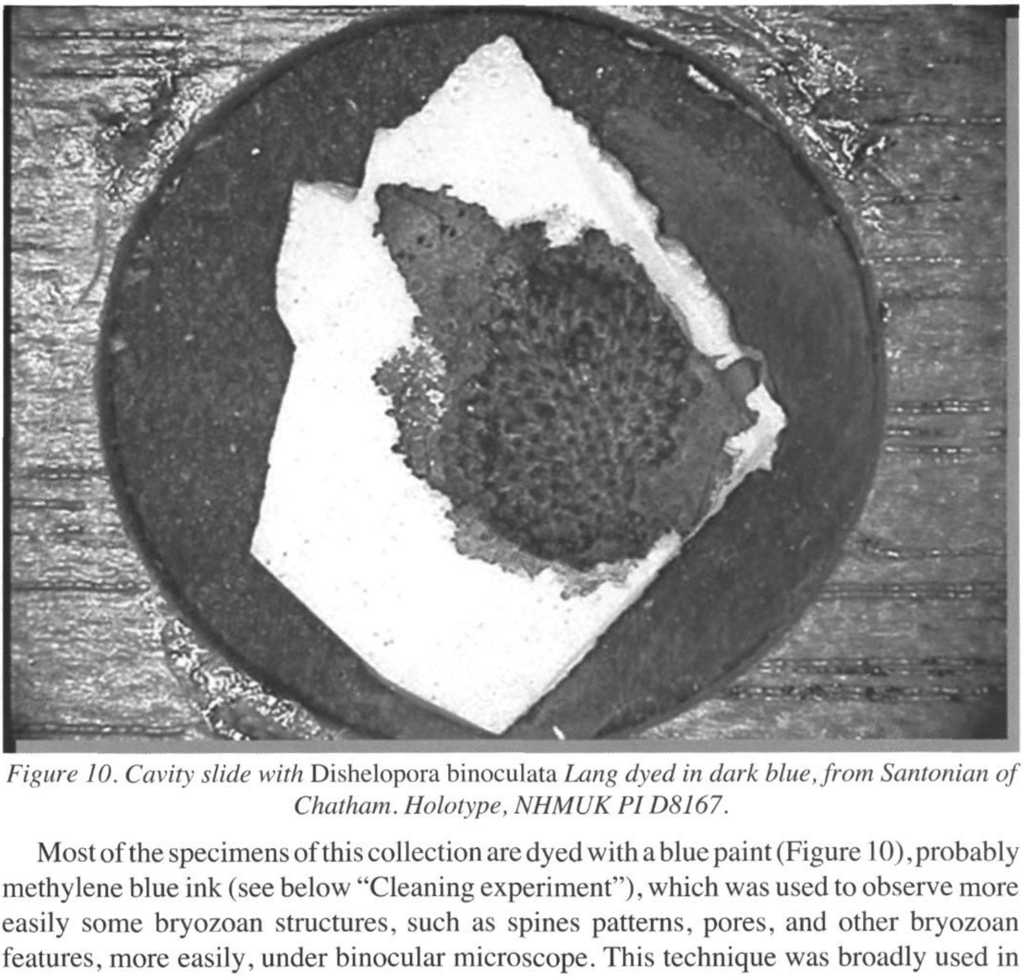


Figure 10. Cavity slide with Dishelopora binoculata *Lang dyed in dark blue, from Santonian of Chatham. Holotype, NHMUK PI D8167.*

Most of the specimens of this collection are dyed with a blue paint (Figure 10), probably methylene blue ink (see below "Cleaning experiment"), which was used to observe more easily some bryozoan structures, such as spines patterns, pores, and other bryozoan features, more easily, under binocular microscope. This technique was broadly used in Entomology[12] and probably Lang learned it when he worked in the Department of Entomology during the First World War as these specimens were published after 1914. This thick coating makes it very hard to identify specimens precisely with the use of current techniques such as SEM (Scanning Electron Microscopy).

Almost 14% (13.71%) of the collection has been redetermined by Dr Gilbert Powell Larwood (1930-1997) in his 1956 Ph.D. thesis[13] and in the *Bulletin of the British Museum (Natural History)* published in 1962.[14]

4. Cleaning experiment

Three cavity slides with a thick layer of blue paint (Figure 11) were chosen for the preliminary cleaning experiment. All of them came from the Cretaceous Chalk of England and are, therefore, resistant to weathering. One was cleaned in the ultrasonic cleaner with normal tap water; another was cleaned in the ultrasonic cleaner with the addition of bleach

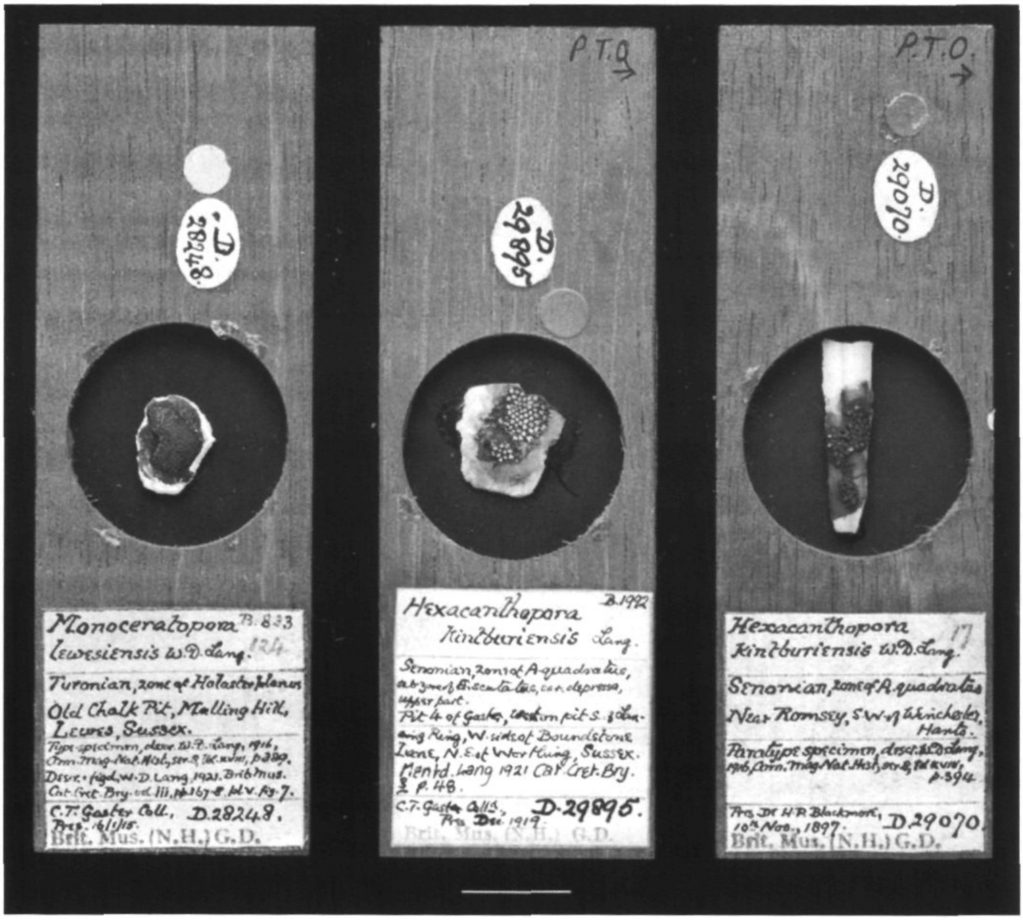


Figure 11. Cavity slides chosen for the cleaning experiment. On the left side NHMUK PI D28248, holotype of Monoceratopora lewesiensis *Lang, 1916 from Turonian of Sussex. In the centre NHMUK PI D29895, cited specimen of* Hexacanthopora kintburiensis *Lang, 1916, from Campanian of Worthing. On the right side NHMUK PI D29070, paratype of* Hexacanthopora kintburiensis *Lang, 1916, from Campanian of Winchester. Scale bar 10 mm.*

(about 5%) and the last one in the same way as the first, but with the addition of Quaternary-O in a similar proportion. The duration of the immersion in the ultrasonic tank was precisely five minutes.

The blue paint that covers the fossil bryozoans could be (1) carbon ink, possibly the oldest ink used, that (during the 19th century was artificially darkened with a blue pigment such as e.g. Prussian blue[15,16]) or it could be also (2) Indian ink.[17] Both inks do not penetrate the surface that cover, but they are highly resistant to chemical bleaches[18] because the colour comes from a layer that has the carbon that is in suspension in the ink. In the experiment carried out, one of the specimens was easily completely cleaned with a solution of bleach, making not possible to have any of inks cited previously. Another possibility is that it is Blue Ink, e.g. the Prussian blue, which when first used was not

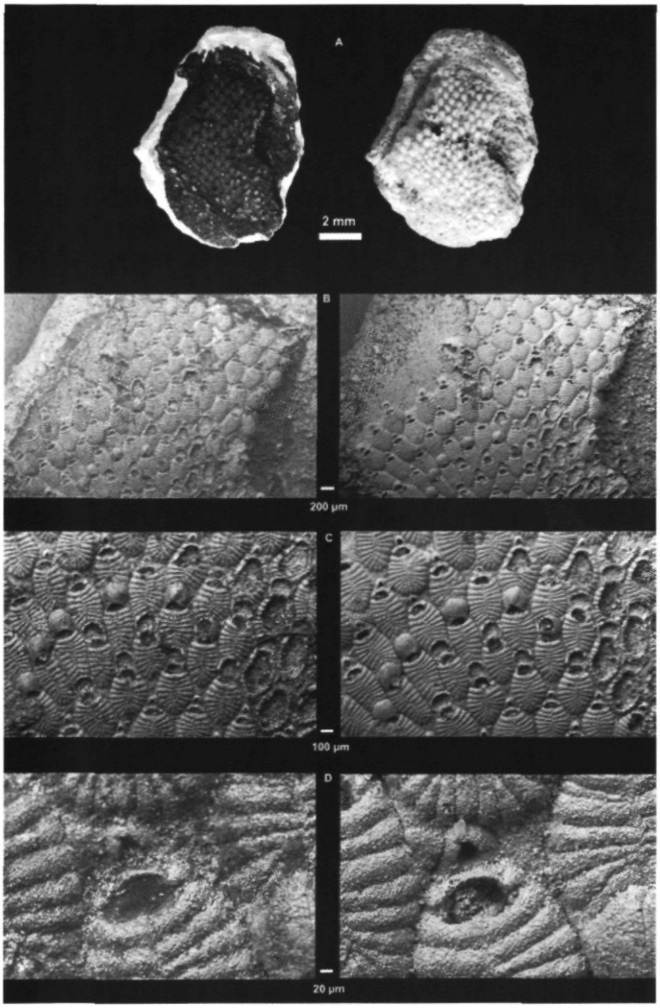


Figure 12. NHMUK PI D28248, holotype of Monoceratopora lewesiensis *Lang, 1916 from Turonian of Sussex. A. General view of the specimen on the left without cleaning and on the right after cleaning in the ultrasonic cleaner plus water. B-D. SEM photographs of the specimen with different magnifications without cleaning on the left side and with cleaning on the right side.*

particularly water-soluble; subsequently a change in composition in 1845 made it less water-resistant. This ink was rarely used at the beginning of the 20th century when Lang dyed the fossil bryozoans of its collection. Finally, the most probable ink used is the methylene blue ink[19, 20] (a thiazine dye), a very important zoological stain[21] that is introduced in the market in 1887 and widely used the first quarter of the 20th century.

NHMUK PI D28248, the holotype of *Monoceratopora lewesiensis* Lang, 1916 was cleaned in the ultrasonic cleaner with normal tap water. This is the most important specimen of the three, and is why it was cleaned only with water. NHMUK PI D29895, a cited specimen of *Hexacanthopora kintburiensis* Lang, 1916 was cleaned in the ultrasonic cleaner with water and 5% of bleach [solution of sodium hypochlorite NaOCl]. NHMUK PI D29070, a paratype of *Hexacanthopora kintburiensis* Lang, 1916 was cleaned in the ultrasonic cleaner with water and 5% of Quaternary-O [a chemical detergent of a high molecular weight mainly used to clean microfossils from clay particles.[22, 23]]

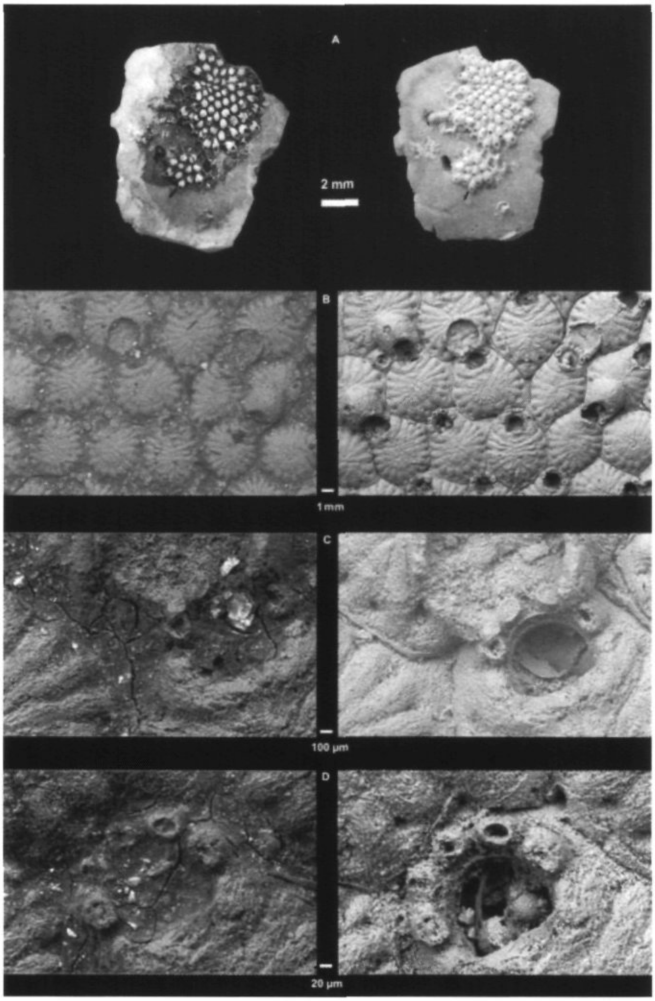


Figure 13. NHMUK PI D29895, cited specimen of Hexacanthopora kintburiensis *Lang, 1916, from Campanian of Worthing. A. General view of the specimen on the left without cleaning and on the right after cleaning in the ultrasonic cleaner plus water and bleach. B-D. SEM photographs of the specimen with different magnifications without cleaning on the left side and with cleaning on the right side.*

5. Result

The results of these experiments were successful for all of three specimens, revealing all the skeletal features preserved in the bryozoans (Figures 12-14). Among the different methods used, it was the combination of water and bleach that obtained the best results, as it completely removed the blue paint. The other two methods, one with Quaternary-O and the other with only water, both left some residual colour.

The reason why bleach was the most successful is that it works breaking the double bonds of chromophores,[24] which are regarded as being responsible for the colored

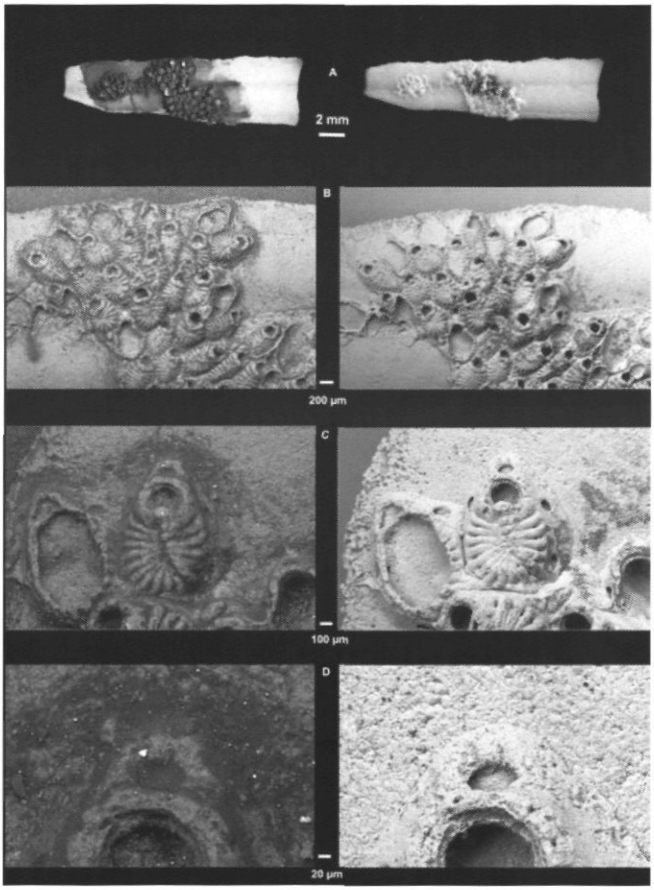


Figure 14. NHMUK PI D29070, paratype of Hexacanthopora kintburiensis *Lang, 1916, from Campanian of Winchester. A. General view of the specimen on the left side without cleaning and on the right after cleaning in the ultrasonic cleaner plus water and Quaternary-O hand side. B-D. SEM photographs of the specimen with different magnifications without cleaning on the left side and with cleaning on the right side.*

properties. The consequence is that this group of atoms loses the colour or reflects it outside the visible spectrum.

6. Conclusions

Good results have been obtained with all three treatments to clean Chalk fossils previously dyed with blue ink -certainly methylene blue ink-, i.e. with normal cold tap water, with water plus 5% solution of bleach and water with 5% Quaternary-O, all of them introduced in ultrasonic cleaner for five minutes. Although all three methods worked, I would endorse the use of a solution of water and 5% bleach because there was no residual blue ink adhering to the specimen after the treatment.

7. Acknowledgements

I am very grateful to Anna Taylor (NHM, London) for databasing the Lang Collection.

Notes

1 Taylor, P.D. 2002. W.D. Lang, orthogenesis and the evolution of Cretaceous cribrimorph Bryozoa, pp. 275-298. *In* P.N. Wyse Jackson and M.E. Spencer Jones, M.E. (eds). *Annals of Bryozoology*. International Bryozoology Association, Dublin.
2 Lang, W.D. 1916. Calcium carbonate and evolution in Polyzoa. *Geological Magazine*, Decade 6, **3**, 73-77.
3 White, E.I. 1966. William Dickson Lang 1878-1966. *Biographical Memoirs of Fellows of the Royal Society* **12**, 366–326.
4 Snow, K.R. 2003. William Dickson Lang-a pioneer of British mosquito study. *European Mosquito Bulletin* **16**, p. 6.
5 White, note 3.
6 Taylor, note 1.
7 Snow, note 4.
8 White, note 3.
9 Taylor, note 1.
10 White, note 3.
11 White, note 3.
12 Balfour-Browne, F. 1922. 5. The life-history of the Water-Beetle *Pelobius tardus* Herbst. *Proceedings of the Zoological Society of London* **92** (1), 79-97.
13 Larwood, G.P. 1956. *A study of certain Polyzoa of the English Chalk*. University College, London, 446 & 138 pls.
14 Larwood, G.P. 1962. The Morphology and Systematics of some Cretaceous Cribrimorph Polyzoa (Pelmatoporinae). *Bulletin of the British Museum (Natural History). Geology* **6** (1), 1-285.
15 Fulton, R.A. and Van Dyke, M.J. 1947. Determination of small quantities of hydrogen cyanide in insects and plant tissue. *Analytical Chemistry* **19** (11), 922-923.
16 Gotoh , A., Uchida, H, Ishizaki, M., Satoh, T., Kaga, S., Okamoto, S., Ohta, M., Sakamoto, M., Kawamoto, T., Tanaka, H., Tokumoto, M., Hara, S., Shiozaki, H., Yamada, M., Miyake, M. and Kurihara, M. 2007. Simple synthesis of three primary colour nanoparticle inks of Prussian blue and its analogues. *Nanotechnology* **18** (34), 345609.
17 Ramachandra Rao, T. 1947. Visual responses of mosquitoes artificially rendered flightless. *The Journal of Experimental Biology* **24** (1-2), 64-78.
18 Ainsworth Mitchell, C. and Ward, T.J. 1932. Sediments in ink and in writing. *Analyst* **57**, 760-770.
19 Nickell, J. 1996. *Detecting Forgery: Forensic Investigation of Documents*. University of Kentucky Press, Lexington, KY, 228 pp.
20 Blüher, A., Haberditzl, A. and Wimmer, T. 1999. Aqueous conservation treatment of 20th century papers containing water-sensitive inks and dyes. *Restaurator* **20**, 181–197.
21 Conn, H.J. 1953. *Biological stains; a handbook on the nature and uses of the dyes employed*

in the biological laboratory. 6th edition. Biological Stain Commission, Maryland, 367 pp.
22 Hills, L.V. and Sweet, A.R. 1972. The use of "Quaternary O" in megaspore palynological preparations. *Review of Palaeobotany and Palynology* **13**, 229–231.
23 Zingula, R.P. 1968. A new breakthrough in sample washing. *Journal of Paleontology* **42** (4), p. 1092.
24 Gordon, P.F. and Gregory, P. 1987. The development of dyes, pp. 1-22. *In* P.F. Gordon and P. Gregory (eds), *Organic chemistry in colour*. Springer Berlin Heidelberg, Berlin, 322 pp.

Bryozoans of the Krusenstern Expedition (1803-1806)

Abigail M. Smith,[1] Mary E. Spencer Jones[2] and Patrick N. Wyse Jackson[3]
[1]*Department of Marine Science, University of Otago, P.O. Box 56, Dunedin 9054, New Zealand*
[2]*Zoology, Natural History Museum, Cromwell Road, London SW7 5BD, United Kingdom*
[3]*Department of Geology, Trinity College, Dublin 2, Ireland*

1. Introduction

In the late 18th century, the western world was well into the Age of Sail, with schooners, sloops, corvettes and frigates increasingly able to cross whole oceans, bringing home scientific specimens from unimaginably distant lands and seas. Among these natural treasures were strange stony creatures, not unlike corals but also not quite like them either. These so-called "zoophytes" were a taxonomic mystery for some time.

By the end of the 18th century, species that would later be known as bryozoans had been described by, among others, Ellis (1755), Linnaeus (e.g., 1758), Pallas (1766), and Ellis and Solander (1786), but in most cases they had been classified as corals. The notion of a group of "polypiers" (*sensu* Lamouroux 1812, 1816; Lamarck, 1816) was yet to come, and the phyla Polyzoa (Thompson 1830) and Bryozoa (Ehrenberg 1831) would not be defined for several decades.

At the same time, Captain Adam Johann von Krusenstern (1770-1846), (also known as Ivan Fjodorovitch Krusenstern) (Figure 1), who had been born in Estonia, and who had served in the English navy for some time, proposed that direct communication between Russia and China could be best achieved by sailing round Cape Horn and then the Cape of Good Hope (Fedorova 2011). Tsar Alexander I subsequently appointed him to command a voyage to the east coast of Asia, which would later prove to be the first

Figure 1. Adam Johann von Krusenstern (1770-1846)

circumnavigation of the world by a Russian expedition. While the main purposes of the voyage were to establish or enhance trade links with China, Japan, South America and possibly even California, amongst the crew were a number of naturalists who undertook the diligent collection of flora and fauna, which were brought back to Europe for subsequent examination, analysis, illustration and publication.

Here we describe, firstly, the expedition and its achievements; secondly, the research carried out on the bryozoans collected; and thirdly, discuss the various bryozoan genera erected from this material.

2. The Expedition

At the beginning of the 19th century, Tsar Alexander I and Baron Nikolai P. Rezanov (1764-1807) commissioned Captain Krusenstern to explore the northern Pacific, establish trade with China and Japan, enhance links in South America, and consider the possibility of using California as a Russian colony (Fedorova 2011).

The importance of this voyage to Russia is difficult to overstate. It was the first time that a Russian ship had crossed the Equator (Vinkovetsky 2001), and the Tsar himself farewelled the ships at Kronstadt (the main seaport of St Petersburg, Russia), and later welcomed them back on their return. The maritime connection between the far-distant ends of the Russian Empire was an important innovation for trade and communication; at

Figure 2. Yuri Fyodorovich Lisiansky (1773-1837) (Portrait by Vladimir Borovikovsky (1757–1825); from www.nasledie-rus.ru)

the same time, observations as to how other major powers managed their colonies informed Russian aspirations regarding their own (Vinovetsky 2001). Participants left accounts that continue to be cited in both current natural history and ethnographic research (Fedorova 2011).

The Russian-American Company acquired for the expedition two British vessels. The HMS *Leander*, a 430 tonne, three-masted sloop built in 1800, was re-christened *Nadezhda* (meaning 'Hope'), and placed under the command of Captain Krusenstern. There were 58 crew and 16 guns aboard (Tredrea & Sozaev 2010). The sloop-of-war HMS *Thames* was re-named *Neva* (after the river that flows through St Petersburg) and placed under the command of Captain-Lieutenant Yuri Fyodorovich Lisiansky (1773-1837) (Figure 2). She was the smaller vessel at 61 m and weighing 380 tonnes, with a crew of about 50, and was equipped with 14 guns (Tredrea & Sozaev 2010). The two ships arrived ready for duty in the Baltic Sea in May 1803.

The *Nadezhda* and the *Neva* set sail from Kronstadt on 7 August 1803 (Krusenstern 1810-14), and Baron Rezanov was on board, bound for diplomatic negotiations in Japan (Tumarkin 1979, Vinkovetsky 2001). They travelled across the Baltic and Atlantic Oceans, past the Canary Islands and Brazil, rounded Cape Horn, where they were separated by a storm. The *Neva* went to Easter Island, whereas the *Nadezhda* sailed to the Marquesas Islands, where the ships were reunited in May 1804. Both ships then sailed on to the Hawaiian Islands (Tumarkin 1979).

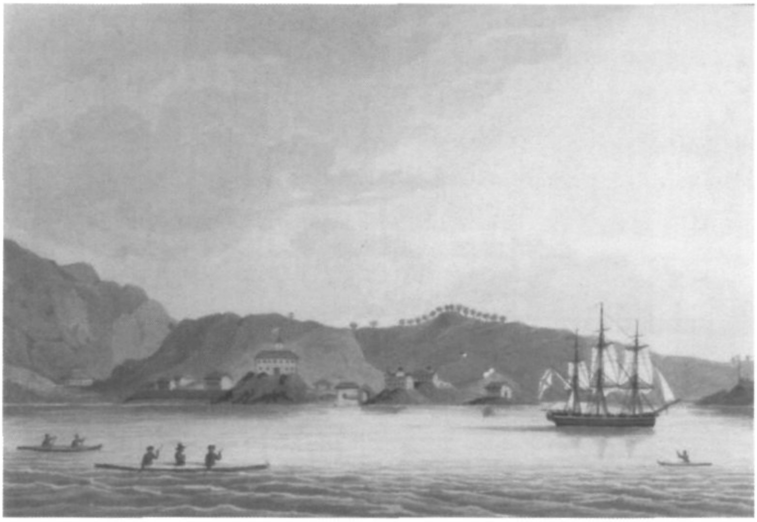


Figure 3. The Neva *entering the harbour of St Paul at Kodiak Island, Alaska (from Lisiansky 1814).*

After they reached Hawaii, the two ships split up (Tumarkin 1979). The *Neva* stayed in Hawaii for a time, then went on to Russian America (Figure 3), ending up in Sitka, Alaska, where she took part in the battle of Sitka, defeating a native Tlingit uprising. Meanwhile the *Nadezhda* travelled to Kamchatka and on to Japan, where she spent six months in Nagasaki harbour (Fedorova 2011). The ships met up again briefly in Macao (Nov 1804 – Feb 1805) but sailed separately thereafter. The *Neva* reached home first, on 22 July 1806. Meanwhile Krusenstern and the *Nadezhda* rounded the Cape of Good Hope and travelled north along the African coast, visiting the island of St Helena before reaching the Baltic Sea, arriving back at Kronstadt on 19 August 1806, just over three years after they had left, with all hands safe on board (Figure 4).

A visit by the expedition was described in *Swiss Family Robinson* (Wyss 1812); indeed, the Swiss astronomer on board brought along one of the (fictional) Robinson children in order to provide further education in astronomy.

Tsar Alexander I made sure that this expedition had the best officers, top scholars, and finest artists on board (Vinkovetsky 2001). Aside from the Captains, Krusenstern and Lisiansky, and the emissary Rezanov there were several naturalists on board: the German, Dr Wilhelm Gottlieb Tilesius, or Vilgelm Gotlob von Tilenau, (1769-1857) stayed with the *Nadezhda*, whereas Grigori Ivanovitch Langsdorff (aka Georg Heinrich von Langsdorff)(1774-1852) left the ship in Kamchatka and explored Alaska for several years before returning in 1808. Johan Caspar Horner (1734-1834) of Zurich was a physicist and astronomer on board.

After completing her circumnavigation of the world, *Nadezhda* became a merchant ship, delivering goods from Russia to the USA. In December 1808 she was caught in ice near Denmark and lost (Tredrea & Soazaev 2010). At least one gulf, four capes, a strait,

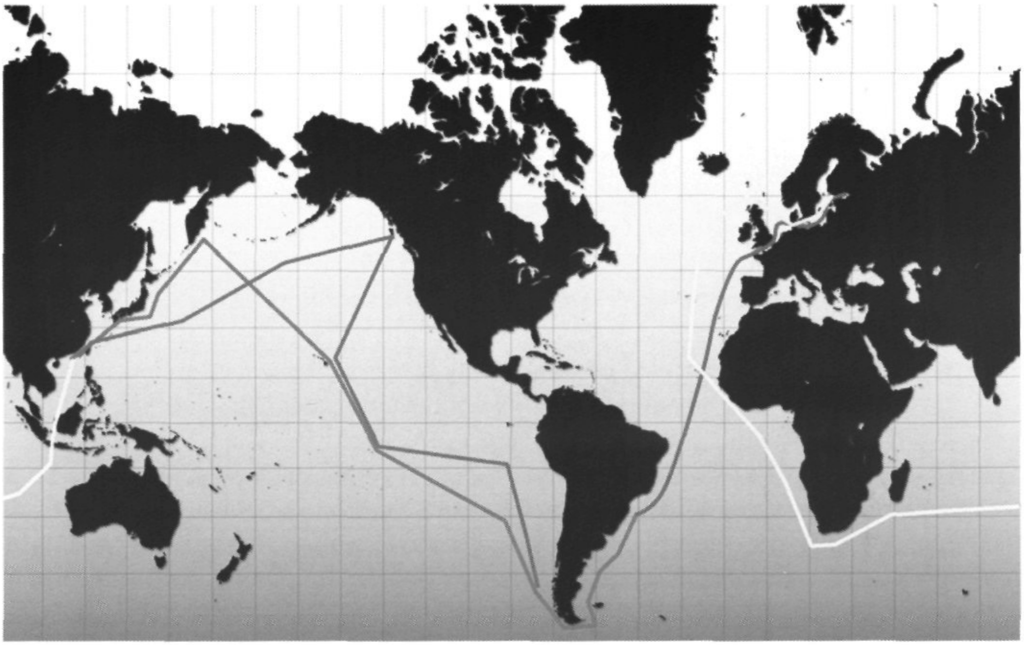


Figure 4. Route of the Krusenstern Expedition. Red line = 1803, Green line = Nadhezda *in 1804, Blue line =* Neva *in 1804, Yellow line =* Nadhezda *in 1805-6. Obtained from original charts in Krusenstern (1810-1814).*

and an island are named for this famous vessel. In 1949 Russia acquired a four-masted barque from Germany as part of war reparations, which was re-named *Krusenstern*. 200 years after the first circumnavigation, this tall ship re-traced the route of the *Nadezhda* in 2005-2006.

Neva, on the other hand, went on to become the first Russian ship to visit Australia in June 1807 (Massov 2007), initiating the first official relations between the two countries, on its way back to the Russian colonies in Alaska.

Upon his return, Krusenstern wrote a detailed report, *Reise um die Welt in den Jahren 1803, 1804, 1805 und 1806 auf Befehl Seiner Kaiserliche Majestät Alexanders des Ersten auf den Schiffen Nadeschda und Newa* (Journey around the World in the Years 1803, 1804, 1805, and 1806 at the Command of his Imperial Majesty Alexander I in the Ships *Nadezhda* and *Neva*) published in three volumes between 1809 and 1812 in St Petersburg. It was published in Berlin in 1811-1812, in English in 1813 and subsequently in French, Dutch, Danish, Swedish, and Italian. His other major scientific work, which includes an atlas of the Pacific based on his travels, was published between 1815 and 1827 in St Petersburg, and gained him honorary membership of the Russian Academy of Sciences.

Krusenstern became a member of the scientific committee of the Russian marine department, and also served as director of the Russian naval school. He was made an admiral in 1841 and awarded the Pour le Merite (Civil Class) in 1842. He died in Estonia in 1846 and is buried at the Tallinn Cathedral. He is remembered today in a wide range of ways: an island in the Bering Strait, a small island group in the Kara Sea, a cape and a lagoon in western Alaska, and a crater on the Moon all bear his name. In 1994, a Russian stamp was issued showing Krusenstern, his ship and the route they took. Nowadays, there is a fictional steamship named after him in a well-loved Russian animated film series, and even a rock band called “Kruzenstern & Steamship”.

Krusenstern donated collections from his voyages to the Museum of Geology at the University of Tartu, increasing their collection dramatically. Other parts of his collection were given to the Tallinn History Museum.

The other commander, Lisiansky, also wrote a book, entitled *A Voyage Round the World in 1803-1806* in two volumes (Lisiansky 1812, 1814), was ennobled and decorated with the Order of St Vladimir, 3rd Degree. Many places are named after him: Lisianski Island in the northwestern Hawaiian Islands, a peninsula of Baranof Island, Alaska, a bay, a strait, a river, a cape in North America, an undersea mountain and a peninsula on the Okhotsk Sea.

The German naturalist Wilhelm Gottlieb Tilesius described a number of species from the North Pacific, particularly fish (e.g., Tilesius 1813), as well as publishing works in other areas (e.g., dermatology; see De Bersaques 2011). Scientifically valuable drawings and watercolours by Tilesius illustrating landscape, peoples, as well as flora and fauna mainly of China and Japan, are housed at the University of Leipzig archives. He contributed many specimens to museums (see, e.g., Woelkerling *et al.*, 2008) and researchers.

Other crew members recorded diaries or wrote memoirs of the voyage, some of which were published at the time, some rediscovered many years afterwards, and, it is thought, some of which remain to be discovered (Tumarkin 1979).

3. The Bryozoans

One of the scientific results of the Krusenstern expedition was the discovery, collection, and naming of many new invertebrates, among them various bryozoans. Most of them were collected off Kamchatka, and brought back to Europe for description by experts.

Despite publishing his own work on a wide variety of subjects (from Mammoths to fish to cows), Tilesius did not describe many invertebrates that he had collected during the expedition. Most of them were passed onto to European experts, such as Lamouroux. Tilesius' main invertebrate contribution from the expedition was a paper on isopods, shrimps and entomostracans (Tilesius 1815) (see Damkaer 2002, p. 156).

Jean-Vincent-Félix Lamouroux (1779-1825) was an enthusiastic and successful professor of natural history who founded the Muséum d'Histoire Naturelle de Caen. He concentrated his research on algae, polyps and zoophytes (as they were then called). He described well over 500 species in the course of his career, and was honoured in his time by various Academies of Science (d'Hondt 1991). His collection, including the type specimens of many bryozoans, was lodged in Paris, and apparently destroyed during World War II (d'Hondt 1991; Mongereau 1972).

In his 1821 report "Exposition méthodique des genres de l'ordre des polypiers, avec leur description et celles de principales espèces figurées dans 84 planches; les 63 premiers appartenant a l'histoire naturelle des zoophytes d'Ellis et Solander", Lamouroux described the then known fossil and extant genera of "Polypiers" – about 127 of them, including many bryozoans, sponges, corals, and algae. He was meticulous in giving credit to those who had provided or collected the specimens, so we know that several were provided by or commemorate people on the Krusenstern expedition.

Pherusa

The genus *Pherusa* was erected by Lamouroux (1816), into which he placed *Flustra tubulosa* (Ellis and Solander, 1786), from the Mediterranean and Caribbean. Its range was considerably widened by material provided by Tilesius from Portugal, Brazil and "the Archipelago of China", described and figured by Lamouroux (1821, p. 3, plate 64, figs 12-14) (Figure 5A). At least some of Tilesius' material (probably that from China) may have come from the Krusenstern expedition, though it is not made explicit by Lamouroux. Of *Pherusa tubulosa*, Lamouroux notes "I strongly doubt that the same species can be found at such different localities." (translated from Lamouroux, 1821, p. 3).

Soule (1951) identified several homonymies and thus renamed the genus *Pherusella*. There are currently three acknowledged species: the genotype *P. tubulosa* (Ellis and Solander, 1786), known from European waters; *P. brevituba* Soule, 1951 from the California coast; and *P. flabellaria* (Kirkpatrick, 1890) from the China Sea. It seems most likely that the Krustenstern material provided by Tilesius could be this species, though it is not at all clear into what species the material from Brazil should be placed.

Krusensterna

The genus *Krusensterna* was described by Lamouroux in 1821, with a nominated genotype of *Krusensterna verrucosa* (Lamouroux 1821, p. 41, plate 74, figs 10-13) (Figure 5B). "This genus is dedicated to the celebrated voyager Krusenstern by his friend and collaborator M. Tilesius, the expedition's naturalist. I am only his intermediary in dedicating this bryozoan to the Russian navigator who has so improved our knowledge of the world's geography" (translated from Lamouroux, 1821, p. 41). He placed it among other reteporiform bryozoans.

Twenty-three years later Agassiz (1844, p. 14) listed the genus as *Krusensternia* Agassiz, 1844-5, either an unjustified amendment or an objective synonym. In any case, the genus *Krusensterna* had been already synonymised by de Blainville (1834, p. 406) with *Frondipora* Link, 1807 in the Frondiporidae: Cyclostomata. Lamarck (1836) commented that de Blainville "thinks that the species figured by Lamouroux and coming from the seas around Kamchatka is distinct from those of the Mediterranean." (translated from Lamarck, 1836, p. 276).

In 1850, King commented, with some disgust, on the confusion (in coral nomenclature) between Blainville's *Frondipora* and Lamouroux's *Krusensterna*. "it involves scientific nomenclature in the greatest possible confusion, and without any prospect of its being

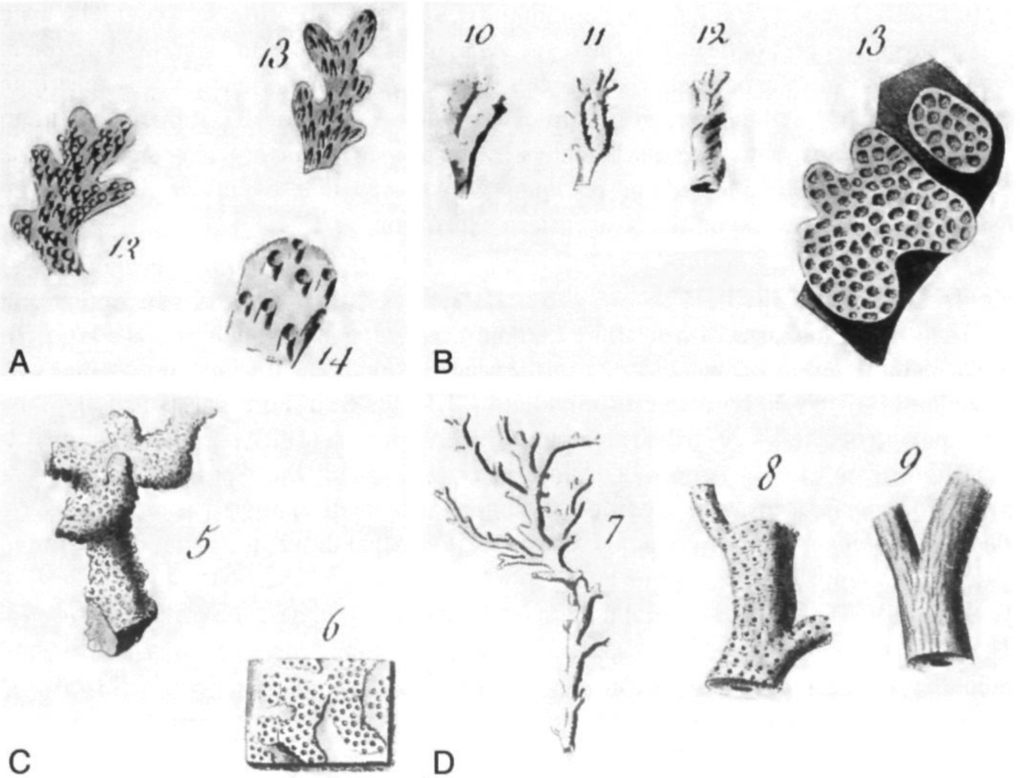


Figure 5. Bryozoans of the Krusenstern Expedition or named after naturalists on that expedition illustrated in Lamouroux (1821). A. Pherusa tubulosa *(from Plate 64, figs 12-14); B.* Krusensterna verrucosa *(from Plate 74, figs 10-13); C.* Tilesia distorta *(from Plate 74, figs 5-6); D.* Hornera frondiculata *(from Plate 74, figs 7-9).*

ended."

But by 1879 the position was clearer, with *Frondipora verrucosa* properly cited by A.W. Waters (1879). Later still, S.F. Harmer (1933) grappled with the genera then considered to be in the Reteporidae. He assigned the genus *Frondipora* ("= *Krusensterna* Lamouroux") to the Cyclostomata. There is a pencil note (of unknown date and authorship) in the Natural History Museum (London) copy of Lamouroux's book, suggesting that the species is now known as *Fasciculipora fratica* MacGillivray. But Bassler (1953, p. G56) regarded *Kursensterna* Tilesius & Lamouroux, 1821 as a synonym of *Frondipora* Link, 1807.

The most likely situation is that the material from Kamchatka is *Frondipora verrucosa*, now known from a number of locations, including Naples, the Adriatic, Oran (Algeria) and perhaps elsewhere in the Mediterranean, Madeira, the Red Sea, Japan, Kerry (Ireland), Senegal, and off Accra (Ghana). Also reported from the Miocene of the Czech Republic by Zagorsek (2010, p. 33)

Tilesia

Lamouroux (1821) dedicated the cyclostome bryozoan genus *Tilesia* to Tilesius, to thank him "for the beautiful polypides with which he has enriched my collection" (translated from Lamouroux, 1821, p. 42). The genotype was *Tilesia distorta* Lamouroux, 1821 (p. 42, plate 74, figs 5-6) (Figure 5C). It was not a specimen from the Krusenstern expedition, but instead a "rare and singular" Jurassic-Cretaceous fossil bryozoan from Caen in north-west France.

By the time de Blainville was looking for it, the type specimen of this species had disappeared (de Blainville 1834, p. 415). He regarded Lamouroux's description and figure to be "inadequate," but considered that it might be a bryozoan of some kind. In 1854, Haime combined Lamouroux's two genera *Tilesia* and *Theonoa*, retaining the latter name and thus the genotype *Theonoa clathrata* in the Theonoidea: Cyclostomata (Haime 1854). Bassler (1953, p. G57) listed the genus *Theonoa* Lamouroux, 1821 (= *Tilesia* Lamouroux, 1821), with a range of Jurassic-Cretaceous.

Tilesia could have been a confusing name to keep. It was also used for a fish by Swainson in 1838 (p. 318), a dipteran (fly) by Robineau-Desvoidy in 1863 (vol. 2, p. 364), and a hexacoralline anemone by Andres in 1883, who designated *Actinia brasiliensis* Milne Edwards, 1857 as the type species (Neave, 1939). The replacement name *Tilesiusia* for the bryozoan was published by Bronn (1848, p. 1264), according to Neave (1939). Incidentally, there is also a genus *Tilesia* in the family Compositae encompassing at least three species of South American flowering plants.

Hornera

The genus *Hornera* and subsequently the family Horneridae were named by Lamouroux (1821) for Johan Caspar Horner (1734-1834), physicist and astronomer of Zurich. The dedication reads: "This polyzoan is dedicated to Mr. Horner, astronomer with the expedition around the world commanded by Captain Krusenstern, in the name of his friend Mr. Tilesius" (translated from Lamouroux, 1821, p. 41). The species *H. frondiculata* (Figure 5D) had been collected by Tilesius from Kamchatka. *Hornera* has been occasionally misspelled *Horneria* (see, e.g., Bronn, 1848, p. 596). Some 136 species have been described, and about 120 remain valid (see Smith *et al.*, 2008 for a detailed history of the Horneridae).

4. Summary and Conclusions

The genus *Pherusa*, erected by Lamouroux in 1816, had its range considerably extended by material contributed by Tilesius from the Krusenstern expedition. Now called *Pherusella flabellaria* (Kirkpatrick, 1890), this ctenostome bryozoan is known from the China Sea. *Krusensterna*, named for the expedition's captain, was a reteporiform bryozoan later synonymised into *Frondipora verrucosa*. The fossil genus *Tilesia*, too, was synonymised with *Theonoa* and the name disappeared. It is in only the genus *Hornera*, a widespread and speciose genus of cyclostome bryozoan, that the Krusenstern expedition continues to be memorialised among bryozoologists.

5. Acknowledgements

We thank the staff of the Natural History Museum Library and Archives at Tring for providing access and assistance with original manuscripts.

References

Agassiz, L. 1844. *Nomenclator Zoologicus. Part 5-6 Nomina Systematica Generum Polyporum*. Soloduri.

Andres, A. 1883. *Le Attinie*. Coi Tipi der Salviucci, Rome, pp. 460.

Bassler, R.S. 1953. Bryozoa Vol. Part G. pp.1-253. In Moore, R.C. (ed.) *Treatise on Invertebrate Paleontology*. Geological Society of America and University of Kansas Press, Lawrence, Kansas.

Bronn, H.G., 1848. *Index Palaeontologicus oder Übersicht der bis jetzt bekannten fossilen Organismen*. 2 volumes. E. Schweizerbart'sche Verlagshandlung und Druckerei, Stuttgart, pp. xxxiv+1381.

De Bersaques, J. 2011. Wilhelm Gottlieb Tilesius – a forgotten dermatologist. *Journal of the German Society of Dermatology* **9**, 563-570.

de Blainville, H.M.D., 1834. *Manuel d'Actinologie ou de Zoophytologie*. Levrauly edition, Paris, pp. 1-644.

Damkaer, D.M. 2002. The Copepodologist's Cabinet: A Biographical and Bibliographical History, Part 1. *Memoirs of the American Philosophical Society 240, Philadelphia*.

d'Hondt, J.-L. 1991. The Bryozoa of the Lamouroux Collection. *Bulletin de la Société des Sciences Naturelles de l'Ouest de la France*, Hors Serié 1, 161-168.

Ehrenberg, C.G. 1831. *Symbolae physicae, seu icones et descriptiones mammalium, avium, insectorium et animalium evertebratorum. . .Pars Zoologica. 4. Animalia evertebrate exclusis insectis*. Decus Primula. Berlin. Officina Academica.

Ellis, J., 1755. *An essay towards a natural history of the corallines, and other marine productions of the like kind, commonly found on the coasts of Great Britain and Ireland*. A. Miller, London, pp. 1-130.

Ellis, J. and Solander, D.C., 1786. *The natural history of many curious and uncommon zoophytes, collected from various parts of the globe by the late John Ellis, systematically arranged and described by Daniel Solander*. White & Elmsly, London. pp. 1-206.

Federova, O. M. 2011. Krusenstern's Circumnavigation (1803-06). *The Journal of Pacific History* **46**, 381-392.

Haime, J. 1854. Description des Bryozoaires fossiles de la formation Jurassique. *Mémoires de la Société Géologique de France* **5**, 157-218.

Harmer, S.F. 1933. The genera of Reteporidae. *Proceedings of the Zoological Society of London*, **1933** (3), 615-627.

Johnston G. 1847. *A History of the British Zoophytes*. John Van Voorst, London.

King, W. 1850. *A Monograph of the Permian Fossils of England*. Palaeontographical Society, London.

Kirkpatrick, R., 1890. Report on the Hydrozoa and Polyzoa collected by P.W. Bassett-Smith, Esq., Surgeon R.N., during the survey of the Tizard and Macclesfield Banks, in the China Sea, by H.M.S. 'Rambler', Commander W.U. Moore. *Annals and Magazine of Natural History* (Series 6) **5**, 11-24.

Kruzenstern, A.J. 1810-1814. *Reise um die Welt in den Jahren 1803, 1804, 1805 und 1806 auf Befehl seiner Kaiserl. Majestat Alexanders des Ersten, auf den Schiffen Nadeshda und Newa unter dem Commando des Capitans von der Kaiserl. Marine A. J. von Krusenstern*. 3 volumes + Atlas. St. Petersburg..

Lamarck, J.B.P.A. de M. de, 1816. *Histoire naturelle des Animaux sans Vertébres*, Volume 2. Verdiere, Paris, pp. 1-568.

Lamarck, J.B.P.A. de M. de, 1836. *Histoire naturelle des Animaux sans Vertébres*. Second Edition, Volume 2. Verdiere, Paris, pp. 1-568.

Lamouroux, J.V.F., 1812. Extrait d'un m moire sur la classification des Polypiers corallignes non entierement pierreux. *Nouveau Bulletin scientifique de la Société Philosophique* **3**, 181-188.

Lamouroux, J.V.F., 1816. *Histoire des polypiers Corallignes Flexibles, vulgairement nommés Zoophytes*. F. Poisson, Caen, pp. 1-599.

Lamouroux, J.V.F., 1821. *Exposition méthodique des genres de l'ordre des polypiers, avec leur description et celles de principales espèces figurées dans 84 planches; les 63 premieres appartenant a l'histoire naturelle des zoophytes d'Ellis et Solander*. V. Agasse, Paris, pp. 1-115.

Linnaeus, C., 1758. *Systemae naturae per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus, differetiis, synonymis, locis*. 10th edition.. Laurentii Salvii, Holmiae, pp. 1-824.

Lisiansky, Y.F. 1812. *Puteshestviye vokrug sveta v 1803-1806 gdakh* [A voyage round the World in 1803-1806]. 2 volumes. F Drechsler, St Petersburg.

Lisiansky, Y.F. 1814. *A voyage round the World in the years 1803, 4, 5, & 6*. Longman, Hurst, Rees, Orme, & Brown, London.

Massov, A. 2006. The visit of the Russian sloop *Neva* to Sydney in 1807: 200 years of Russian-Australian contacts. *Australian Slavonic and East European Studies* **20**, 203-214.

Mongereau, N. 1972. Le genre *Hornera* Lamouroux, 1821, en Europe (Bryozoa – Cyclostomata). *Annalen des naturhistorischen Museums in Wien* **76**, 311-373.

Neave, S.A. 1939. *Nomenclator zoologicus. A list of the names of genera and subgenera in zoology from the tenth edition of Linnaeus 1758 to the end of 1935*. Volume 1, A-C. Zoological Society of London, London, pp. i-xiv+957.

Pallas, P.S., 1766. *Elenchus zoophytorum sistens generum adumbrationes generaliores et speciarum cognitarum succintas descriptiones cum selectis auctorus synonymis*. Petrum van Cleef, Hagae-Comitum, pp. 1-451.

Robineau-Desvoidy, A.J.B. 1863. *Histoire naturelle des diptères des environs de Paris. Oeuvre posthume du Dr Robineau-Desvoidy. Publiée par les soins de sa famille, sous la direction de M.H. Monceaux*. 2 volumes. Masson et Fils, Paris. 1500 p. (Volume 2: 364).

Smith, A.M., Taylor, P.D. and Spencer, H.G. 2008. Resolution of taxonomic issues in the Horneridae (Bryozoa: Cyclostomata). In: P.N. Wyse Jackson & M. E. Spencer Jones, (eds), *Annals of Bryozoology 2: aspects of the history of research on bryozoans*, International Bryozoology Association, Dublin, pp. 359-412

Smitt, F.A. 1866. Kritisk förteckning öfver Skandiaviens Hafs-Bryozoer. *Öfversigt af Kongl. Vetenskaps-Akademiens Forhaldingar* **23**, 395-533

Soule, J.D. 1951. Two new species of incrusting ctenostomatous Bryozoa from the Pacific. *Journal of the Washington State Academy of Sciences* **41**, 367-370

Swainson, W. 1838. *On the natural history and classification of fishes, amphibians, & reptiles, or monocardian animals*. Volume 1. Longman, Orme, Brown, Green & Longmans & John Taylor, London, pp. i-vi+1-368.

Thompson, J. V., 1830. On Polyzoa, a new animal discovered as an inhabitant of some Zoophites–with a description of the newly instituted Genera of Pedicellaria and Vesicularia, and their Species. *Zoological Researches and Illustrations*, **4**,. Memoir 5. King & Ridings, Cork, pp. 89-102.

Tilesius, W.G. von. 1813. Iconum et descriptionum piscium Camtschaticorum continuatio tertia tentamen monographiae generis Agoni Blochiani sistens. *Mémoires de l'Académie Impériale des Sciences de St. Petersbourg* **4**, 406 478.

Tilesius, W.G. von. 1815. De Cancris Camtschaticis, Oniscis, Entomostracis et Cancellis Marinus Microscopicis Noctilucentibus. *Mémoires de l'Académie Impériale des Sciences de St. Petersbourg* **5**, 331-405.

Tredrea, J. and Sozaev, E. 2010. *Russian Warships in the Age of Sail, 1696-1860: Design, Construction, Careers and Fates*. Seaforth Publishing.

Tumarkin, D.D. 1979. A Russian view of Hawaii in 1804. Pacific Studies *2, 109-131*.

Vinkovetsky, I. 2001. Circumnavigation, Empire, Modernity, Race: The Impact of Round-the-World Voyages on Russia's Imperial Consciousness. Meeting of Frontiers Conference Paper: http://www.loc.gov/rr/european/mofc/vinkovetsky.html

Waters, A.W. 1879. On the Bryozoa (Polyzoa) of the Bay of Naples. *Annals and Magazine of Natural History* (Series 5) **3**, 28-43.

Woelkerling W.J., Millar, A.J.K., Harvey, A. and Baba, M. 2008. Recognition of *Pachyarthron* and *Bossiella* as distinct genera in the Corallinaceae, Subfamily Corallinoideae (Corallinales, Rhodophyta). *Phycologia* **47** (3), 265-293.

Wyss, J. D. 1812. *The Swiss Family Robinson; or Adventures in a Desert Island*. http://www.gutenberg.org/files/11703/11703-h/11703-h.htm [English translation of *Der Schweizerische Robinson*]

Mary Dora Rogick: Mid-Century Nexus of Bryozoology

Judith E. Winston

Virginia Museum of Natural History, 21 Starling Avenue, Martinsville, Virginia 24112, USA

1. Introduction

Mary Dora Rogick (Figure 1), a daughter of immigrants, was a Ph.D. student of Raymond C. Osburn and, after him, the most important American bryozoan worker of her time, producing papers on freshwater and marine bryozoans from the 1930s to 1965. As a woman graduating in the mid-Depression she looked long and hard for a job. By finding one and by succeeding as a professor and research scientist despite many difficulties, she became one of the few internationally known American women biologists to come out of the decades between the 1930s and the 1960s. College of New Rochelle students remembered her for her excellent teaching, her subdued dress, and the 1930s hairstyle she retained all her life. But Mary had talents besides teaching and research, however, she was a skilled illustrator who included original humorous cartoons in her articles and letters. She was also a dedicated correspondent, who delighted in exchanging letters and cards with colleagues, many of the invertebrate biologists and bryozoologists of her time among them.

Mary's many correspondents included Anna Androsova, Anna Hastings, Libbie Hyman, and Ernst and Eveline Marcus. Mary's friendly nature and willingness to share her life with others often led to extended long-distance friendships. Her death in 1964 at the age of 58 put a premature end to a life that kept many bryozoologists and invertebrate zoologists in touch with each other in the years before the formation of the International Bryozoology Association in 1968.

Figure 1. Portrait of Mary Dora Rogick as a young woman.

2. Family and Early Years

Mary Dora Rogick was born in East Sandy, Pennsylvania on October 7, 1906. Her parents, Nicolas and Sara Rogick (originally spelled Rogíc), had grown up and married in Poitelj, Lika Province, Yugoslavia (44° 26' 56" North, 15° 26' 52" East), once part of Austria, now part of Lika-Senj, Bosnia and Herzegovina. They immigrated to the United States as adults (her father in 1903, her mother in 1904)[1] where they became U.S. citizens.

Mary's parents had belonged to the Serbian Orthodox Church, but as she told Libbie Hyman, "I was born into the Serbian Orthodox faith which is similar to the Russian and Greek Orthodox or Episcopalian faiths but lived most of my life in towns or cities where there was no church of our denomination so grew up without much formal religious training. Consequently I never learned to regard any one creed or belief as more privileged or better or less deserving of respect than the other beliefs."[2] She does also mention in correspondence that she was brought up to observe the holidays of the Julian calendar, as well as the Gregorian (current) calendar. "I naturally think in terms of two birthdays, two Xmases, etc. It is fun. If things don't get done by the new calendar there is always the old one to fall back on."[3]

Her parents had three other children, but Mary was the only one to live beyond infancy.[4] The family moved to Council Bluffs, Iowa when Mary was a girl and she went to elementary and high school in that Midwestern city. Council Bluffs was a busy railroad town. Earlier in the 1800s it was the beginning point of the Mormon Trail and other Emigrant wagon trails west. As railroads developed it became a railroad hub for several different lines and in 1869 the mile 0 of the Union Pacific link that created the first transcontinental railroad. Mary's father was a railroader.

Mary's mother and father were divorced in 1918. Her father later remarried, but Mary's mother did not, living with her remaining child, Mary, for the rest of her life. During Mary's high school years, she and her mother lived on South 25th Street in Council Bluffs (1920 census) and on 13th Street in 1925 (1925 census). According to a reference librarian at the Pottawattamie County Genealogical Society, this area of town was where railroaders in Council Bluffs generally lived, and it was considered to be the "wrong side of the tracks."[5]

Mary attended Abraham Lincoln High School (Figure 2) in Council Bluffs, graduating in 1925. Figure 2 shows her senior picture from the 1925 *Crimson and Blue*, her high school year book. It lists Mary as a member of the "Normal Course", the teacher training track, Delta Tau (a high school sorority), Rifle Corps, 1924 President of the T. N. T. (The Normal Training Club, an organization for future teachers), and B. B. Team 1924.

A yearbook picture of the T. N. T. (Figure 2) shows her in the center of the group, with round glasses on her face and her brown hair in a short bob. The caption of the picture states, "The Normal Training Club is the only professional organization of the high school. Its purpose is to develop a stronger spirit of co-operation and, at the same time, to cultivate a sense of professional responsibility."[6]

High school life was not all serious, however. Unfortunately there is no photograph to

Figure 2. (Top) Abraham Lincoln High School, Council Bluffs, Iowa. Mary Rogick's senior yearbook picture, class of 1925. C. Group photograph of members of the T.N.T. (Abraham Lincoln High School Future Teachers' Club). (Postcard image of ALHS, early 1900s; 1925 ALHS Yearbook photographs, courtesy Pottawattomie County Genealogical Society, Iowa.

accompany the other mention of her in the yearbook, at the graduating class's evening program, when it was announced that "Mary Rogick and Eileen Heuermann will entertain us with a bizarre (?) Grecian interpretation including balloon, barefoot and scarf work".[7]

3. Professional Education

Mary moved to Lincoln, Nebraska shortly after high school graduation to study at the University of Nebraska. She obtained her A. B. in Education in 1929, then went on to take her A. M. in Zoology in 1930, where she was Phi Beta Kappa. Her thesis title was "The comparative histology of the digestive tract of a minnow (*Campostoma anomalum*)." Dr Irving Hill Blake was her thesis advisor. The *Journal of Morphology* article[8] was her first

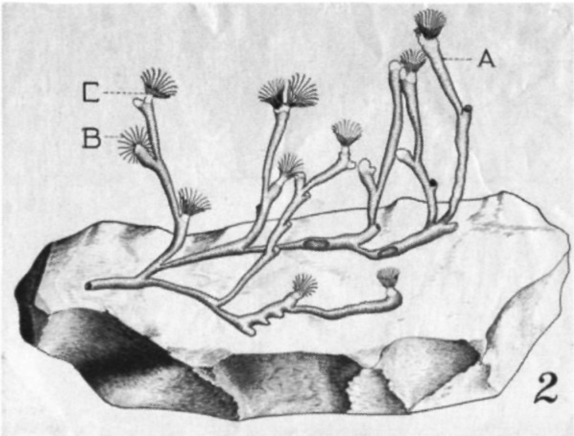


Figure 3. One of the original illustrations by Mary Rogick from her Ohio State Ph.D. dissertation on the Bryozoa of Lake Erie.

publication, but she had apparently already decided that she wanted to be a college teacher and research scientist rather than a K-12 teacher, as she had planned in high school. To qualify for a college teaching job she needed a Ph.D. degree. She studied for that degree at Ohio State University under the supervision of Dr Raymond C. Osburn, a well-known bryozoan taxonomist, receiving her Ph.D. in Zoology in 1934. During the summers of 1932 and 1933 she attended courses in Ecology, Algology, and Research at the Franz Theodore Stone Biological Station at Put-In Bay on Lake Erie, and carried out her Ph.D. research project there. Her dissertation was on the freshwater Bryozoa of Lake Erie[9] One of her original illustrations is shown in Figure 3.

4. Professional Life

Graduating in the middle of the Great Depression made job hunting difficult for anyone, but the task was even more daunting for a woman scientist. With her usual whimsical sense of humor Mary documented her educational history and job search in a series of cartoons (Figures 4 and 5) that she created for her 25th high school reunion. In the first cartoon of Figure 5 a wet and baffled new Ph.D. stands in the Depression storm.

The 1982 book by Margaret Rossiter[10] showed that while the number of Ph.Ds awarded to women in the sciences increased substantially during the time period from 1921-1938 (from 4.7% in 1921 to 7.0% in 1938), listings in the 1938 *American Men of Science* showed 8.9% of the Ph.D. women were unemployed, vs. only 1.3% of men. The strategy of the women of Mary's generation, in contrast to that of the previous suffragette generation who had pioneered women's entry into professional science, was apparently much less confrontational. Rather than documenting inequalities and trying to change them, most women who persisted in science during that time did so by the "Madame Curie" strategy of "deliberate overqualification and personal stoicism."[11] This led to professional success for some, but personal constraints for most, including the necessity to stay single (married women were expected to resign their positions) and sometimes nervous breakdowns from overwork.

While Mary searched for a professional position, she worked as a research assistant in Frank A. Hartman and Katherine Brownell's adrenal physiology lab at Ohio State (August 1935 to February 1935) (Figure 5). She later told Libbie Hyman, "I can still smell that rat

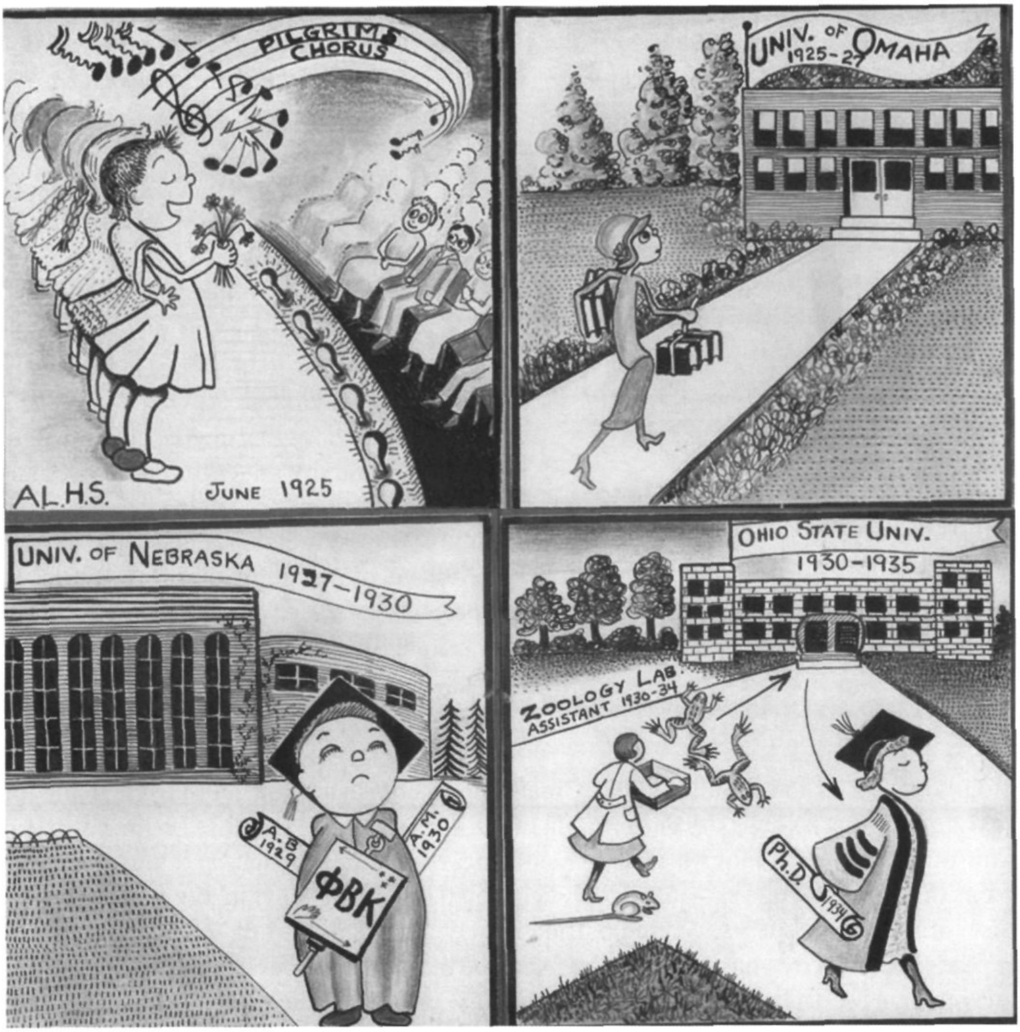


Figure 4. Mary's Rogick's cartoon illustrations of the four educational institutions she attended. (Courtesy College of New Rochelle Archives).

colony of theirs!—900 rats at its height, plus a bunch of cats, guinea pigs, mice, dogs, and even a monkey. Give me Bryozoa any day,"[12] but Hartman and Brownell became long-time friends meeting again in summers at Woods Hole.

Mary wrote more than 200 letters seeking a teaching job before she finally received an offer from the College of New Rochelle, in New Rochelle, N. Y., very near New York City (Figure 6). She joined the faculty there in 1935. A college newspaper article written soon after her arrival described her as a lab-coated figure with lively brown eyes, an irresistible smile and a warm and sincere enthusiasm.[13] She stayed at New Rochelle for the rest of her life, eventually becoming a full professor and for a number of years (more than she wanted) Chairman of the Zoology Department. Lay faculty salaries were low. Mary's

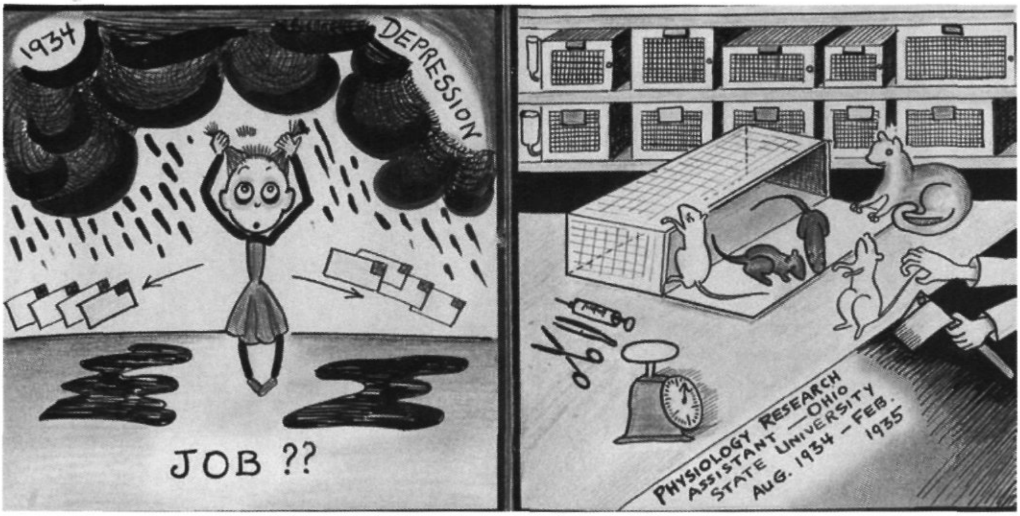


Figure 5. Mary Rogick's cartoon illustrations of her professional job search in mid-Depression days and of her job in the adrenal physiology labororatory at Ohio State while she searched for a professional position (Courtesy College of New Rochelle Archives).

starting salary was $2700. On that she supported herself and her mother and any research related travel or supplies. By 1955 her salary had increased to $5200, an amount that seemed adequate to her, "I never thought I would earn that much."[14]

She and her mother took up residence in a 3½ room apartment at 25 Prospect Street in New Rochelle where they lived until her mother's death on March 21, 1951, and where Mary continued to live until her own death. She wrote to a friend, "We have always lived together. I was her last remaining relative and took care of her."[15]

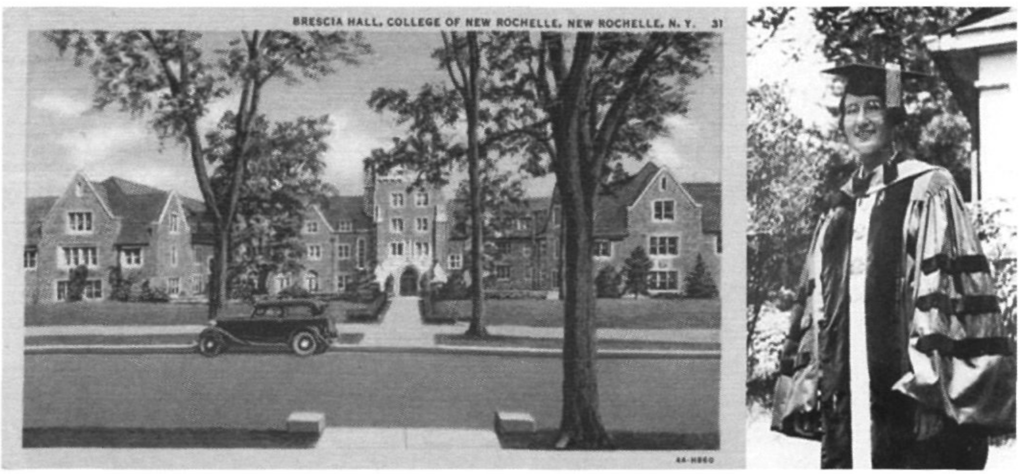


Figure 6. The College of New Rochelle. Postcard view of the College in the 1920s. Dr Mary Dora Rogick in her academic regalia, 1930s. Photograph Courtesy College of New Rochelle Archives.

Teaching

Mary taught an assortment of biology courses during her academic career including Zoology (beginning and advanced), Animal Biology, Histology, Comparative Anatomy, Genetics, Embryology, Microtechnique, Hygiene, Physiology, Parasitology, Ecology, Biological Literature, and Teaching of Biological Science (Methods).[16]

Teaching took up almost all of Mary's time during the academic year. "During the school year (from September to June) I teach Zoology to first-year college students, Comparative Anatomy of Vertebrates to second year college Biology majors and Histology to third-year majors (Figure 7). During the summer (June to Sept. 1) I do my bryozoan research".[17] But she clearly enjoyed her students and her teaching activities. In later years she apparently thought of finding a different job where the students might be more serious. She wrote "the students are most congenial & a lot of fun but unfortunately few have the burning scholarly zeal that I wish for." But in the same letter she stated that "I hesitate to make a change unless a better job than I already have comes along."[18]

Grading exams, papers and lab reports was never the best part of the job, of course, but she managed to keep a sense of humor about it, "Tortured poor innocent students with peculiar form of torture known as Essay type final exam.... After the students had taken the agonizing cure it was my turn. Would you believe it—it took me 47 hours to grade 88 freshman exams.... Golly, I thought I'd float off on a sea of ink & letter crested waves." [19]

In later years she did lament the biochemical trend in the teaching of biology, as she wrote to George M. Moore at the University of New Hampshire, "Thank goodness I had the traditional type of zoology and botany rather than the warmed-over chemistry that is now passing for biology. I'm afraid our students are missing much of the joy of study of whole live organisms...." [20] However, she added, "Since most of our students who work in science jobs after college go on to work in places like Sloane-Kettering we find that the biochemical or molecular biology approach serves their purpose best."

She had little patience for some of her other academic obligations, writing to R. S. Bassler, in 1956,

> The teaching I like, but the other "stuff" tries my patience. I have been waging a determined war against becoming enmeshed in various get-together, faculty discussion, cultural exchange gatherings where the faculty "shoot the breeze" among themselves or with the students — wasting precious time in what they think is stimulating intellectual activity but which usually ends up in the "philosophers" always haranguing the "scientists" about not broadening their outlook....Time I need. Wind I can do without.[21]

Continuing Education

Mary continued her own studies even after she had earned her Ph.D. and found a full time teaching job. She wrote to Elena Androsova that "During the summers of 1936 and 1937 I took courses (Physiology, Hygiene, Bacteriology) at Columbia University (N.Y.) and during the summers of 1938, 1939 I took Embryology and Invertebrate zoology at the Marine Biological Laboratory at Woods Hole, Massachusetts." [22]

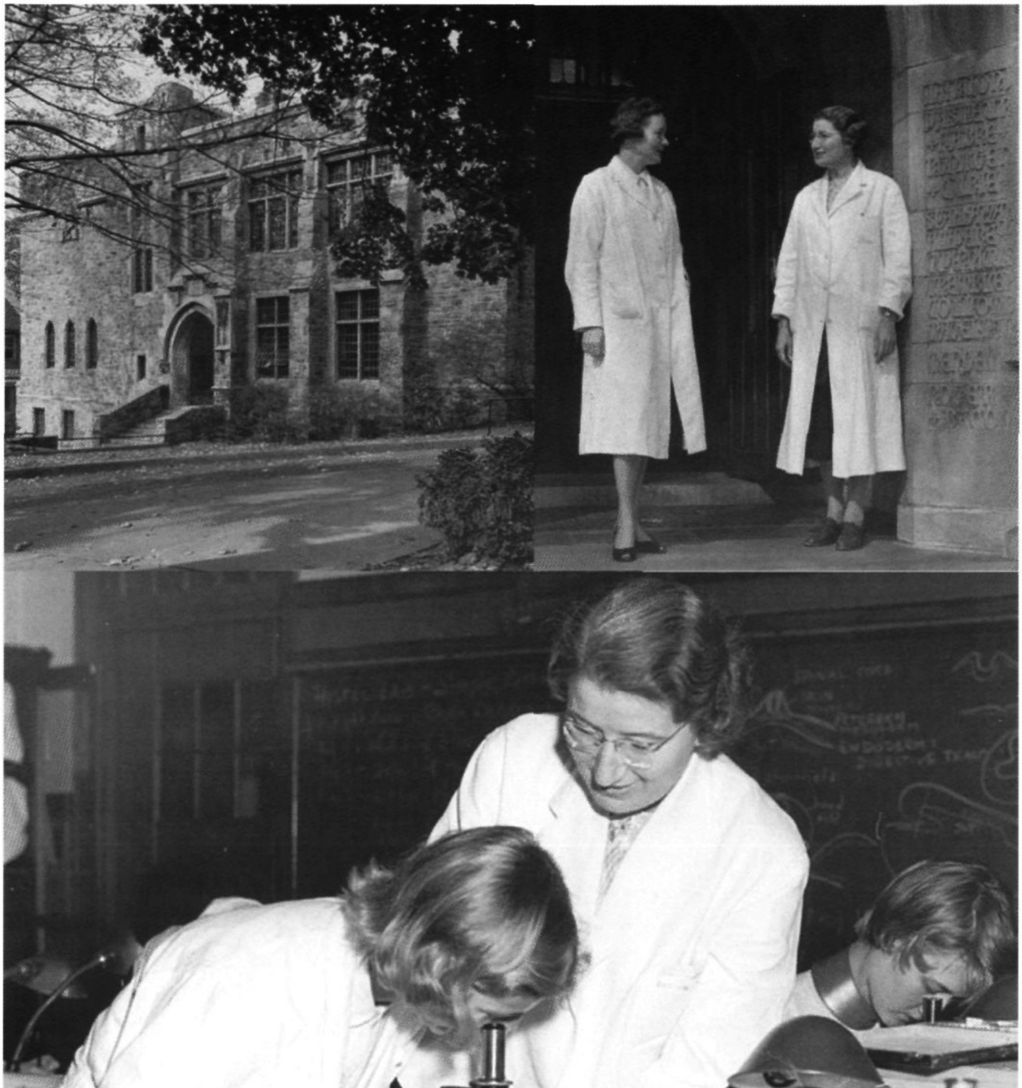


Figure 7. College of New Rochelle and teaching career. Top. College of New Rochelle Science Building 1955. Dr Mary Dora Rogick and colleague Dr Mary Grace Connell on the steps of the Science Building, 1956. Bottom. Dr Rogick in biology laboratory with students, 1955. (Courtesy College of New Rochelle Archives).

Research

Research was not a necessity for College of New Rochelle faculty.

> "The teaching (plus a considerable amount of related clerical work—reports on student progress, grading of innumerable student papers, etc.) is a full-time occupation. What research I do is done entirely during the summer or during vacations or such time as I can squeeze out of my waking or sleeping hours and is not done on school time or required of me by the school since our teaching load is considered to be our full obligation to the school.... Over the years I have steadily done a little bit of research because I felt it to be an obligation to my own professional development and an obligation to the profession itself, even though the school did not expect it of me. I have derived a great deal of pleasure, as well as untold hours of lost sleep, from it." [23]

However, she realized that there were advantages as well in not being required to produce research. "In some colleges and universities a teacher is almost forced to do research in order to hold his position on the faculty. I am happy that is not the case here, because I work best when I am not under pressure, and also I can take more time to be careful, and careful research is the most desired kind." [24]

Space for research was lacking during the years Mary worked at CNR. The college was growing rapidly and the science building; relatively new when Mary arrived in 1935 seems to have had the lowest priority when it came to expanding the physical plant. Mary wrote that

> "...working space at college is so limited that my office is the storage-preparation room just off the zoology (student) lab and students are forever popping into my cubbyhole for glassware, supplies, or to soak their lab specimens (preserved).... Part of the bryozoan collection is kept at home. The rest (the part I work on currently or at the particular moment, as during the summer) is kept in my "office" at school where I do the microscopic work." [25]

Despite these constraints Mary seems to have focused on research whenever she had a spare hour, carrying out much of her taxonomic research on the kitchen table in her apartment, and very often giving up sleep in order to do so.

<u>Freshwater Work</u>. The first years of Rogick's research career were devoted to a continuation of her research on the biology and systematics of freshwater bryozoans. She produced a total of 18 papers on freshwater species. Many of them became classic sources on the biology and ecology of the group. Her freshwater work was cited more than a dozen times by Libbie Hyman in the Phylactolaemate section of volume V of *The Invertebrates*, published in 1959, and it is still in use today, although there have been some changes in phylactolaemate taxonomy since Rogick's work appeared, e.g. in 2002, Tim Wood reported that the species she had recorded from Pennsylvania as *Stolella indica* is actually *Plumatella rugosa*.[26]

<u>Woods Hole Summers</u>. After taking Embryology and Invertebrate Zoology at the Marine Biological Laboratory at Woods Hole, Massachusetts, in the summers of 1938 and

Figure 8. Summer marine research and teaching at the Marine Biological Laboratory, Woods Hole, Massachusetts. Top: In the laboratory, on a fishing expedition, and with a colleague on the dock. Bottom: Photograph of the summer marine invertebrate class, 1946. Mary is in the third row wearing her distinctive overalls. (Top 3 photographs courtesy of the College of New Rochelle Archives; Photograph of 1946 summer class, courtesy of Dr Mary E. Rice, a student in the class).

1939, Rogick was invited to teach in the MBL summer school only a few years later. She taught in the Invertebrate Zoology course during the summers of 1943, 1944, 1945, 1946 (Figure 8, bottom photograph), and 1947. It was hard work with long hours, but she found it enjoyable. She wrote to her friend Dr James Ackert,

> I have been at Woods Hole since July 1, and shall stay till August 31. For the first 6 weeks I have been teaching at the Children's School of Science here (a summer school similar to the Marine Biol. Lab courses but suitable for "small fry" of 7 to 16 yrs. (Of age). My group ranges from 11 to 16 years. Each member fairly bulges with questions. It is really almost as much work to teach youngsters as college students. These next 2+ weeks I shall be pinch-hitting for a member of the MBL Invertebrate course—this time teaching the college product which comes for the regular MBL course. That course runs on a 14 to 15 hour day as you perhaps know, —lecture at 9, then maybe a field trip (1/2 day or whole day), then back to lab to put specimens in proper containers before changing to dry clothes, then supper, then back at 7:30 p.m. for working over the collection & identifying specimens & writing up reports and by that time it is 11 p.m. or there-abouts. However, it is a lot of fun. The class goes on scheduled field trips RAIN or shine." [27]

Marine Work. Starting with the summer of 1943 her interest in marine bryozoans began to develop. She also began to become more of a specialist in bryozoan taxonomy, although she always kept the relationship of taxonomic with the biology and ecology of the living animals in perspective. Even in purely taxonomy papers she tried to note biological or ecological observations when possible. Teaching at the MBL summer courses gave her access to living marine bryozoans. It also gave her the opportunity to meet and make friends with some of the best professional marine biologists of her day, as well as, in the classes she taught, the students who became the next generation of professionals (Figure 8). She missed their company. As she wrote to a friend in the summer of 1948, the first summer she spent at home again, "Going to MBL and Woods Hole is like going back home to one's own family".[28] She returned to northeast coast bryozoans only briefly, producing the bryozoan section for the *Woods Hole Keys*, 1964.[29]

Antarctic Work. The last year she taught at Woods Hole was in 1947. Partly this appears to have been because she began to study a collection of Antarctic Bryozoa belonging to the Smithsonian Institution. Her mother's health was also declining at that time and Mary had to take care of her in addition to her other duties. As her opportunities for study of live material decreased she became more focused on the Antarctic work. She did visit Woods Hole again later in her career, but only for a few days at a time.

As often seems to happen in science, her work on Antarctic bryozoans started almost accidentally. As she wrote to Dr Frank Brown of Northwestern University:

> Last August I was in 7th Heaven, having cleaned up practically all the back research. Boy, was I going to take it easy (I thought)! I just had one more little paper (on an Antarctic bryozoan) which Wm Randolph Taylor had sent me) to finish. Then conscience poked a sharp finger in my ribs & I thought maybe it would be wise to ask permission of some higher up (in this case the Smithsonian Institution, from which the specimen had originally come to Taylor) before I

barged into print with the fancy little bryozoan number. I asked, & got MORE than I had bargained for — —the Smithsonian, in practically the return mail offered me the whole darn Bryozoan collection which the U.S. Navy had collected during the winter of 1947-48 (in Jan & Feb) in their Antarctic voyage. So far I have pawed over at least 81 spp.—not one of which is like the Woods Hole stuff...every blame one of them a stranger.[30]

In September 1952 she applied for a grant from the National Science Foundation to support her work on the Antarctic collection. The funding she received in April 1953 paid for a new dissecting microscope and light, office typewriter, and supplies. She wrote,

This summer I finished 3 manuscripts totaling about 150 pages of typing and 18 plates & these were finally sent to the Smithsonian to publish in the Proc. U.S.N.M....I learned more basic zoology (taxonomic procedures, type selection, etc.) this year thru research than any amt. of reading (without research) could have taught me.[31]

Teaching Biology Papers. Rogick felt very strongly about the need to improve biology teaching. She published articles on teaching methods and in the summer of 1952 she taught a course in biology teaching methods at the University of New Hampshire. She wrote to a former CNR student, "The course is keeping me busy because the students in it are high school teachers of several years experience so I have to teach on a different level. They are very eager to learn. We went on a field trip to a freshwater mucky pond last Thursday. It was fun. The course hours number 16½ per week."[32]

Professional Service. Over the years Mary contributed articles on bryozoans to encyclopedias (e.g. *Encyclopaedia Britannica* and *McGraw Hill Encyclopedia of Science and Technology* and reviewed books about bryozoans for journals. She provided the chapter on Bryozoans for Frank Brown's book, *Selected invertebrate Types*.[33]

Her most time consuming contribution was to serve as a section editor for *Biological Abstracts* (1957-1964). In a letter to Dr Fenner Chace at the Smithsonian she wrote:

The BIOLOGICAL ABSTRACTS has just, with blarney and wile, asked me if I would take on the late Dr. Osburn's duties (very light they assure me) of editing the Bryozoan Section of the Abstracts. Dr. Osburn would be pleased that it passed on to one of his students...Dear Dr. Irving Hill Blake, of the Univ. of Nebr. Under whom I got an A.M. degree back in 1930 got me involved with abstracting for Biol. Abstr. Way back in the early 1930's, and I did quite a bit of it, tho haphazardly and at irregular intervals thru the years. It was wonderful training.[34]

Despite her initial pleasure at the invitation abstracting brought its own aggravations, as she wrote to a friend at the University of Louisville, Kentucky:

In fact I find myself devoting almost as much time to the non-paying chores like abstracting, research, science societies involvements and similar associated "extracurricular" chores as I do to the teaching job the brings in the bread, butter and bacon.... I just got thru translating a 21

> page French article on bryozoan gametogenesis and budding and making a sizeable abstract of it— —with the aid of 2 dictionaries, a French grammar and all my stock of ladylike cuss words....[35]

But in the same letter she added, "all those "frills" and side-activities are important too because they enrich the teaching and our students are the indirect as well as direct beneficiaries. I do not envy the teacher who does just his teaching job and no more because I think he is losing out on a lot of valuable training that he cannot pick out of text books."

Society Activities. Mary participated in a number of scientific societies during her career including the American Association for the Advancement of Science, American Microscopical Society, American Society of Zoologists, Ecological Society of America, Ohio Academy of Science, Marine Biological Association, American Association of Limnology and Oceanography, National Association of Biology Teachers, Society of Systematic Zoology, Sigma Delta Epsilon (Science Women's Society), and Phi Beta Kappa.[36] She seems to have been most involved in Sigma Delta Epsilon (now called Graduate Women in Science), and was involved for several years in finding speakers for New York City meetings.

In 1953 Dr Waldo Schmitt of the Smithsonian Institution asked Mary to participate in a symposium on lophophorates at the annual meeting of the A.A.A.S. in Boston, Massachusetts. Mary was asked to speak on "Why Entoprocta and Ectoprocta should be put in the same phylum." Libbie Hyman was supposed to moderate the session and Mary was extremely anxious all that autumn about the presentation and possibly facing off with Dr Hyman. In early November she wrote to the Marcuses:

> Dr. Hyman thinks they should be 2 separate phyla. . . . I dread the prospect of facing such a formidable and well-informed opponent, particularly as I have no very good arguments to support my stand at the moment! Any good arguments you can offer for putting Entoprocta and Ectoprocta into one Phylum, the Bryozoa, will be welcomed with the greatest joy. What I am afraid of is that I shall agree with Libbie Hyman if I keep reading her texts and do not read convincing enough proof from other sources, and that most surely would never do![37]

As it turned out, the symposium went well, and Libbie did not give her the cross-examination she dreaded.

5. Personal Life

Mary never complained about living with her mother, Sara. Over the years she and "Mamma" had worked out a system for sharing the housework and shopping that freed up more time for Mary to work. Before her mother's eyesight failed, they also sewed most of their own clothing. Some of Mary and her mother's activities wound up as cartoons in her correspondence (Figure 9).

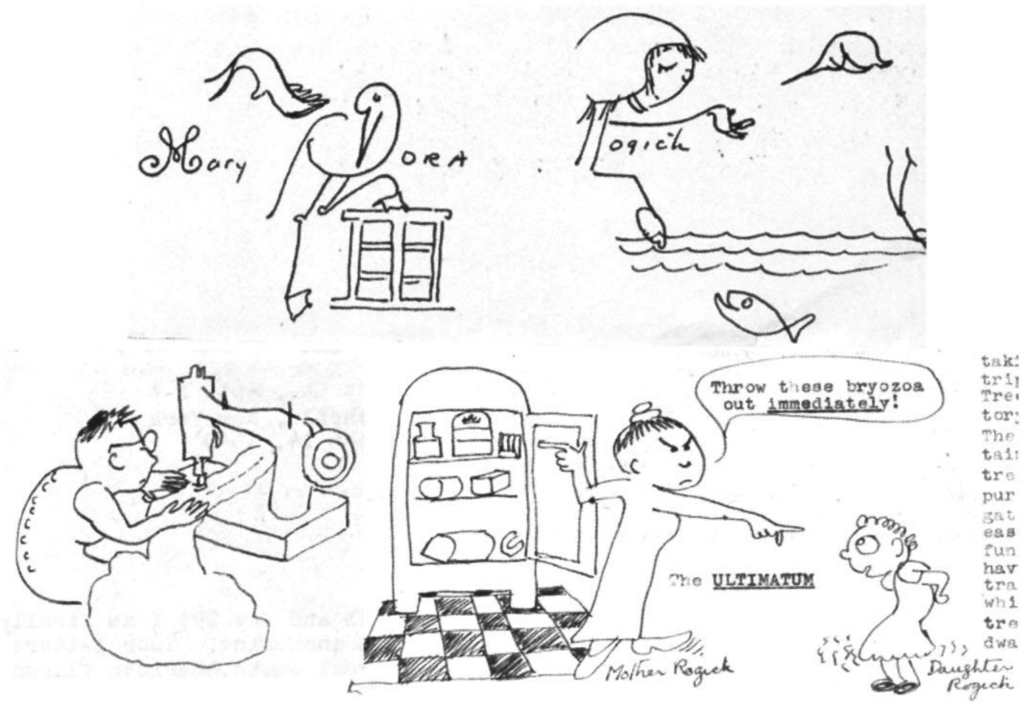


Figure 9. Drawings about her personal life from Mary's correspondence. Top. Learning to swim. Bottom Left. Sewing a new wardrobe during the summer break. Bottom right. Her mother's reaction to Mary's keeping phylactolaemate statoblasts in the kitchen refrigerator.

Although she apparently had no contact with her father once her parents were divorced, she and her mother did correspond with her mother's family in Europe, except during the WWII years. In April, 1946, she wrote to the Marcuses:

> We have just established contact with my mother's family in Croatia (Yugoslavia). They are scattered and some are missing due to the war. We have had only 1 short letter from them and do not have the full particulars as to how they fared other than that they lost homes, clothes and livestock. They lived about 50 miles south of Zagreb where there was a lot of fighting. Mother and I spend most of last week buying and packing material and food for them.[38]

In the late 1940s her mother's health began to decline. After a couple of years of increasing illness and blindness, she finally died of uremia and gradual heart failure on March 21, 1951, aged 67. Mary wrote "I miss her very much but fortunately so much work had piled up during her illness that the work kept me from thinking about her loss too constantly."[39]

Since her mother had done the cooking for the household, after her death Mary struggled with learning to cook for herself. "So far I have held up magnificently under my own cooking, though losing weight (a goal I am aiming for) has not been achieved—mostly because of genuine lack of will power! Can't get below the 143 pound mark without cutting down on food! As for housecleaning—the less said the better." [40]

Interests. Mary was a skilled artist and cartoonist whose drawings and cartoons enlivened her articles and her correspondence with colleagues. She also illustrated a book called *Are You Your Garden's Worst Pest,* by Cynthia Westcott.[41]

She tried painting in oils also. She wrote to her friend J. E. Gray at Duke University:

> This winter I've been "making like Rembrandt!?" or learning how to paint in oils, one night a week in art class. The subjects: all complicated Woods Hole scenes. The results: not half bad! The score: 3 small oil paintings-everything in them recognizable and according to our art teacher—Walter Beach Humphrey[42] —"scientific" if not artistic. . . . The painting is a lot of fun and much more enjoyable than stippling, but there is really very little time for it.[43]

She apparently kept up her interest in painting. A 1956 letter mentions that she had spent an hour teaching the daughter of an apartment house neighbor the basics of oil and water-color techniques.[44]

A correspondent once asked her how she got started on her characteristic cartoon signatures. She replied:

> My friends all enjoy the latter and expect them on every letter. If the funny pictures aren't forthcoming the very well-meaning friends think I'm sick, or that something drastic has happened to me. So I try to please and entertain them. The caricatures are a rebellion against the large amount of deadly, dreadfully dull scientific writing thru which I have to "wade" in the course of my teaching or research.[45]

Figure 10 shows a page of doodles from a piece of scrap paper found in her correspondence files. Her use of initials and random ink squiggles as starting points for drawings and signatures in her letters is interesting in view of her original plans to become a public school teacher. The subject of one of her papers for the *American Biology Teacher* was the use of cartoons and simple sketches as visual aids. Art and English teachers still use squiggle drawings today to encourage creativity in students and lesson plans incorporating them can even be found online. Squiggle drawings are also used by professional cartoonists and child psychologists. Figures 11 and 12 show some examples of drawings and signatures from her letters. Figure 11 shows some of the varied hairstyles found in her signatures over the year. Figure 12 shows a bryozoan cartoon and a bryozoan signature.

Mary Rogick learned to swim as an adult (Figure 9). This endeavor initially began because of the sinking of the Woods Hole boat which her class had used for collecting the previous summer. That event made her realize her vulnerability as a non-swimmer. As she said to Libbie Hyman, "It is the only exercise that I've ever taken that didn't wear me out or get me frightfully winded (outside of walking).[46]

She liked to read for pleasure when time permitted, as in the summers. "The N. R. Public Library has a wonderful collection of adventure and biographical books. I manage to read one or 2 books each 2-week borrowing period although the time is spent grudgingly

Figure 10. Page of doodles on scrap paper from her correspondence files, perhaps to generate ideas for her unique squiggle signatures.

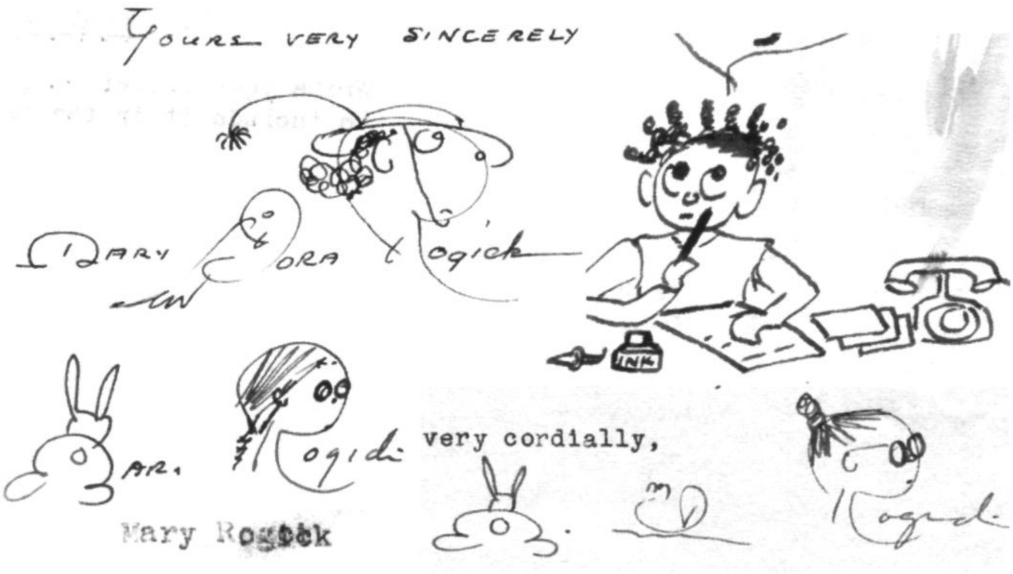


Figure 11 Hairstyle squiggle signature drawings. In real life Mary changed her hairstyle very little, but on paper her signature's coiffure varied.

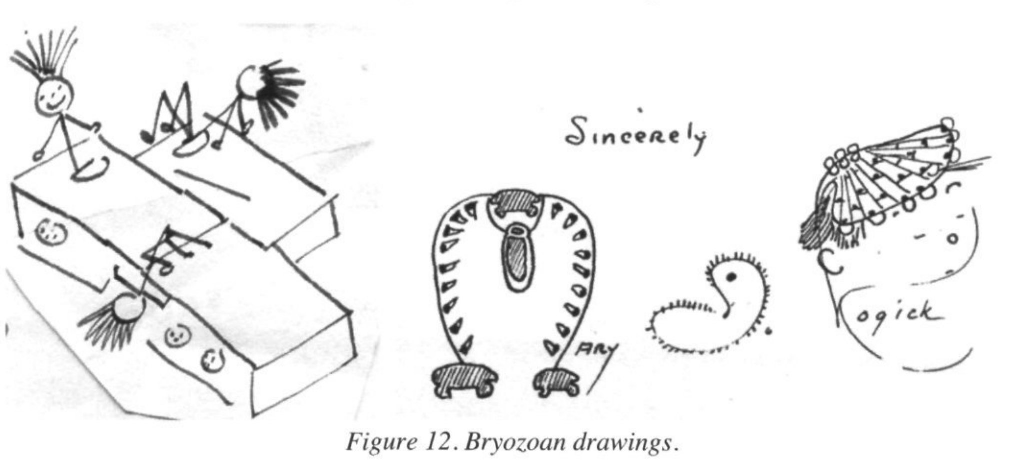


Figure 12. Bryozoan drawings.

but very enjoyably. The Puritan-Slave Driver in me surely is hard to live with sometimes."[47]

Once Mary moved to New Rochelle she seems never to have travelled beyond the northeastern part of the U.S., although in letters she expressed her desire to do so. For example, "I enjoyed your letter, and the Arizona picture made me want to start travelling. Someday I shall take time to see some of the wonders of our great and beautiful country but it won't be until the blasted Antarctic project is done."[48] Unfortunately, that time never came.

6. Correspondence

During the earlier part of her career Mary devoted a considerable amount of time to answering requests for identification of material collected by other scientists. Sometimes the inquirer was knowledgeable, more often the request was similar to this one from a North Dakota ecologist, "I have taken some clumps of material from a local fresh-water lake that appeared to be a bryozoan. I would like to know if you would make identification for me...." [49]

Until the late 1950s she seems to have carried out such identifications, but at that point she had become so immersed in her Antarctic work that she had to turn both identification requests and new projects away. "The fact is I'm tied up with too many research commitments already. The most pressing one is the Smithsonian collection which I should like to finish while it is still covered by a research grant. It is going to tie up the next three summers." [50]

Mary continued to respond politely, if negatively to such requests throughout her career, but her real energy lay in corresponding with her friends, former students and other scientists, especially those studying bryozoans.

Exchanges of letters with the professional bryozoan workers often began with her requesting reprints of their publications to increase the personal collection of bryozoan taxonomic literature so urgently needed in her own work. But as the exchanges continued, long-distance friendships developed. She told her bryozoan correspondents much about life in New Rochelle, her college teaching and research and, they often reciprocated with personal stories of their own. Some, like David Brown, who stopped on his way back to New Zealand from a stay in England, even came to visit her in New Rochelle.[51]

These long-distance friendships filled a gap in her life, crowded as it was with the demands of students and her own drive to do research despite the lack of space at CNR. Her CNR colleagues remembered her as shy, but her egalitarian mid-western friendliness and irrepressible sense of humor come out in her whimsical drawings and stories in letters to friends. Some of her frequent correspondents were Anna Hastings, Libbie Hyman, Ernst and Eveline Marcus, R. C. Osburn, and in later years, Elena Androsova.

Raymond C. Osburn. Mary continued corresponding with Osburn and his wife for many years after her graduation from Ohio State. Two years after her graduation he wrote encouraging her to continue her research, "I hope you have not thought of giving up work on the Bryozoa. As I have told you, you are in the best position of anyone in the country to become an authority on the group."[52]

As her research skills and interests developed they also exchanged scientific information and opinions. While working on part 3 of the Pacific Bryozoa, Osburn wrote:

> Canu and Bassler did a lot of good work on the ovicells and certainly stressed their importance, but they failed to take into account the possibility of parallel evolution in the development of the ovicell and, I fear, followed their own scheme to rigidly. At any rate, strictly following the

ovicell as the only criterion certainly makes for a strange lot of bed-fellows.
On the other hand the identification of species without the ovicells, as the forefathers of bryozoology did, is very much worse, and certainty is usually impossible.[53]

Ernst and Eveline Marcus (Figure 13). The first message from the Marcuses was sent in June 1937 after they had arrived in Brazil. It was a postcard with a brief request from Ernst, "May I ask you to be so kind as to send me a copy of your studies on freshwater Bryozoa V and also of all your future publications because I am still working on Polyzoa...." [54]

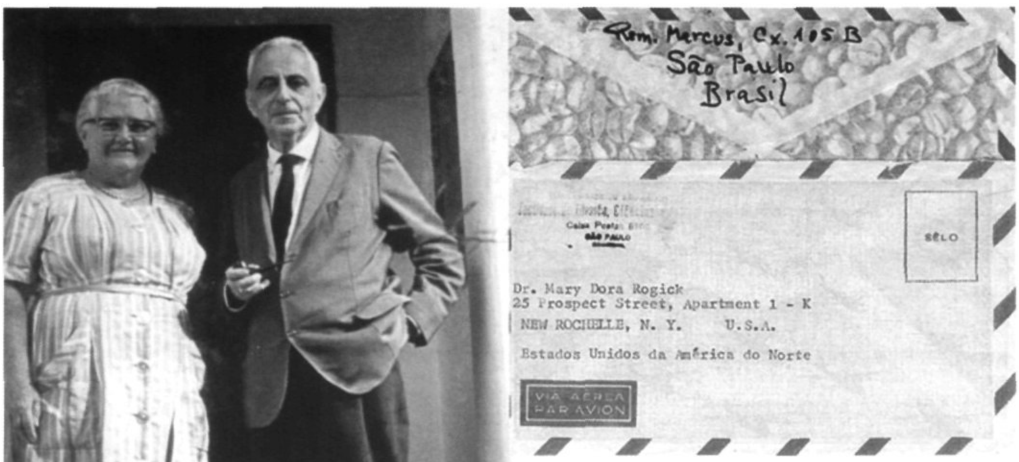


Figure 13. Correspondents: Ernst and Eveline Marcus. Envelope of letter from the Marcuses in Brazil. Greeting to Mary and signature drawn by Eveline Marcus. Mary's drawing of her difficulties in translating a German article by Ernst Marcus.

Within a year, the letters between them had become much longer and more personal. They paid her compliments on her scientific illustrations as well as those in her letters, ". . . . Your art has already proved itself in Dr. Osburn's paper on the Mount Desert Bryozoa, but it seems, that you every time reach a higher degree of skill and beauty.[55] They managed to exchange letters even during the years of WWII and after, giving each other news of other bryozoologists and scientists in Europe, e.g., "You inquired why Dr. Hastings is working on the Siboga Monograph. It is because Dr. Harmer is now too old and ill to do it so she has kindly taken the work on her able shoulders."[56]

One of Ernst's former students, Marta Vanucci Mendes, was at Yale for a year, and Mary met her at Woods Hole in 1946. She wrote, "I did so enjoy knowing Marta, little Erico and Erasmo Mendes and talking with Marta about you."[57]

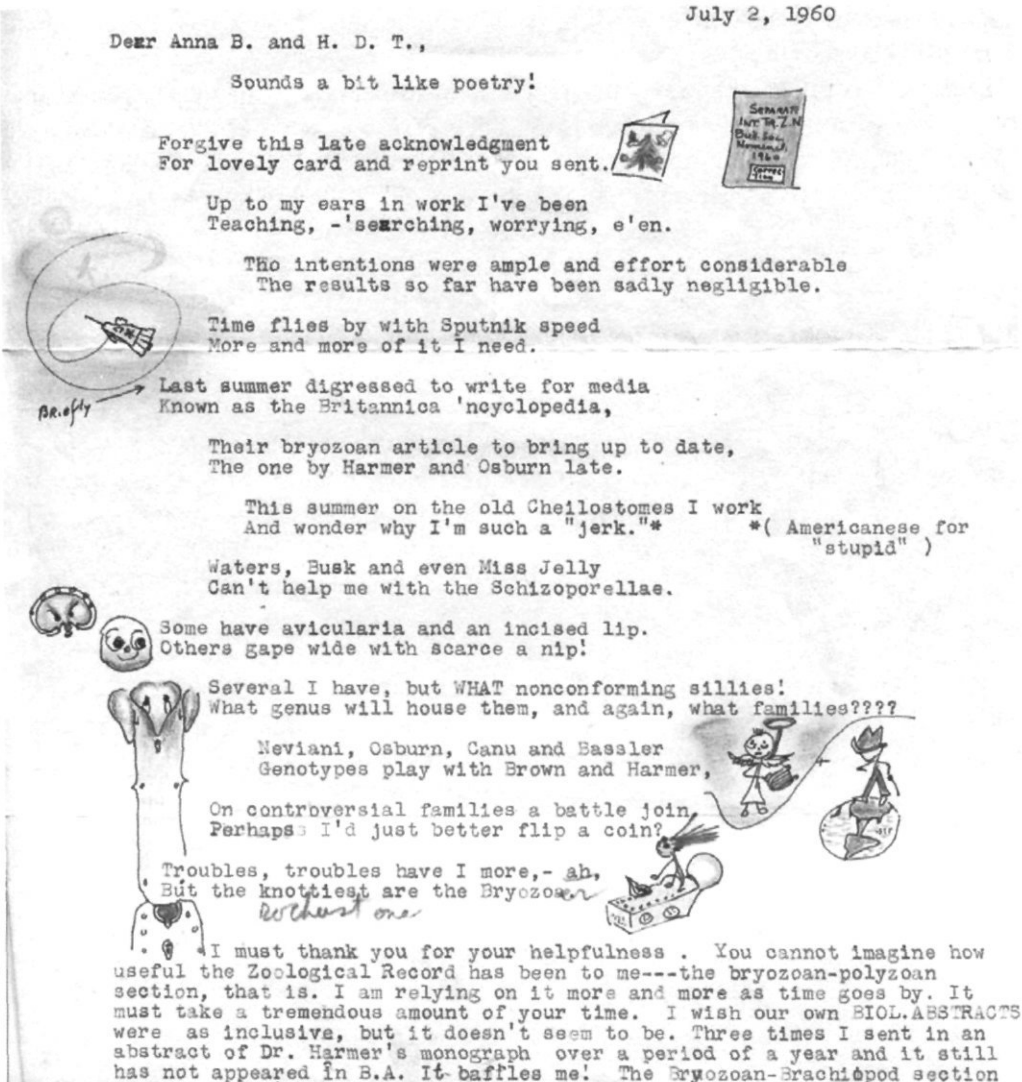
Anna Hastings (Figure 14). Her correspondence with Anna Hastings lasted from 1934 into the early 1960s. They exchanged both information about their respective lives and their scientific work. In 1941, Mary sent a food package for her war-battered friends' Christmas, "Dear Dr. Hastings, Did you ever receive the food packet which I had sent from a New York store to reach you by Christmas? Would you let me know if it failed to reach you?"[58]

I hope that you received a letter from me, crossing yours, telling you of my marriage in June, 1941, and that we were looking forward to a baby. . . .Our son, James Dighton Thomas was born on Sept. 3rd, 1942, and is a strong and lively fellow. . . That letter also thanked you very much indeed for your excellent food parcel. It was such a kind thought and the contents very welcome.[59]

> You must be wondering what has happened to me. . . . In 1950 I was short handed in the house the whole year, sometimes no help at all, and husband and son both had ailments of various kinds involving bed and care, and, at long last, we had our war-damage repairs done (every ceiling in the house). That was the home front. On the scientific side, I still have Sir Sidney Harmer's Siboga MS and my own reports on Chaperia and Arachnopusia, which were virtually complete 8 years ago, to get into shape for press.[60]

Russian Workers. G. G. Abrikosov and Elena Androsova (Figure 15). Once correspondence with people in the USSR became easier, Mary undertook correspondence with two of the Russian Workers. In 1958 she wrote to Abrikosov,

> My bryozoan research progresses slowly because there are so many diversions and because it can only be done during the summers. The diversions however, are altogether pleasant. One of them, the abstracting and editing of bryozoan literature for BIOLOGICAL ABSTRACTS, is most gratifying, because it enables me to know what research is being done in the field. Although I am in touch by correspondence with many of the bryozoologists there are still a number with whom I should like to establish contacts and the abstracting helps in that. During the summer (June to Sept.1) I do my bryozoan research. For several years now I have been working on a collection of Antarctic Bryozoa which the U.S. National Museum, Smithsonian Institution, has lent to me to work up. There remain about 3 or more summers' work on the



July 2, 1960

Dear Anna B. and H. D. T.,

Sounds a bit like poetry!

Forgive this late acknowledgment
For lovely card and reprint you sent.

Up to my ears in work I've been
Teaching, -'searching, worrying, e'en.

Tho intentions were ample and effort considerable
The results so far have been sadly negligible.

Time flies by with Sputnik speed
More and more of it I need.

Last summer digressed to write for media
Known as the Britannica 'ncyclopedia,

Their bryozoan article to bring up to date,
The one by Harmer and Osburn late.

This summer on the old Cheilostomes I work
And wonder why I'm such a "jerk."* *(Americanese for "stupid")

Waters, Busk and even Miss Jelly
Can't help me with the Schizoporellae.

Some have avicularia and an incised lip.
Others gape wide with scarce a nip!

Several I have, but WHAT nonconforming sillies!
What genus will house them, and again, what families????

Neviani, Osburn, Canu and Bassler
Genotypes play with Brown and Harmer,

On controversial families a battle join,
Perhaps I'd just better flip a coin?

Troubles, troubles have I more,- ah,
But the knottiest are the Bryozoa.

I must thank you for your helpfulness . You cannot imagine how useful the Zoological Record has been to me---the bryozoan-polyzoan section, that is. I am relying on it more and more as time goes by. It must take a tremendous amount of your time. I wish our own BIOL.ABSTRACTS were as inclusive, but it doesn't seem to be. Three times I sent in an abstract of Dr. Harmer's monograph over a period of a year and it still has not appeared in B.A. It baffles me! The Bryozoan-Brachiopod section of B.A. doesn't approach the coverage of your Z.R. I try to abstract as many of the bryozoan articles as I can but some of the foreign articles take a bit too much time to translate. Ah, if only some of our French-writing brethren and "sisteren" could be induced to include a summary at the end of their sometimes rather long histological or morphological or philosophical papers, life would be simpler for the translators!
Must stop this rambling and get to work. With best wishes,

...nk you for your Christmas greeting and Recent Reprint.

Rogick

Figure 14. Correspondents: Anna Hastings.

project. I keep publishing small papers on it after each summer so that the work is always progressing a bit. In that way, each summer's work is generally published by the time the following summer comes around. One of my biggest difficulties is finding journals which will accept the taxonomic type article for publication…."[61]

And later that year she wrote,

> I do not know Russian, but at am willing to learn although it may take me a VERY LONG time! My parents were from Croatia and we spoke that when I was a child but my knowledge of it is imperfect – very ungrammatical and rather phonetic. We used both Latin and Cyrillic script but it has been so long since I did any reading in the later script (outside of trying to translate enough of the Russian articles on Bryozoa in order to write abstracts for BIOLOGICAL ABSTRACTS) that I get mixed up on some of the letters.[62]

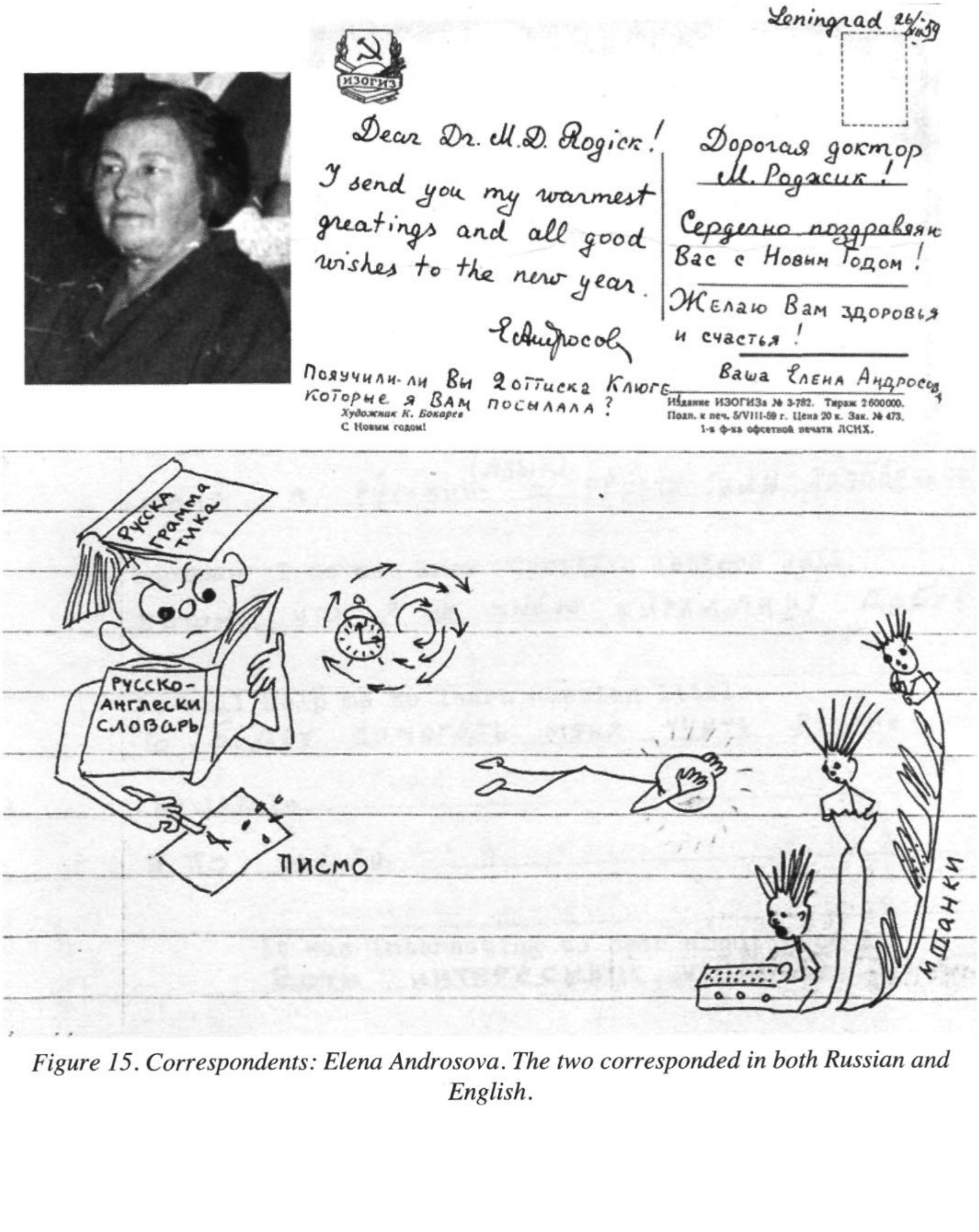


Figure 15. Correspondents: Elena Androsova. The two corresponded in both Russian and English.

Her letters to Elena Androsova also covered personal and scientific topics. Some of them Mary wrote in painstaking Russian, telling Elena first that

> I have at hand 2 Russian dictionaries (Alexandroff 1923, Segal 1958) and 2 Russian grammars (Magnus 1917, Motti 1922) but, unhappily what is inside THEM is not inside MY HEAD. However, after a real effort, I managed to write an abstract of your North Japanese Sea paper for BIOLOGICAL ABSTRACTS. It took me most of a whole day to translate the first page of your paper and to make an abstract of it—so you can see I am not very proficient, —or better say I am more determined than persistent.[63]

Younger Bryozoan Workers. Although she concentrated mostly on her Antarctic work in later years, she still corresponded with freshwater biologists, giving graduate students such as John H. Bushnell, then at Michigan State, her advice on describing phylactolaemates, "...you should include pictures of the statoblasts (both faces and edge), measurements of the statoblasts, pictures of the growth habit of the colony, make tentacle counts and get the shape of the lophophore itself. Even if your identification is faulty at least if the pictures are included and measurements given whoever comes after you can check as to the accuracy of your identification or at least know what you had."[64]

She gave similar advice to John S. Ryland, in a letter telling him that she had sent him a batch of *Bugula* from Woods Hole, "My sympathies to you on your struggles with the Bugulae....Isn't bryozoan taxonomy a glorious mess! One can work up a full-blown case of frustration, mental collapse, hallucination, or what have you by trying to unravel some of the synonymy. But keep "plugging" away. If you just include enough good clear drawings illustrating your points you will do a great service to all your colleagues and those who come after you. Harmer's and Ann B. Hastings' works are most admirable examples to follow."[65]

To Tom Schopf, then a new postdoctoral fellow at the MBL, who wrote her in early October, 1964, she responded with what may have been her last letter of encouragement. "You have my blessings and good wishes for your projected study of Woods Hole & New England Bryozoa. It in no way infringes on my "territory"....Unfortunately, I can't be of any help to you on the WH & NE bryozoa because of a severe illness at present...."[66] This letter may have been her last scientific correspondence and her last signature (Figure 16). She died less than two weeks later on October 26, 1964.

7. Final illness

Mary's terminal illness seems to have progressed rapidly. The previous summer she had taught a summer course in Invertebrate Zoology at the University of Rhode Island and participated in a research cruise that was one of the peak experiences of her life. There are no mentions of illness in any of her letters that winter or spring, but by June, she was in the hospital with cancer, although the treatment she describes below would have been standard at the time for something like lymphoma as well for abdominal cancer.[67]

Sept. 27, 1964

Dear Ursuline nuns and others of the college community,

Words cannot adequately express my heartful gratitude to you for your universal concern, your many gracious prayers, letters and cards of inspiration and encouragement, your generous gifts of flowers, food, literature, personal items and other reminders of your love and kindness; also, the visits from, and transport by faculty and office staff when I had to go to the doctors or to the hospital.

All these constant revelations of the greatness of your hearts helped me through these past 3 months when I was so unaccustomedly helpless physically. It is with sincere regret that I cannot write each one of you a personal note of thanks but strength is something I sadly lack.

It was as if God meant this illness to be a new lesson in my ever continuing education. If I had not been so ill I would never have discovered the deep well of love, compassion and generosity that is so much a part of every one of you.

I thank every one of you from the depth of a grateful humble heart.

Yours most gratefully,

Figure 16. Last signatures. Letter of thanks to the nuns at CNR. Signature from letter to T.J.M. Schopf written on October 7, 1964, shortly before her death.

> This summer I had 3 blood transfusions, anemia, an exploratory abdominal operation, 40 debilitating cobalt radiation treatments with 3 more blood transfusions interspersed – and still the anemia. The treatments left me nearly, helpless, very weak and sick. Most of my summer has been spent in bed—and even now.... [68]

Her illness was diagnosed as a malignant sarcoma, which by the time she visited her doctor had spread to lymph nodes along the aorta, liver, stomach, etc. After surgery and radiation treatment she was advised not to teach. The College President, Mother Mary Robert Falls, gave her a paid leave of absence. From her letters it appears that Mary Rogick was not aware her illness was terminal until a few weeks before her death.[69]

Then, as now, there are no explanations as to why she succumbed to terminal illness at that point. She had been told by friends for years that she worked too hard. Osburn told her not to work too hard – 1930s or 40s.

Libbie Hyman told Mary's former student Rosemary Kenedy that "She (meaning Mary Rogick) works too hard."[70]

It is clear from her letters that Mary was almost constantly sleep deprived, often telling correspondents that she had been able to sleep only a few hours because of her workload, but this may have been partly her own work/sleep style. In a 1955 letter to the Marcuses, after urging them to stay healthy and not overwork, she confessed:

> Fortunately my health is excellent, but this summer I made a surprising discovery – how wonderful one can really feel after a good long night's sleep. Never before this summer had I had the opportunity for very many nights of 8 or 9 hours sleep. Always in the past if I got 5 or 6 hours sleep I thought I was very well off. Now that I have discovered how wonderful it is to sleep 8 or 9 hours—I shall have to reform my old way of living. That will be difficult, since I seem to work best from midnight onward.[71]

She said something similar to R. S. Bassler in a 1956 letter, "Since early childhood I've had an insatiable desire for reading. My mother used to let me stay up till the wee small hours even when I was in grade school so long as I wanted to read. That habit of late study or night work has been with me all these years and it is a hard one to break."[72]

Maybe the fact that her only workspace at the College was in a room where chemicals were stored, and her long career teaching histology, had an effect on health – but we'll never know. What is clear is that she died in the prime of her research career, and her loss affected all who know her, whether personally or by correspondence.

8. Scientific Legacy

Figure 17 shows some examples of her scientific and artistic legacy. Despite her heavy teaching load, Mary was an extremely productive scientist, publishing 64 papers on freshwater and marine bryozoans and on biology teaching methods. In his 1967 study of the literature of the phylum Ectoprocta between 1555 and 1963, Tom Schopf defined the major contributors to the bryozoan literature during that time period as the 2% of authors who published 10 or more papers. This group was responsible for 36% of the literature published. Mary Rogick ranked 8th overall with respect to the number of papers produced, an amazing feat of focus and dedication.[73]

When you remember that most of her work was done before the invention of the Xerox machine so that the extensive series of references necessary for taxonomy had to be copied by hand or expensively Photostatted, her accomplishments seem even more remarkable. Many of the references she needed were not in the CNR library. To find them she had to take the train into New York City and spend long hours in the American Museum of Natural History Library. She was overjoyed when the NSF grants she received for her

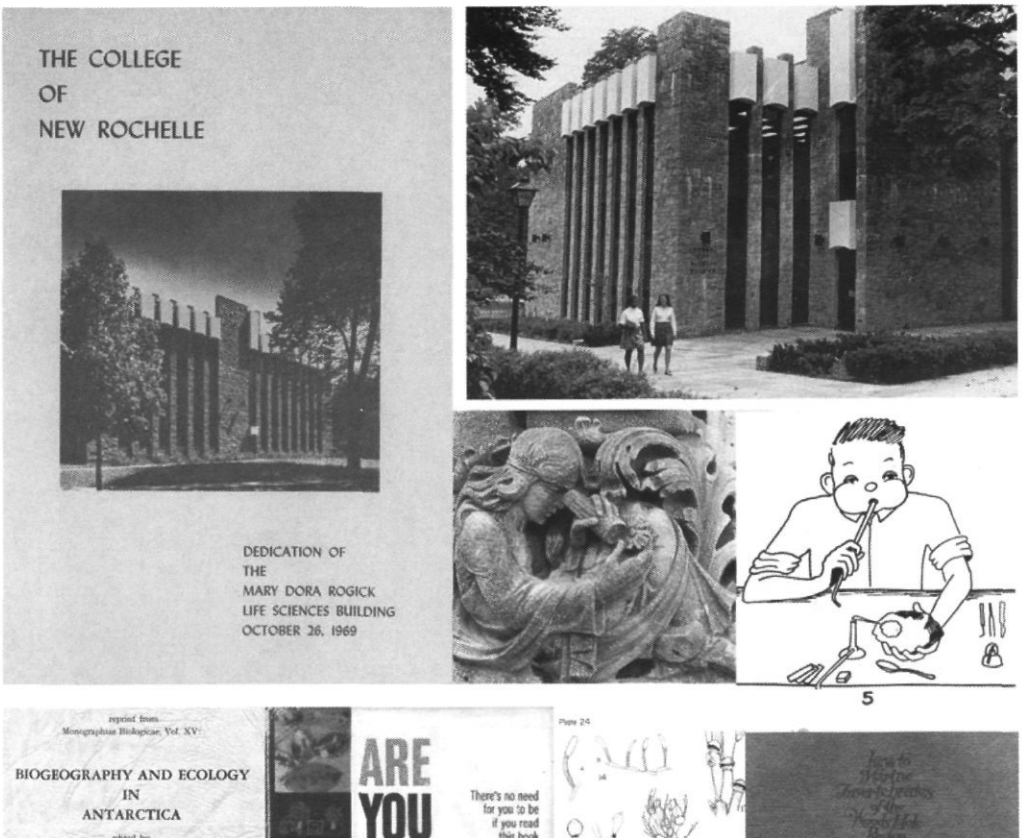


Figure 17. Some examples of Mary Dora Rogick's bryozoan legacy. Cover of the Dedication program for Rogick Hall, 1972. Rogick Hall, College of New Rochelle. Cover page of her article on Bryozoa of the Antarctic. Cover of gardening book by Cynthia Westcott, illustrated by Mary Rogick. Part of Plate 24 and cover of the 1964 Woods Hole Key *for which Mary wrote the bryozoan chapter.*

Antarctic work during the 1950s finally let her purchase some of the necessary monographs and have them bound and to have Photostats of the entire bryozoan section of the *Zoological Record* made for her own collection.[74]

In spite of her personal shyness, when it came to her research she was not at all shy to state her opinions, although with her usual good humor. Regarding the use of keys she wrote:

> In bryozoan work I usually ignore the keys found in various works because the keys are only on limited collections and not applicable to all species in a particular genus or to all genera in a particular family. Bryozoan identification is far from scientific yet. One has to be a mind-reader, crystal-gazer, modern-or-ancient- "art"-interpreter, divining rod user, coin flipper or gifted with the imagination of an H.G. Wells or H.C. Andersen in order to identify some of the bryozoans that crop up.[75]

Antarctic Work. Her papers on the taxonomy of Antarctic bryozoans were her most far-reaching legacy. From the material she received from the Smithsonian that had come from collections made by the U.S. Navy's Antarctic Expedition, she produced 13 papers on taxonomy of Antarctic Bryozoa, the last published in 1965, after her death. This work included 29 new species, some of the "strangers" as she called them, were found by later workers to deserve new genera, as well.

In his 1995 book on Antarctic cheilostomes Peter Hayward summed up her contribution as follows, "…her clear, detailed descriptions and beautiful, accurate drawings made her work of great practical value to other workers".[76]

The only thing Mary did for which those who followed cannot be grateful, was to promote and use "calcining" as a means of cleaning bryozoans to produce skeletons suitable for illustration. Unfortunately the beautiful skeletons produced by this technique were not permanent, and her calcined types at the Smithsonian's Natural Museum of Natural History have turned to unrecognizable ashes. Any aspiring bryozoan taxonomists who are not aware of the drawbacks of this method should be advised against the technique.

Mary's premature death meant that she never received the honors that come to senior scientists, no medal was ever awarded to her, no Festschrift was held in her honor, and sadly, she did not get to enjoy the retirement travel she had dreamed of. CNR did build a new science building in 1972, and it is called Rogick Hall. She was also honored by the College at its 100th anniversary celebration in 2004, and a virtual exhibit about her was created by the CNR Library.

The lack of honors does not diminish the contribution she made to invertebrate zoology, bryozoan taxonomy and biology teaching. Her life serves as a model of productivity and collaboration for all her scientific descendents.

9. Acknowledgements

Mary's will left her scientific library to the Woods Hole Marine Biological Laboratory. Dr Melbourne Carriker, Director of the Systematics and Ecology Program there, asked his postdoctoral fellow, Dr Thomas J. M. Schopf, to sort through the material received from the College of New Rochelle. That is why when I was a graduate student at the University of Chicago a few years later some of the material on which this work is based was in still in Tom's laboratory. Mary's library eventually became part of the MBL library; her notebooks and other material were deposited at the Smithsonian Institution. I received the envelopes of her letters from Tim Wood when I was at the American Museum, with the idea that their archives might be interested, but since I am no longer connected with AMNH, the letters will be deposited with her other papers once this work is published. My thanks to Tim for saving this valuable historical material. My thanks go also to Sr. Martha Counihan, Archivist at the College of New Rochelle Library, for allowing the use of photographs and correspondence related to Mary Rogick's career at the College in this paper and for her thoughtful comments on Mary's career. Finally, thanks to the staff at the Pottawattamie County, Iowa Genealogical Society for their help with information on Mary's youth in Council Bluffs.

Notes

1 United States of America, Bureau of the Census. 1920.
2 M.D. Rogick to L. Hyman, September 21, 1951.
3 M.D. Rogick to Mrs Fiske, December 26, 1954.
4 Schopf, T.J.M. 1965. Mary Dora Rogick (obit.) *Ohio Journal of Science* **65** (4), 238-239.
5 Pottawattomie County Genealogical Society corresp. to J. Winston March 26, 2013.
6 *Crimson and Blue*, Abraham Lincoln High School, Council Bluffs, Iowa. 1925 Yearbook. Vol. 27, p. 94.
7 Op. cit., p. 49.
8 Rogick, M.D. 1931. Studies on the comparative histology of the digestive tube of certain teleost fishes II. A minnow (*Campostoma anomalum*). *Journal of Morphology* **52**, 1-25.
9 Rogick, M.D. 1934. Studies on the freshwater Bryozoa of Lake Erie. Ph.D. dissertation. Columbus, Ohio, Ohio State University.
10 Rossiter, M.W. 1982. *Women scientists in America: Struggles and strategies to 1940*. Baltimore: John Hopkins University Press, xviii + 448 pp.
11 Op. cit. p. 129.
12 M.D. Rogick to L. Hyman, August 7, 195
13 College of New Rochelle *Tatler*, June 2, 1960, p. 3.
14 M.D. Rogick to R.G. Kenedy, November 5, 1955.
15 M.D. Rogick to G.M. Moore, March 26, 1951.
16 M.D. Rogick to S. Mentz, October 30, 1958.
17 M.D. Rogick to G.G. Abrikossov, February 24, 1958.
18 M.D. Rogick to H. Kaan, February 18, 1957.
19 M.D. Rogick to R.G. Kenedy, February 23, 1957.
20 M.D. Rogick to G.M. Moore, October 20, 1961.
21 M.D. Rogick to R.S. Bassler, June 12, 1956.
22 M.D. Rogick to E. Androsova, January 25, 1959.
23 M.D. Rogick to S. Mentz, October 30, 1957.
24 M.D. Rogick to E. and E. Marcus, November 3, 1953.
25 M.D. Rogick to L. Hyman, November 5, 1956.

26 Wood, T. S. 2002. Freshwater bryozoans: a zoogeographical reassessment, pp. 339-344. *In* P.N. Wyse Jackson, C.J. Buttler and M.E. Spencer Jones (eds). *Bryozoan Studies 2001*. Lisse, Swets & Zeitlinger.
27 M.D. Rogick to J. Ackert, August 11, 1943.
28 M.D. Rogickto R. Nauss, June 12, 1948.
29 Rogick, M.D. 1964. Phylum Ectoprocta, pp. 167-187. *In* R. I. Smith (ed.). *Keys to Marine Invertebrates of the Woods Hole Region*. Woods Hole, Massachusetts, Systematics-Ecology Program, Marine Biological Laboratory. 208pp.
30 M.D. Rogick to F. Brown, November 3, 1949.
31 M.D. Rogick to P. Schaefer December 11, 1953).
32 M.D. Rogick to S. Jackowska, July 5, 1952.
33 Brown, F. 1950. *Selected Invertebrate Types*. John Wiley & Sons, Inc. New York.
34 M.D. Rogick to F. Chace, July 27, 1957.
35 M.D. Rogick to G.A. Cole, March 2, 1958.
36 M.D. Rogickto S. Mentz, October 30, 1957.
37 M.D. Rogick to E. and E. Marcus, November 3, 1953.
38 M.D. Rogick to E. e and E. Marcus, April 26, 1946.
39 M.D. Rogick to A. Hastings, May 19, 1951.
40 M.D. Rogick to C. Goodchild, April 10, 1952.
41 Wescott, C. 1961. *Are You Your Garden's Worst Pest?* Garden City, New York, Doubleday. 305 pp.
42 Walter Beach Humphrey was a well-known local artist and magazine illustrator.
43 M.D. Rogick to J.R. Gray, March 12, 1949.
44 M.D. Rogick to R.G. Kenedy May 4, 1956.
45 M.D. Rogick to S. Mentz, October 30, 1957.
46 M.D. Rogick to L. Hyman, June 5, 1948.
47 M.D. Rogick to R.G. Kenedy, July 23, 1955.
48 M.D. Rogick to Mrs Fiske, December 26, 1954.
49 G.W. Comita to M.D. Rogick, October 6, 1956.
50 M.D. Rogick to R.W. Dexter, March 5, 1958.
51 Letters exchanged between D. Brown and M.D. Rogick in 1959.
52 R.C. Osburn to M.D. Rogick, October 11, 1937.
53 R.C. Osburn to M.D. Rogick, October 2, 1951.
54 E. Marcus to M.D. Rogick June 13, 1937.
55 E. and E .Marcus to M.D. Rogick, December 5, 1938.
56 M.D. Rogick to E. and E. Marcus, September 4, 1946.
57 M.D. Rogick to E. and E. Marcus, September 4, 1946.
58 M.D. Rogick to A. Hastings, February 22, 1942.
59 A. Hastings to M.D. Rogick, September 14, 1943.
60 A. Hastings to M.D. Rogick, February 2, 1951.
61 M.D. Rogick to G.G. Abrikosov, February 24, 1958.
62 M.D. Rogick to G.G. Abrikosov, May 25, 1958.
63 M.D. Rogick. to E. Androsova, January 25, 1959.
64 M.D. Rogick to J. Bushnell, January 29, 1959.
65 M.D. Rogick to J.S. Ryland, October 25, 1958.
66 M.D. Rogick to T.J.M. Schopf, October 7, 1964.

67 Personal communication from retired oncologist Thomas Berry, M.D. to J.E. Winston, May, 2013.
68 M.D. Rogick to T.J.M. Schopf, October 7, 1964.
69 Sr. M. Counihan, CNR Archivist, email to J.E. Winston, July, 12, 2013.
70 R.G. Kenedy to M.D. Rogick, March 12, 1956.
71 M.D. Rogick to E. and E. Marcus, November 3, 1953.
72 M.D. Rogick to R.S. Bassler, October 14, 1956.
73 Schopf, T.J.M. 1967. The literature of the phylum Ectoprocta: 1555-1963. *Systematic Biology*, **16** (4), 318-327.
74 M.D. Rogick to R.S. Bassler, June 12, 1956.
75 M.D. Rogick to G.C. Stephen, June 29, 1960.
76 Hayward, P.J. 1995. *Antarctic Cheilostomatous Bryozoa*. Oxford, Oxford University Press, 335 pp, p. 4.

Appendix 1. Publications of Mary D. Rogick

MS Thesis

Rogick, M.D. 1931. Studies on the comparative histology of the digestive tube of certain teleost fishes II. A minnow (*Campostoma anomalum*). *Journal of Morphology* **52**, 1-25.

Ph.D. Thesis

Rogick, M.D. 1934. *Studies on the freshwater Bryozoa of Lake Erie*. Ph.D. Dissertation, Ohio State University Columbus, Ohio. 152 pp.

Fresh-water and marine bryozoans

Rogick, M.D. 1934. Studies on fresh-water Bryozoa I. The occurrence of *Lophopodella carteri* in N. America. *Trans. Am. Micros. Soc.* **53**, 416-424.

Rogick, M.D. 1935a. Studies on fresh-water Bryozoa II. Bryozoa of Lake Erie. *Trans. Am. Micros. Soc.* **54**, 245-263.

Rogick, M.D. 1935b. Studies on fresh-water Bryozoa III. Development of *Lophopodella carteri*, var. *typica*. *Ohio J. Science* **35**, 457-467.

Rogick, M.D. 1936. Studies on fresh-water Bryozoa IV. On the variation of statoblasts in *Lophopodella carteri*. *Trans. Am. Micros. Soc.* **55**, 327-333.

Rogick, M.D. 1937a. Studies on fresh-water Bryozoa V. Some additions to Canadian fauna. *Ohio J. Science* **37**, 99-104.

Rogick, M.D. 1937b. Finer anatomy of *Lophopodella carteri* var. *typica*. *Trans. Am. Micros. Soc.* **56**, 367-396.

Rogick, M.D. 1937c. "Culturing fresh-water Bryozoa", 179-181. *In* P.S. Galtsoff, F.E. Lutz, P.S. Welch and J.G. Needham (eds). *Culture Methods for Invertebrate Animals*.

Ithaca, Comstock Publishing Company.

Rogick, M.D. 1938. Studies on fresh-water Bryozoa VII. On the viability of dried statoblasts of *Lophopodella carteri* var. *typica*. *Trans. Am. Micros. Soc.* **57**, 178-199.

Rogick, M.D. 1939. Studies on fresh-water Bryozoa VIII. Larvae of *Hyalina puncata*. (Hancock) 1850. *Trans. Am. Micros. Soc.* **58**, 199-209.

Rogick, M.D. 1940a. Studies on fresh-water Bryozoa IX. Additions to New York Bryozoa. *Trans. Am. Micros. Soc.* **59**, 187-204.

Rogick, M.D. 1940b. Studies on fresh-water Bryozoa XI. The viability of dried statoblasts of several species. *Growth* **4**, 315-322.

Rogick, M.D. 1940c. An ecological effect of the New England hurricane. *Ohio J. Science* **40**, 163-167.

Rogick, M.D. 1941a. Studies on fresh-water Bryozoa X. Occurrence of *Plumatella casmiana* in N. America. *Trans. Am. Micros. Soc.* **60**, 211-220.

Rogick, M.D. 1941b. Resistance of fresh-water Bryozoa to desiccation. *Biodynamica* **3**, 369-378.

Rogick, M.D. 1941c. Supplementary note on the effect of the 1948 hurricane. *Ohio J. Science* **41**, 453-456.

Rogick, M.D. and Brown, C.K. 1942. Studies on fresh-water Bryozoa XII. A collection from various sources. *Ann. N.Y. Acad. Sci.* **43**, 123-144.

Rogick, M.D. 1943a. Studies on fresh-water Bryozoa XIII. Additional *Plumatella casmiana* data. *Trans. Am. Micros. Soc.* **62**, 265-270.

Rogick, M.D. 1943b. Studies on fresh-water Bryozoa XIV. Occurrence of *Stolella indica* in North America. *Ann. N.Y. Acad. Sci.* **45**, 163-178.

Rogick, M.D. 1945a. Studies on fresh-water Bryozoa XV. *Hyalina punctata* growth data. *Ohio J. Science* **45**, 55-79.

Rogick, M.D. 1945b. Studies on marine Bryozoa I. *Aeverrillia setigera* (Hincks) 1887. *Biol. Bull.* **89**, 201-214.

Rogick, M.D. 1945c. Studies on fresh-water Bryozoa XVI. *Fredericella australiensis* var. *browni*, n. var. *Biol. Bull.* **89**, 215-228.

Rogick, M.D. 1945d. Calcining specimens. *American Biology Teacher* **8**, 66-70.

Rogick, M.D. 1949. Studies on marine Bryozoa IV. *Nolella blakei*, n. sp. *Biol. Bull.* **97**, 158-168.

Rogick, M.D. and Croasdale, H. 1949. Studies on marine Bryozoa. III. Woods Hole region Bryozoa associated with algae. *Biol. Bull.* **96**, 32-69.

Rogick, M.D. 1950. Entoprocta and Ectoprocta. Chapter 7. *In* F.A. Brown, Jr. (ed.). *Selected Invertebrate Types*. New York, John Wiley and Sons, Inc. 597 pp.

Rogick, M.D. and Van der Schalie, H. 1950. Studies on fresh-water Bryozoa XVII. Michigan Bryozoa. *Ohio J. Science* **50**, 136-146.

Rogick, M.D. 1955a. Genus *Emballotheca*. *Trans. Am. Micros. Sci.* **74**, 103-112.

Rogick, M.D. 1955b. Studies on marine Bryozoa VI. Antarctic *Escharoides*. *Biol. Bull.* **109**, 437-452.

Rogick, M.D. 1956a. Studies on marine Bryozoa V. *Clithriellum inclusum* (Water) 1904.

Trans. Am. Micros. Soc. **75**, 70-74.

Rogick, M.D. 1956b. Studies on marine Bryozoa VII. *Hippothoa. Ohio J. Science* **56**, 183-191.

Rogick, M.D. 1956c. Studies on marine Bryozoa VIII. *Exochella longirostris* Jullian 1888. *Biol. Bull.* **111**, 123-128.

Rogick, M.D. 1956d. Bryozoa of the United States Navy's 1947-1948 Antarctic Expedition, I – IV. *U.S. Nat. Mus. Proc.* **105**, 221-317.

Rogick, M.D. 1957a. Studies on marine Bryozoa. IX. *Phylactellipora. Ohio J. Science* **57**, 1-9.

Rogick, M.D. 1957b. Studies on marine Bryozoa. X. *Hippadenella carsonae*, n. sp. *Biol. Bull.* **112**, 120-131.

Rogick, M.D. 1959a. Studies on marine Bryozoa. XI. Antarctic Osthimosiae. *Ann. N.Y. Aca. Scie.* **79**, 9-42.

Rogick, M.D. 1959b. Studies on marine Bryozoa. XII. *Porella. Ohio J. Science* **59**, 233-240.

Rogick, M.D. 1960. Studies on marine Bryozoa. XIII. Two new genera and new species from Antarctica. *Biol. Bull.* **119**, 479-493.

Rogick, M.D. 1962. Studies on marine Bryozoa. XIV. *Dakaria. Trans. Am. Micros. Soc.* **81**, 84-89.

Rogick, M.D. 1964. Phylum Entoprocta, pp. 165-166. *In* R.I. Smith (ed.). *Keys to Marine Invertebrates of the Woods Hole Region.* Woods Hole, Massachusetts, Systematics-Ecology Program, Marine Biological Laboratory. 208pp.

Rogick, M.D. 1964. Phylum Ectoprocta, pp. 167-187. *In* R.I. Smith (ed.). *Keys to Marine Invertebrates of the Woods Hole Region.* Woods Hole, Massachusetts, Systematics-Ecology Program, Marine Biological Laboratory. 208pp.

Rogick, M.D. 1965. Bryozoa of the Antarctic. *Monographiae Biologie* **15**, 401-413.

Biology Teaching

Rogick, M.D. 1939. A modern teaching aid. *American Biology Teacher* **2**, 40-42.

Rogick, M.D. 1941. The training of biology teachers. *American Biology Teacher* **3**, 159-163, 177-178.

Rogick, M.D. 1941. Cartoons and simple sketches as visual aids. *American Biology Teacher* **4**, 45-48.

Rogick, M.D. 1943. Compiling supplementary reading lists. *American Biology Teacher* **5**, 178-179.

Rogick, M.D. 1943. A "KEY" to corrections for Lab Drawings. *American Biology Teacher* **6**, 8-10.

Rogick, M.D. 1945. Field trips with long-range purpose. *American Biology Teacher* **7**, 79-83.

Rogick, M.D. 1946. Symbiosis. *Turtox News* **24**, 30.

Rogick, M.D. 1946. The demonstration ocular. *American Biology Teacher* **8**, 162-164.

Rogick, M.D. 1947. *General Zoology Laboratory Manual*. St. Louis, Missouri, C.V. Mosby Co. 314 pp.
Rogick, M.D. 1965. Search for *Sargassum*. *Turtox News* **43** (8),178-181.

Book review

Rogick, M.D. 1957. [review of] Faune de France, 60. Bryozoaires. Part 1. Entoproctes, Phylactolèmes, Cténostomes. Marcel Prenant and Geneviève Bobin. Lechavalier, Paris, 1956. *Science*, **126** (3268), 311.

Encyclopedia articles

Rogick, M.D. 1960. *McGraw-Hill Encyclopedia of Science and Technology*. New York, McGraw-Hill Book Co., Inc. Bryozoa. Vol. 2, 354-35; Cheilostomata vol. 3, 16-17; Cryptostomata vol. 3, 579; Ctenostomata, vol. 3, 611; Cyclostomata, vol. 3, 644; Entroprocta, vol. 5, 7-9; Gymnolaemata, vol. 6, 299-200; Lophophore, vol. 7, 583; Phylactolaemata, vol. 10, 201-202; Statoblasts, vol. 13, 75; Stenolaemata, vol. 13, 125; Trepostomata, vol. 14, 80; Trochophore,vol. 14, 113-114.
Rogick, M.D. 1969. Bryozoa. *Encyclopaedia Britannica*. Vol. 4, 321-333.

Appendix 2. Taxa named by Mary Dora Rogick

Antarcticaetos bubeccata (Rogick, 1955) Antarctica
Cellaria coronata (Rogick, 1956) Antarctica
Cellaria monilorata (Rogick, 1956) Antarctica
Cellarinella laytoni Rogick, 1956 Antarctica
Cellarinella margueritae Rogick, 1956 Antarctica
Cellarinella njegovanae Rogick, 1956 Antarctica
Cellarinella nutti Rogick, 1956 Antarctica
Cellarinella rossi Rogick, 1956 Antarctica
Dakariella dabrowni (Rogick, 1963) Antarctica
Eminooecia carsonae (Rogick, 1957) Antarctica
Exochella hymanae (Rogick, 1956) Antarctica
Melicerita latilaminata Rogick, 1956 Antarctica
Rhamphosmittina bassleri (Rogick, 1956) Antarctica
Romancheina barica (Rogick, 1955) Antarctica
Smittina abditavicularis Rogick, 1956 Antarctica
Smittina alticollarita Rogick, 1956 Antarctica
Smittina exertaviculata Rogick, 1956 Antarctica
Smittina obicullata Rogick, 1956 Antarctica
Smittinella rubrilingulata Rogick, 1956 Antarctica
Smittoidea ornatopectoralis Rogick, 1956 Antarctica
Toretocheilum absidatum Rogick, 1956 Antarctica

Appendix 3. Bryozoan taxa named in honor of Mary Dora Rogick

Genus

Rogicka Uttley & Bullivant, 1972. Type species: *Schizoporella biserialis* Hincks, 1885. This genus includes *Rogicka biserialis* (Hincks, 1885) S. Pacific, S. Atlantic; *Rogicka joannae* Vieira, et al. 2010, SW Atlantic; *Rogicka oceanica* Gordon, 1984, Kermadec Region, and *Rogicka scopae* (Canu & Bassler, 1928), SW Atlantic.

Species

Cellarinella rogickae Moyano, 1965 Antarctica
Cigclisula rogickae (Soule, 1961) Gulf of California, E. Pacific
Drepanophora rogickae (Brown, 1958) Tertiary, Australia
Exochella rogickae Hayward 1991 Antarctica
Microporella rogickae Winston, Hayward & Craig, 2000 NW Atlantic
Smittina rogickae Hayward & Taylor, 1984
Thrypticocirrus rogickae Hayward & Thorpe, 1988

James Edwin Duerden (1865–1937): zoological polymath

Patrick N. Wyse Jackson[1] and Paul F.A. Maderson[2]
[1]*Department of Geology, Trinity College, Dublin 2, Ireland*
[2]*210 Axe Handle Rd., Quakertown, PA 18951, USA*

1. Introduction

James Edwin Duerden (1865–1937) (Figure 1) was a zoologist of considerable ability who published on many diverse topics: tortoises, ostriches, wool, corals and bryozoans (Table 1). Given such a varied research output it is surprising that these contributions are not well-known today, and the man remains an enigmatic character.

2. Early life and education

Duerden was born on 7th April 1865 (some sources[1] quote 1869) in the family home, 4 Byerden Lane, Briercliffe, northeast of Burnley, Lancashire, England. His parents were John Duerden (born Burnley 1841, died 27 December 1915) a cotton power loom weaver (and later market gardener) and Margaret (née Simpson) (born Roughlee Booth, Lancashire 1840, died 11 February 1892).[2] The Family was non-conformist and attended the Ebenezer Baptist Church, Hill Lane, Briercliffe.[3] The fourth of twelve children, eight of whom survived infancy (Figure 2), James Edwin (known in family circles as Eddie) was the eldest son.[4] He received his early education at the Ebenezer Baptist School, and from the age of twelve worked in a local mill[5] as a cotton weaver, as did his elder sisters Mary,

Figure 1. James Edwin Duerden c. *1935 (Photograph courtesy of Albany Museum, Grahamstown) with his signature below (From a letter in the Geological Museum, Trinity College, Dublin).*

Table 1. J.E. Duerden's research output, by major topic, numbers of publications, and dates.[115]

Topic	Number of publications	Dates spanned
Hydroids	11	1892-1895
Bryozoans	9	1893-1896
Sea Anemones	14	1895-1905
Corals	27	1896-1906
Anthropology and Eugenics	4	1897-1925
Ostriches	56	1905-1924
Tortoises	4	1906-1907
Wool	25	1923-1939

Priscilla, and brother Samuel,[6] and most of their neighbours.[7]

During the 1800s Lancashire was the center of the cotton industry which employed over 600,000 people.[8] However, competition from mills operating on the Continent intensified at the end of the century which saw a 20% decline in the value of British cotton exports.[9] This might explain why John Duerden moved from the mill to set up his own business as a market gardener, or perhaps this was for health reasons.[10]

Given Duerden's working class background it is perhaps surprising that he rose to an elevated academic position in later life; that he did is surely testifies his great determination. A full Professor at age forty, he was nominated (albeit unsuccessfully) for election to Fellowship of the Royal Society.[11] As a young man Duerden attended night classes at the Burnley Mechanics' Institute[12] (Figure 3) after a full day at work.[13] In 1885 he obtained an Exhibition at the Normal School of Science (renamed Royal College of Science from 1890), London. This institution was one of a number established as part of the late 19th drive to broaden educational opportunities. Primarily offering courses in applied sciences and technology to working and lower-middle class males (and later women), it was hoped that such institutions would expedite industrialization.[14] At the Normal School (NSC) Duerden enrolled in courses in Inorganic Chemistry, Physics, Mathematics and Freehand Drawing (in the first year – 1885-86), Biology, Geology and Astro-Physics (in 1886-87), and sat Advanced Zoology in 1889 gaining a mark of 75% in the examination.[15] He was taught by Thomas George Bond Howes (1853-1905) then Assistant Professor of Zoology.[16] Concurrently he attended lectures at Kings College, London where he gained an Associateship in Zoology in 1890. He was also conferred with the degree of B.Sc. from the University of London at around this time. Later in his life he was awarded a Ph.D. by Johns Hopkins University, USA, and an M.Sc. from the University of Capetown in South Africa. His sister Margaret went on to become a teacher in a local Board School and his brother Samuel eventually became a mechanical engineer; in 1911 he was working in a paper works in Bristol.[17]

Figure 2. Duerden Family Portrait, c. 1892-1895. Standing (from left): John Rawson (possibly) (1861-1895), Jane Duerden (née Rukin) (wife of Samuel) (1886-1944), John Duerden (1882-1939), Samuel Duerden (1868-1950), Mary Jane Duerden (née Haworth, wife of James Edwin) (1866-1950), James Edwin Duerden (1865-1937), Frank Duerden (1880-1930). Sitting (from left): Margaret Duerden (1875-1939), Mary Jane Rawson (née Duerden) (1860-1933), John Duerden (1840-1915), Priscilla Duerden (1863-1948). On Floor: Martha Duerden (1876-1957). It is possible that this family group photograph was taken just before James Edwin and Mary Jane travelled to the West Indies in early 1895 (From Ancestory.co.uk).

3. Dublin 1888-1895: bryozoans and hydroids

In 1888 James Edwin moved to Dublin on his appointment as Demonstrator in Biology and Palaeontology at the Royal College of Science for Ireland. Like its London namesake, this institution provided a strongly practical-based education. Duerden was to hold an additional post from 1890 with the Irish Fisheries Survey. While in Dublin Duerden most likely lived in rented accommodation; in 1893 he is listed as living at 3 Great Charles Street.[18]

During his time in Ireland he became interested in locally-collected bryozoans and hydroids from the coast of Co. Dublin.[19] He also collected from the west and south-west coasts and around Bundoran, Co. Donegal,[20] at the behest of the Fauna and Flora Committee of the Royal Irish Academy. Established in 1893, this Committee, of which

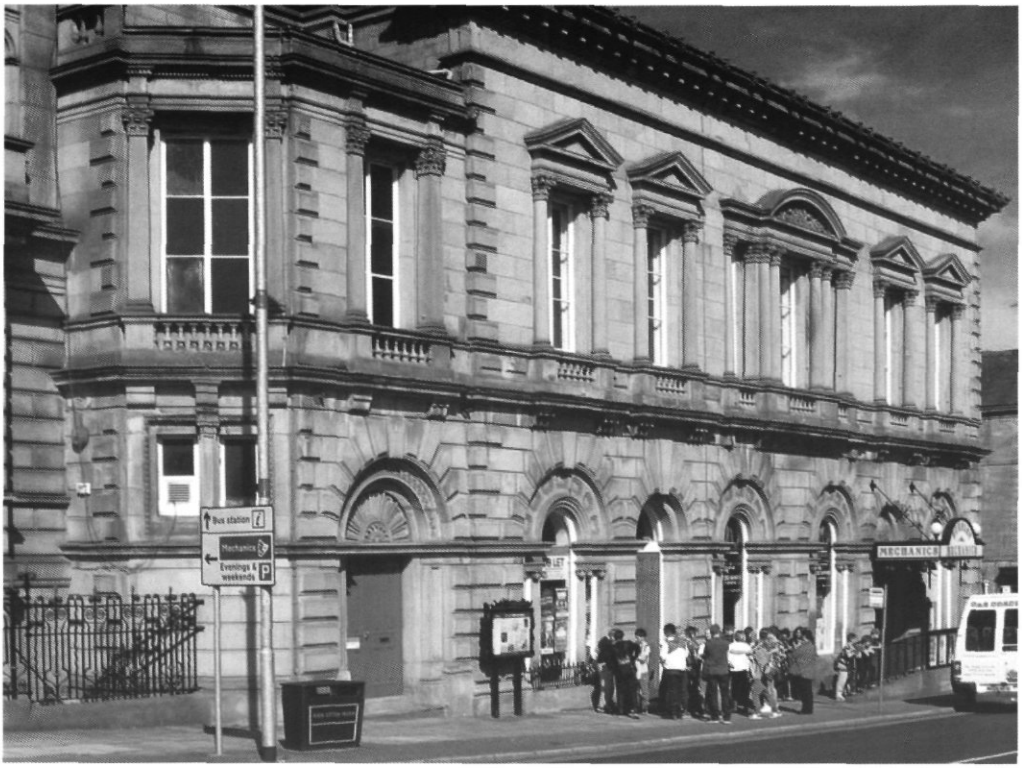


Figure 3. Burnley Mechanics' Institute (Photograph © Dave Bevis 2011 and reused under the Creative Commons Licence; http://www.geograph.org.uk/more.php?id=2638980; accessed 17 January 2014).

Duerden was a member, provided small grants for biological and geological fieldwork, and did much to foster understanding of biodiversity in Ireland. Its first grant, made in 1893 allowed Duerden and others to survey Berehaven, Co. Cork.[21] Perhaps its most significant contribution resulted from the celebrated Survey of Clare Island, Co. Mayo organized between 1909 and 1911 by Robert Lloyd Praeger. By the time this survey was undertaken Duerden had left Ireland—the bryozoans were surveyed by Alfred Russell Nichols.[22]

During the summer of 1894, some of the material collected during excursions of the Dublin Naturalists' Field Club,[23] including the bryozoan *Crisia ramosa* from Dublin Bay, was exhibited at meetings of the DNFC and the Dublin Microscopical Club.[24] These two groups fostered close links between amateur and professional naturalists and scientists in the city. They were responsible for generating quantities of biological data and publicizing them through meetings and via publications. In due course Duerden served as a Committee member of the DNFC.

Details of Duerden's findings, notably new and unusual bryozoans, were published by the Royal Irish Academy (1893) and the Royal Dublin Society (1895). Between 1893 and 1896 many short papers, and reports of various society activities, appeared in *The Irish*

Figure 4. Membranipora aurita *(Hincks) [accepted name* Callopora aurita *Hincks, 1877] on crab. Collected 13 August 1887 in Dublin Bay; donated by Duerden to Natural History Museum, Dublin 1895 (Photograph by Antoinette Kelso).*

Naturalist, a local but important natural history monthly. An example is one by William Swanston (1841-1932) and Duerden,[25] which lists bryozoans dredged from various depths of up to 72 fathoms around Belfast Lough from Larne in the north to Donaghadee in the south. This was based on collections made in 1876 and 1877 by Swanston, a leading light of the Belfast Naturalists' Field Club. Thomas Hincks had identified the bryozoans soon after their collection: Duerden augmented the list with information on species' distributions. Swanston and Duerden noted that this was the first major listing of Irish bryozoans: the junior author took the opportunity to ask the scientific community to send him additional specimens, particularly from the north and west of Ireland.

He recorded over 30 bryozoan species from shorelines in north County Dublin in a number of papers,[26] including *Alcyonidium mytili* which was new to Ireland, while he recorded the rare species *Triticella boeckii* from the eye stalks of crabs collected from the southwest, as well as *Hippuraria egertoni*.[27] Duerden's last contribution on Irish bryozoans, published by the Royal Dublin Society, comprised results of collecting undertaken in 1890 and 1891 in the west of Ireland as part of his duties for the Irish Fisheries Survey.[28]

His hydroid work, reported in several papers and summarized in that of 1895 and 1896,[29] added 33 species to the Irish records and one to the British records, of these, two were new: *Perigonimus gelatinosus* (now accepted as *Leuckartiara octona* (Fleming, 1823)[30]) and *P*. (?) *inflatus* (now not recognized).[31]

In the seven years Duerden spent in Ireland he made significant contributions to bryozoological recording and he remains one of only a small number of researchers who have focused their attention on Irish marine bryozoans over the last 180 years.[32] His work on bryozoans and hydroids increased awareness of their diversity (recording over 50 bryozoan taxa – Table 2) and distribution.

At the end of the 19th century, Dublin was a centre of excellence in scientific research. It was home to various learned, professional and amateur societies, universities and colleges, and possessed an excellent natural history museum. Working in the city would have brought any young biologist into contact with several naturalists with major international reputations: it was an ideal environment for Duerden to begin making his name. His abilities as a collector[33] and research scientist were to find fruition over the next ten years of his life when he turned from bryozoans to corals. In 1895, just before he departed for the West Indies, his collection of bryozoans and hydroids, together with some

Table 2. Bryozoans recorded or collected by J.E. Duerden from around Ireland. Taxa are listed alphabetically as given by Duerden in his publications and not updated to accepted modern nomenclature [except in a few cases†]

Taxon – Locality and date collected – Notes

Alcyonidium mytili – Rush, Co. Dublin 1894 – New to Ireland
Alcyonidium parasiticum – Laytown, Co. Meath 1894
Amathia lendigera – Laytown, Co. Meath 1894
Bicellaria alderi – Skelligs, Co. Kerry 1890
Bicellaria ciliata – Rush, Co. Dublin 1894
Bowerbankia imbricata – Laytown, Co. Meath 1894
Cellaria sinuosa – Laytown, Co. Meath 1894
Cellepora armata [= *Turbicellepora avicularis* (Hincks, 1860)] – *Laytown, Co. Meath 1894
Cellepora avicularis Hincks, 1860 – Laytown, Co. Meath 1894
Cellepora pumicosa – Laytown, Co. Meath 1894
Cribrilina punctata – Rush, Co. Dublin 1894
Crisia aculeata – Killiney, Co. Dublin 1893, Laytown, Co. Meath 1894
Crisia cornuta – Dublin Bay, Co. Dublin 1893
Crisia eburnea – Glandore Harbour, Co. Cork 1885/6, Berehaven, Co. Cork 1893, Dublin Bay, Co. Dublin 1893, Laytown, Co. Meath 1894
Crisia geniculata – Glandore Harbour, Co. Cork 1885/6, Berehaven, Co. Cork 1893, Dublin Bay, Co. Dublin 1893
Crisia ramosa – Dublin Bay, Co. Dublin 1893
Diastopora patina – 45 miles west of Blackrock island (12 miles west of Blacksod, Co. Mayo)
Diastopora suborbicularis [= *Eurystrotos compacta* (Norman, 1866) – *Kilkieran Bay, Co. Galway 1894
Eucratea chelata – Rush, Co. Dublin 1894, Laytown, Co. Meath 1894
Flustra barleei – Skelligs, Co. Kerry 1890
Gemellaria loricata – Laytown, Co. Meath 1894
Hippothoa divaricata – *Kilkieran Bay, Co. Galway 1894
Hippuraria egertoni – Berehaven, Co. Cork 1893
Idmonea serpens – Laytown, Co. Meath 1894
Lepralia pallasiana [= *Cryptosula pallasiana* (Moll, 1803)] – *Berehaven, Co. Cork 1894
Lepralia pertusa - *Roundstone, Co. Galway 1894
Lichenopora hispida [= *Disporella hispida* (Fleming, 1828)] – *Valentia Island, Co. Kerry 1890, Laytown, Co. Meath 1894
Membranipora aurita – *Dublin Bay, Co. Dublin 1887

Table 2 continued

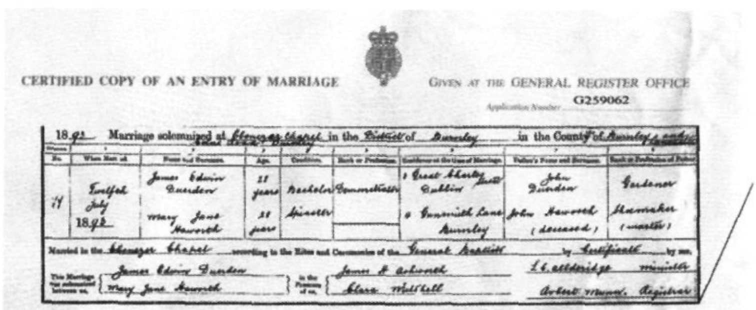
Membranipora lineata [= *Callopora lineata* (Linnaeus, 1767)] – *Roundstone, Co. Galway 1894
Membranipora membranacea – Laytown, Co. Meath 1894
Membranipora pilosa – Laytown, Co. Meath 1894
Microporella ciliata – *Roundstone, Co. Galway 1894
Microporella impressa – *Bundoran, Co. Donegal 1894, Howth, Co. Dublin 1894
Mucronella coccinea – *Kilkieran Bay, Co. Galway 1894, Howth, Co. Dublin 1891, 1894
Mucronella variolosa – 45 miles west of Blackrock island (12 miles west of Blacksod, Co. Mayo)
Pedicellina cernua - Rush, Co. Dublin 1894
Retepora beaniana – off Co. Kerry, 1886
Retepora couchii – Glandore Harbour and Dursey Head, Co. Cork, 1885/6
Schizoporella hyalina – Laytown, Co. Meath 1894, *Roundstone, Co. Galway 1894
Schizoporella linearis – *Kilkieran Bay, Co. Galway 1894, 45 miles west of Blackrock island (12 miles west of Blacksod, Co. Mayo)
Schizoporella unicornis – *Roundstone, Co. Galway 1894
Scrupocellaria reptans – Laytown, Co. Meath 1894
Scrupocellaria scruposa – Laytown, Co. Meath 1894
Smitta landsborovii – *Berehaven, Co. Cork 1893
Smitta reticulata – 45 miles west of Blackrock island (12 miles west of Blacksod, Co. Mayo)
Triticella boeckii – Berehaven, Co. Cork 1885, Kenmare River, Co. Kerry
Triticella flava – off southwest Ireland 1885/6
Triticella korenii – Berehaven, Co. Cork 1885
Triticella pedicellata – Skelligs, Co. Kerry 1890, Slyne Head, Co. Galway 1890
Tubulipora flabellaris – Laytown, Co. Meath 1894
Umbonula verrucosa – *Dursey Point, Co. Cork 1893, Rush, Co. Dublin 1894
Valkeria uva – Rush, Co. Dublin 1894, Laytown, Co. Meath 1894
Vesicularia spinosa – Bundoran, Co. Donegal 1894, Laytown, Co. Meath 1894

†taxonomic identifications updated by Mary Spencer Jones 2006
*specimen(s) in Natural History Museum, Dublin, Ireland
The bryozoans recorded in Swanston and Duerden (1893)[24] are not listed here as the identifications of Swanston's material were provided by Rev. Thomas Hincks. Duerden contributed notes about the Irish distributions of the taxa.

Figure 5. Ebenezer Baptist Chapel (right) and adjoining School (left), Hill Lane (Courtesy of Briercliffe Society; www.briercliffesociety.co.uk).

molluscs was donated to the Museum of Science and Art (now the Natural History Museum), Dublin (Figure 4): it continues to be of research value to the present day.

Duerden found personal happiness in Dublin. At the Ebenezer Chapel, Hill Lane, Briercliffe, Burnley (Figure 5), on 12 July 1893, he married. His fiancée, Mary Jane (Pollie) Haworth (daughter of John Haworth, a master shoemaker), then living at 4 Gunsmith Lane, Burnley (Figure 6), was a teacher at his old primary school. Both were 28 years old at the time of their marriage.[34]


CERTIFIED COPY OF AN ENTRY OF MARRIAGE

GIVEN AT THE GENERAL REGISTER OFFICE

G259062

CERTIFIED to be a true copy of an entry in the certified copy of a register of Marriages in the Registration District of Burnley

Given at the GENERAL REGISTER OFFICE, under the Seal of the said Office, the 28th day of October 2004

MXB 798135

CAUTION: THERE ARE OFFENCES RELATING TO FALSIFYING OR ALTERING A CERTIFICATE AND USING OR POSSESSING A FALSE CERTIFICATE. ©CROWN COPYRIGHT

WARNING: A CERTIFICATE IS NOT EVIDENCE OF IDENTITY.

Figure 6. Marriage certificate of James Edwin Duerden and Mary Jane Haworth, 12 July 1893 (Kindly supplied by Mary Spencer Jones).

4. Jamaica 1895-1901: anthropology, sea anemones and corals

In 1894 Sir William Flower was asked to recommend a suitable candidate for the position of Curator of the Museum in the Institute of Jamaica, Kingston,[35] (Figure 7): Duerden was chosen from a group of thirty-three candidates at salary estimated to have been between £400 and £600 per annum.[36] Assuming the post on 12 March 1895,[37] he also served as Acting Secretary and edited the scientific portion of the *Journal of the Institute of Jamaica*.

As funds for the Museum were initially absent or very low, collecting and curation were limited, but in the second year Duerden received an extra grant of £100. The scope of his employment freed him to pursue his developing interests, as he spent one day a week engaged in fieldwork and gave a lecture course at the Institute on 'Philosophy of Biology'.[38] He wrote on the island's marine resources, studied its caves (subject of a paper to *Nature* in 1895), and was the first to illustrate their rock carvings. In 1897, in collaboration with a former Dublin colleague, Alfred Cort Haddon (1855-1940), he reported on anthropological finds partially based on collections made by the wife of Jamaica's Governor General. Sixty years later, his anthropological work was described as being 'the best published summary to date on Jamaican archaeology."[39]

His study of Jamaican sea anemones and corals attracted American interest. The research on madreporarian corals (published in a monograph in 1902) came to the attention of William Keith Brooks (1848-1908), Chairman of Biology at Johns Hopkins University, Baltimore (1894-1908). Brooks and his colleagues had been visiting Jamaica since 1891 as they organized the annual "Chesapeake Biological Laboratory".[40] The laboratory was established in 1891 at Port Henderson (Figure 8) at the mouth of Kingston Harbour and later occupied rented premises at Port Antonio on the island's northern coast.[41] Hopkins' physical presence in Jamaica ended in tragedy with the 1897 visit: the botanist James Ellis Humphrey (1861-1897) who worked on palms, wild ginger and boring algae, and the zoologist Franklin Story Conant (1870-1897) who studied the cubomedusae, both died of yellow fever contracted on the island.[42] Following these sad events John Hopkins ceased to visit the island.[43] Participants on these trips, including Caswell Grave who collected brittle stars, and Edward William Berger who collected false scorpions and later completed Conant's work, received field training. Duerden, an experienced marine

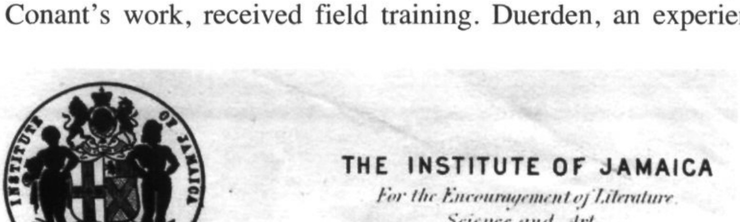


Figure 7. The Institute of Jamaica letterhead (from one of Duerden's letters to Grenville Cole, August 1895) (Geological Museum, Trinity College, Dublin).

Figure 8. Johns Hopkins Marine Biological Laboratory, Port Henderson, near Kingston, Jamaica (from Windle 1894).[41]

zoologist was a valuable local source of knowledge and specimens, aided in the field teaching, and studied the sea anenomes. Brooks was undoubtedly impressed, and arranged for Duerden to submit a Ph.D. thesis entitled *West-Indian Madreporarian Polyps* to his university, and following its review by Brooks and Ethan Allen Andrews (1858-1956), also of the Zoology Department, the degree was conferred on 12 June 1900.[44]

Duerden assisted others in obtaining Jamaican material. Notably, for Ray S. Lankaster, he procured numerous specimens of the onychophore *Peripatus*: this rare "living fossil" had eluded earlier collectors. Duerden maximized returns by displaying some specimens in the museum and offering a reward for others; as a result, the locals brought in 130 individuals and a further 50 were offered. These were later reported on by Andrews.[45] Duerden kept in touch with several former Dublin colleagues. He sent a collection of Jamaican rock specimens (mainly volcanics and metamorphics) to Grenville Cole (1859–1924), Professor of Geology at the Royal College of Science for Ireland.[46] The shipment included spiders, centipedes and slugs for Francis Scharff and George Carpenter of the Natural History Museum.[47] At James Edwin's request, Cole reported on a specimen of volcanic ash containing a granite fragment from Montrose, Jamaica, to members of the Dublin Microscopical Club.[48] His letter to Cole announced the birth of a son, Edwin Noel, on 30 March 1896 and described as, 'a promising little boy, who is now the joy of his ma and pa'.[49]

In 1900 the Government grant provided to the Institute was halved, and as a result the salary offered by its Board to its Museum Curator was lowered to £100 per annum. The committee that had overall responsibility for the museum argued that Duerden undertook numerous tasks and implied that he should be kept on, but this did not happen and his appointment was reluctantly terminated.[50] News of these difficulties reached the scientific press. *Nature* published a letter by the zoologist Hubert Lyman Clark (1870-1947), a Hopkins' alumnus, later curator of echinoderms at the Museum of Comparative Zoology, Harvard.[51] Clark asserted that ever since Duerden's 1895 arrival he had been the target of "local jealousy" stemming from a belief that a local candidate for the Institute's position had been overlooked. Clark speculated that Duerden's willingness to help fellow scientists, e.g., himself and his Hopkins' colleagues and Robert Thomas Hill (1858-1941) of the US Geological Survey was being criticized. Had such assistance, combined with Duerden's own coral research, led to a perception that curatorial duties had been neglected? Such a sentiment would have been surprising given Duerden's many positive contributions to the Institute.[52] Clark seems to have misread the fiscal condition of the Institute which, after Duerden's removal in March 1901, appointed no replacement (local or otherwise) until 1939.[53] We wonder how James Edwin felt as he and his family sailed away from Port Antonio – whose marine life he knew so well – on 12 May 1901.

5. USA 1901-1905: corals

Arriving in Philadelphia the Duerdens moved on to Baltimore. As a Bruce Fellow at Johns Hopkins University he researched Palaeozoic corals and expanded his interests into madreporian biology. Fifteen papers on the latter topic, dated between 1902 and 1906 were published by the University, the *Journal of Natural History* and *Science*.

In June 1902 Duerden was appointed Acting Professor of Biology at the University of North Carolina, Chapel Hill (UNC) to replace Professor Henry Van Peters Wilson during his leave of absence to study sponges at a Berlin museum.[54] Tragedy visited the family with the death of six year-old Edwin Noel on 24 September 1902; the child was buried at the Old Cemetery on the UNC campus (Figure 9). His parents endowed "The Edwin Noel Duerden Memorial Trust" with the Chapel of the Cross Episcopal Church, Chapel Hill to ensure an annual sermon on the benefits of a continuing friendship between the British and American peoples. The endowment is puzzling given that at the time Duerden was neither a financial contributor to the church nor was he listed as a communicant.[55] Perhaps the Duerdens

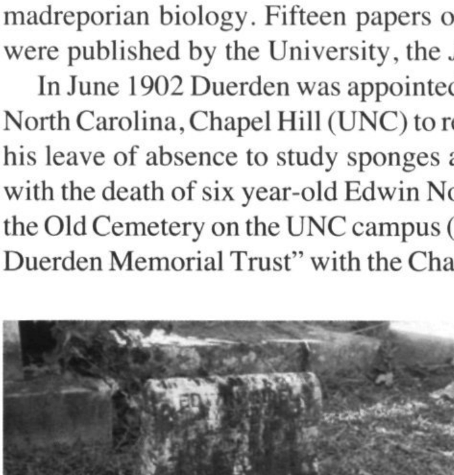


Figure 9. Headstone over grave of Edwin Noel Duerden, Old Cemetery, Chapel Hill, North Carolina (Photograph by Bill Burk, Chapel Hill).

were occasional congregants or perhaps they were acknowledging Rector William Meade's funeral service. These events may have been the beginning of Duerden's life-time role as a lay Anglican although he and his wife returned to their "chapel roots" at the time of their deaths.

At UNC Duerden taught general biology, mammalian anatomy, vertebrate embryology and histology, and zoology (comparative anatomy of invertebrates and vertebrates). He joined UNC's Elisha Mitchell Scientific Society (established in 1883 "to promote scientific studies and publication"), and in 1903 published a short paper on Palaeozoic corals in its journal.

When his UNC contract ended Duerden applied unsuccessfully for posts in Charleston, South Carolina, and Bryn Mawr, Pennsylvania. In 1903, as Honorary Curator of Coelenterates at the American Museum of Natural History in New York City, he assembled an exhibit on the biological characteristics of corals. He used the large collection of West Indian material (including type specimens) that he had donated that year.[56] Working in the recently established Department of Invertebrate Zoology he was perhaps hopeful of securing permanent employment, but this did not happen and he moved on to Michigan.

In July 1903 he was appointed Acting Assistant Professor of Zoology at the University of Michigan in Ann Arbor, for one year on a salary of $1,15057 as a replacement for George Wagner,[58] but didn't take up residency until late September of that year. Reappointed in May 1904 for a further year with a raise of $50 per annum,[59] he resigned in 1905. While at Ann Arbor he also served as a Vice-President of the Michigan Academy of Sciences.

Duerden's coral research caught the attention of the Carnegie Institution in Washington. They gave him access to their research facilities and appointed him leader of a 1904 expedition to Hawaii in 1904 to study Pacific corals. He made extensive collections of shallow-water forms, and used the newly-constructed aquarium at Waikiki Beach, Honolulu,[60] during his studies of their post-embryonic development and soft-part anatomy and the effects of mucus on their growth.[61] Later T.W. Vaughan utilized a number of Duerden's specimens which had been deposited in the United States National Museum in Washington and in the American Museum of Natural History (having originally come from the collections of the Carnegie Institution), and erected the two species named for Duerden: *Porites duerdeni*[62] – a coral of irregular appearance that could reach a height of 3m (Figure 10).

Undoubtedly Duerden made valuable contributions to coral and sea anemone taxonomy, anatomy and development. He wrote many papers, and named the actiniarian genera *Mitactis* Haddon & Duerden, 1896 (although this is now considered to be a synonym of *Anthothoe* Carlgren, 1938)[63] and *Homostichanthus* Duerden, 1900. However, following his subsequent move to South Africa in 1905 he gave up his cnidarian work and his research took completely different directions.

Did he seek a position in Britain during this period? While we have no evidence of any applications made by him, he must have contacted fellow researchers when he attended the 1903 British Association for the Advancement of Science (BAAS) meetings in York.

Figure 10. Pavona duerdeni *Vaughan, 1907 'Duerden's coral' or 'Pork Chop coral', Northwest Hawaiian Islands. (Photograph by Dwayne Meadows, July 2004; http:// en.wikipedia.org/wiki/File:Pavona_duerdeni.jpg; accessed 17 January 2014).*

Although not then a BAAS member, he presented a paper on his coral work[64] and no doubt made his availability known to the academic community. It seems probable that in York he first met his fellow Lancastrian, Walter Garstang (1868-1949), a rising star in British marine biology.[65] Garstang was to assume the Chair of Zoology at Leeds University in 1907 where, as will be discussed later, Duerden spent the years before his death.

6. South Africa 1905-1932: ostriches, wool and eugenics

In May 1905 Duerden assumed the position of Professorship of Zoology at Rhodes University, Grahamstown, Eastern Cape Province, South Africa (Figure 11) at an annual salary of £500 per annum, a portion of which was paid (until 1910) by the Albany Museum.[66] As it was considered appropriate that the post should carry a University of Capetown qualification, he was conferred with the degree of M.Sc. *ad eundem* in 1906.[67] Duerden was the first to hold this Chair, and for many years he was Department's only staff member. His teaching load eventually decreased when in 1924 Gertrude T. Brock was

Figure 11. Duerden in academic dress, Rhodes University, 1911 (Photograph courtesy of the Department of Zoology and Entomology, Rhodes University, PIC M 3893).

appointed Demonstrator of Zoology (on his 1932 retirement, she succeeded him as Acting Professor). Rhodes offered several Zoology courses: intermediate (1st year), advanced (2nd and 3rd year) and honours (4th year), and a course in Applied Biology (Figure 12). In collaboration with the Professor of Botany a Biology course was offered: unsuccessful, it was discontinued in 1914. Later M.Sc. students were enrolled.

Figure 12. Zoology class of 1921 with Duerden in the centre of the front row. The behatted and pipe 'smoking' skeleton also appears in a class photograph of 1928 (Photograph courtesy of the Department of Zoology and Entomology, Rhodes University, PIC M 3957).

Soon after his arrival at Rhodes, Duerden began to study tortoises, naming a new species *Homopus boulengeri* in 1906. However, by December 1905, he had identified a research problem with potential economic benefits: defects in ostrich feathers (Figure 13).

The ostrich industry was flourishing, meeting the demands of European and American fashion. The many farms in the Albany district generated over £3 million per annum Duerden befriended many of the farmers who provided a steady supply of research material for his laboratory: a useful symbiosis between the farmers who had organized the "Ostrich Farmers' Association of South Africa" and the research scientist. Much of the

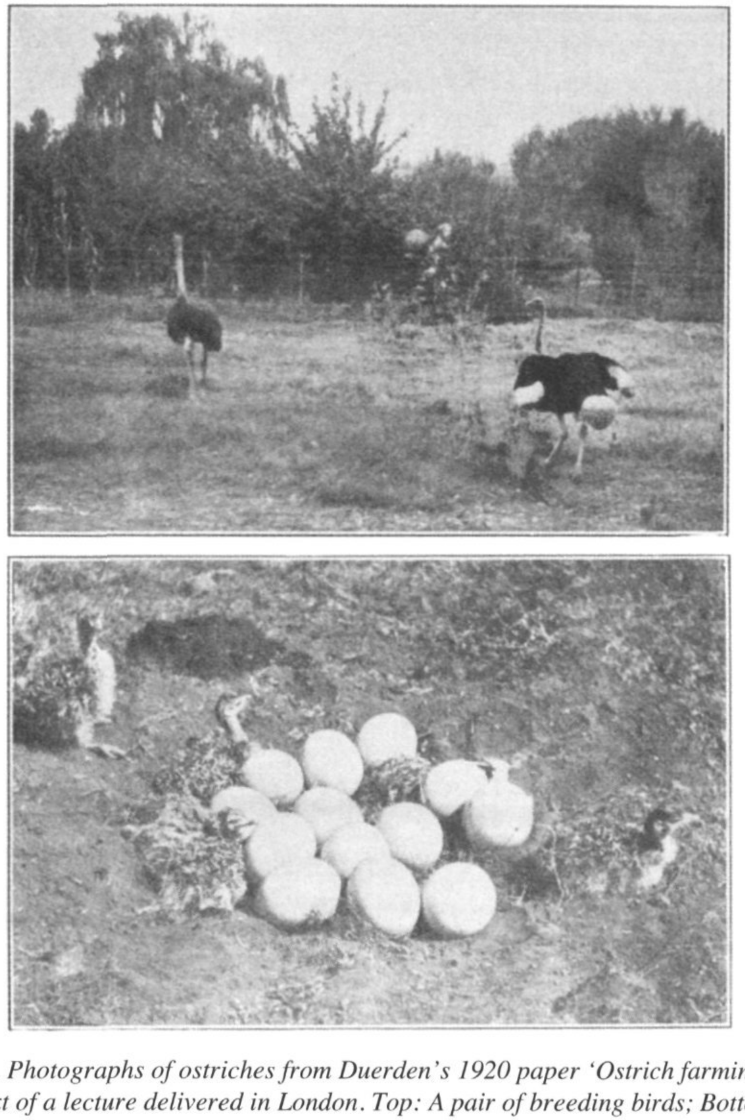


Figure 13. Photographs of ostriches from Duerden's 1920 paper 'Ostrich farming in South Africa', text of a lecture delivered in London. Top: A pair of breeding birds; Bottom: Chicks hatching in nest.

ostrich work was carried out at Grootfontein College of Agriculture, Middelburg (established in February 1911) where he was appointed Officer-in-Charge of Ostrich Investigations. Duerden was keen to promote his work and just two years after his appointment to Rhodes was contributing a paper on the effects of domestication in ostriches to the 7th International Zoological Congress in Boston in September 1907.[68] Some members of his audience – especially several junior faculty and graduate students, known to one another from summers spent in various East Coast marine laboratories, were perhaps unimpressed by this "promotion." As documented by Riddle (1908),[69] in his 1906 paper, Duerden had inaccurately and without permission, misattributed Riddle's preliminary experiments aimed at explaining the origin of "fault bars". The rapidity of production of Duerden's numerous papers on feathers - many merely transcriptions of lectures to farmers' groups, coupled with idiosyncratic citation formats, gives the canon of some fifty-six papers,[70] a mixed flavor with regard to quality. A series concerning cross-breeding between South and North African birds is of some interest. Some of this canon appeared in international journals and gave Duerden a global reputation.

As the ostrich feather industry began its decline just before World War I, Duerden continued his research in the field for a short time. On a 1920 visit to London he gave a well-received lecture at the Imperial Institute, South Kensington on 28 May.[71] This was well-recieved, but the industry was in terminal and rapid decline and never recovered.

Nevertheless, the industry was dying leaving many farmers in economic distress. Amid considerable agitation blame for its demise was variously attributed to other commercial and trading interests and groups, groups such as the Royal Society for the Protection of Birds (RSPB) concerned for the protection of birds, and government legislation of 1913 and 1914.[72] On his return to South Africa, Duerden turned his attention to reptilian limbs and pelvic girdles but, after publishing a few papers he applied his talents to wool research.

Why did Duerden turn to wool as a research topic? Certainly he recognized that the South African wool industry was growing and he knew that research was required to enhance the product's marketability. Equally he may have been drawn by a sentimentality that reflected his early years working in the Lancashire textile industry. From his ostrich work he had acquired a knowledge of skin biology so that intellectually it was not a great jump from feathers to wool.

Much of the work was carried out at Grootfontein College which switched its focus from ostriches (this institution is still active today in wool research)[73] and the veterinary laboratories at Onderstepoort. Donations from local farmers had largely paid for the excellent facilities at Grootfontein. With his new research team, Duerden soon became such an authority on wool that the Department of Agriculture appointed him Director of Wool Research, and he became a Fellow of the Textile Institute. He devised a method for cutting wool into lengths whose diameter could be measured, and in 1929 he established the 'Duerden Crimp Scale' for assessing the quality of Merino wool. This scale was long used by the industry.[74] Although largely replaced by that of 'Fibre Diameter', in South Africa, the 'Duerden' remains a commonly used measure.[75] His studies on the embryology and evolution of the merino fleece lasted into his post-retirement years.

Highly regarded in scientific circles in South Africa, Duerden served the national Association for the Advancement of Science (SAAAS) in many roles. Having helped organize the Grahamstown meeting in 1908,[76] he worked subsequently as Council Member and Honorary Secretary, and on several committees. His peers elected him President of the SAAAS for the Durban meeting in 1921. At its close, he was thanked for 'the masterly fashion and charming manner in which the various meetings had been conducted ... to which to a large extent was to be attributed the success of the Session'.[77] He represented the SAAAS at the 1932 British Association for the Advancement of Science meeting in York. At the meeting he was appointed Vice President of Section D (Zoology),[78] and contributed to a discussion on conservation of wild life and national parks.

While in South Africa Duerden's attention turned to eugenics. Now universally discredited due to its association with Nazi atrocities during World War II, this topic was widely and approvingly discussed in academic circles in the early 20th century.[79] During his American sojourn, Duerden must have either met, or at least became aware of, Charles Benedict Davenport (1866-1944), a contemporary whose life and career were remarkably, indeed uncannily, similar to his.[80] Well-known in the world of Eastern marine laboratories, Davenport became Director of the Carnegie Institution of Washington's Cold Spring Harbor (CSH) laboratory in Long Island, New York in 1904. Research on bryozoans for his 1892 Harvard Ph.D. had resulted in five papers between 1890 and 1899.[81] An early proponent of Harvard's "post-Agassi quantitative biology", Davenport soon embraced the new Mendelian genetics. He and his wife Gertrude first studied color inheritance in birds and mammals, and then addressed human skin. In 1910, Davenport established the Eugenics Record Office at the CSH richly funded through 1940 by the widow of the railroad magnate, E.H. Harriman.[82] It is unclear how much influence Davenport had on Duerden's thinking on eugenics. A common interest in eugenics is but one topic touched upon in a fourteen year correspondence and reprint exchange between the two.[83]

Duerden had published on Jamaican anthropology as far back as 1897. His ideas on eugenics in the period 1910-25 were probably influenced by his ostrich work which had considered the interactions between genetics and environmental factors such as climate and feeding. For his 1921 presidential address to the important and powerful SAAAS Duerden partially returned to anthropology,[84] Other papers, based on addresses delivered to the Grahamstown Social Welfare League,[85] discussed the affects of environment on what he referred to as the 'poor white' in South Africa.[86] Noting that their ancestors were 'the two most virile nations of Europe, the industrious, adventurous, sea-faring Dutch and British' he concluded that the diminished status of their descendents had resulted from the isolated geographical locations in which they worked, far from 'centres of activity'. He felt that education could improve their status given the agricultural and industrial revolution that was sweeping the country.[87] Duerden firmly believed that his ostrich and wool research was contributing to this economic and social recovery. In his final 1925 foray into this controversial area, he emphasized the interaction between environmental factors and human heredity.[88]

7. Retirement and later life

After his retirement from Rhodes University in March 1932 Duerden moved to England arriving at London on 8 May on the White Star Line's ship *Ceramic*.[89] However, he maintained his professional association with Grootfontein Agricultural College for some time. This institution still awards the annual Duerden Shield, to a student who demonstrates proficiency in examinations and in practicals on sheep, goats and wool. On retirement James Edwin wanted to continue research. In May 1932, in furtherance of this aim he joined the Woollen and Worsted Industries Research Association (WIRA - now the British Textile Technology Group) at Headingly, Leeds in an unpaid, honorary capacity. An appointment as Honorary Fellow of the University of Leeds on 21st December 1932 required residence in the city. The Association provided appropriate accommodation *gratis* – one of the several flats in Ashwood House, 46 Headingley Lane, Leeds 6. This imposing residence had been built by the wool stapler Joseph Austin (1803-1857) and was the childhood home of Alfred Austin who succeeded Alfred, Lord Tennyson as Poet Laureate in 1896.

WIRA, established after World War I, no doubt benefited from close links with the University where Walter Garstang (1868-1849) served as Professor of Zoology from 1907 to 1933.[90] Garstang perhaps owed his Chair to the "practical importance" of his early career in fisheries research. As teacher and administrator he fostered interests in both applied and basic skin research. Of several students, two are important in tracing the history of, and evaluating, the relationship between Garstang and Duerden – William Francis Dry (1891-1979) and Ann Hosker (1908-1965).[91] Their Leeds' education, Dry's status as the father of Australasian sheep genetics, and Hosker's feather studies through 1936, are discussed elsewhere.[92] Hosker's later career as founder of the University of Leicester's Zoology Department, as a medical student in London during WWII, and work as a general practitioner in Leeds until her death in 1965 are now known.[93] Her career raises two questions. First, what led Garstang (a marine biologist and, by the 1930s, an important theorist in evolution) to propose a study of feather regeneration to his last graduate student? Second, why do Hosker's publications make neither reference to Duerden's feather research, nor even his presence in the Leeds' Zoology Department between 1932 and 1937 when she left for Leicester?

As noted earlier, Duerden and Garstang (the younger by three years, a member of BAAS since 1894[94]) probably knew of one another's work in marine biology since early in their careers. They may have first met at the 1903 BAAS meeting. Did they discuss employment prospects in the UK or elsewhere, heavy teaching loads, or the relative merits of pure versus applied research? It is unlikely they spoke of feathers: Duerden states in a 1906 paper that he began pursuit of this literature *after* his May 1905 arrival in Grahamstown. From this we may infer that if Duerden planted the seeds of feather-related questions in Garstang's mind, he did so later than 1903. Garstang may have heard of James Edwin's "feather interests" as late as the late 1920s when his old student Dry, by then in New Zealand, was communicating with Duerden on sheep genetics.[95] Hosker's apparent

Figure 14 (left). Haggate Baptist Chapel and graveyard (Courtesy of Briercliffe Society; www.briercliffesociety.co.uk).
Figure 15 (right). Duerden family burial plot, Haggate Baptist Chapel graveyard (Photograph by David Barker; Courtesy of Briercliffe Society; www.briercliffesociety.co.uk).

unawareness of Duerden's presence around the Leeds' Zoology Department is puzzling in light of the similarities of their interests. Throughout his retirement he was studying hair follicle patterns in embryos from different British sheep breeds. Later, at his widow's request, the findings were collated by a WIRA colleague and published.[96]

Aged 72, Duerden died 4 September 1937 in the General Hospital, Nottingham. He had sustained a spinal fracture and subsequent chest complications following a fall while he and his wife were travelling to attend that year's BAAS meeting in Nottingham. As he was taking his seat, their bus moved forward and he was thrown to the floor. He appeared to have sustained no injury, but later complained of feeling unwell: his wife gave him some brandy. On reaching Nottingham it was found that his legs were paralysed. At a subsequent inquest, his widow and family agreed that the fall was accidental and that no blame was apportioned to the driver or conductor.[97]

His ashes and those of his wife (who died 27 April 1950 at 56 Park Road, Southport, Lancashire[98]) are interred at Haggate Baptist Chapel, Nelson Road, Haggate, just north of Burnley (Figures 14 and 15).[99] They lie in the family plot beside his parents, three siblings who died in infancy (Sarah, Thomas and Maria), and his sisters Margaret (born 1876, died 21 January 1939, aged 63 years) and Priscilla (born 1863, died 14 November 1948 aged 85 years).[100]

The provisions of his will, published in *The Times* on 13 October 1937 reveal an estate valued at just over £8,502 11s 7d (nearly half a million in 2014 pounds). Rhodes University and Grahamstown were eventual beneficiaries. Following his wife's life interest, he left the university £1,000, St Michael and St George's Cathedral (where he had served as an Sidesman[101]) £500, and the Diocesan School for Girls £250.[102]

8. Assessment and legacy

James Edwin Duerden was a man of considerable ability. Despite humble origins, early eking out of a meager existence as London student, then peripatetic scientist and lecturer in Ireland and the New World, he rose to the top of his profession in South Africa. His career involved continuous hard work and dedication to research (Table 3). He became a noted expert in several fields, especially the biology of corals and bryozoans, ostriches and their feathers, and the nature of wool: on these and other topics, he published extensively (Table 1). After his 1937 death, an anonymous assessor wrote in *Nature*: "His enthusiasm and personality made him a delightful colleague and an inspiration to all who worked with him."[103] At the same time, the *Burnley Express* encapsulated his achievements in the headline 'Famous Burnley Scientist. World Authority on the Growth of Wool' and went on to remark that he was 'one of the most notable of Burnley men who have achieved renown in the realm of science'.[104]

In 2014, this remarkably versatile researcher is formally remembered in two ways. First, Rhodes University awards the annual Duerden Scholarship to an outstanding undergraduate student in the Department of Zoology and Entomology who will continue to postgraduate studies: this Department also hosts an annual Duerden Lecture. Second, his name is perpetuated in both common names and formal nomenclature. 'Duerden's sun anemone' (*Homostichanthus duerdeni* Carlgren, 1900) perhaps reflects the memories of those who knew him, while the scleractinian corals, 'Duerden's coral' (aka Pork Chop coral) (*Porites duerdeni* Vaughan, 1907) and 'Knobby Finger Coral' (*Pavona duerdeni* Vaughan, 1907) are regrettably listed as threatened in the IUCN Red List.[105] 'Duerden's Burrowing Asp' (aka the 'Beaked Burrowing Asp') (*Atractaspis duerdeni* Gough, 1907) enshrines his name in herpetology.

Although it has been noted that some of Duerden's research is still of scientific, commercial and agricultural value today,[106] such statements apply strictly to the period between the end of World War I and his death in 1937. The present essay addresses his early life covering his educational background and research in marine biology. A detailed appraisal of the scientific merit of his "ostrich-wool canon", mentioned here only briefly, is planned. At this point, what can we say about the career and accomplishments of the author?

Because Duerden's eclectic interests might elicit comment by a 21st century reader, it is important to emphasize that eclecticism in biological research *per se* was not unusual until the late 20th century. What makes Duerden's record extraordinary is the rate of output of publications (Table 1) compared to where and when the work was carried out (Table 3): the man was a prodigious researcher and traveller. We have sparse documentation of the reasons behind and/or causes of his choices of research topics and place of employment: which drove which? Ironically the absence of such written data may be attributed to his frequent moves. Knowing so little of his childhood, we cannot identify what amateur interests in the Natural Sciences he might have entertained in his native Brierfield, a tiny industrial town nestled amid the hills of the Western Pennines.[107] It is difficult to imagine

Table 3. J.E. Duerden's employment history and honorary positions.

1890-1895	Demonstrator Royal College of Science for Ireland, Dublin, Ireland
1895-1901	Curator of Museum, Institute of Jamaica Kingston, Jamaica
1901-1902	Bruce Fellow, Johns Hopkins University, Baltimore, USA
1902-1903	Acting Professor of Zoology, University North Carolina Chapel Hill, USA
1903-1905	Acting Assistant Professor of Zoology, University of Michigan Ann Arbor, USA
1903	Honorary Curator of Coelenterates American Museum of Natural History New York
1905-1932	Professor of Zoology, Rhodes University, Grahamstown, South Africa
1932-1937	Honorary Staff Member, Wool Industries Research Association Leeds, England
1932-1937	Honorary Fellow, University of Leeds, Leeds, England

how the 20 year old James Edwin felt when he left home in 1885 to pursue his academic studies in London.[108] To visit the many available, free cultural activities and to travel between the Normal School of Science in South Kensington and Kings College in the Strand, he probably used the "Metropolitan/District Line" (completed in 1884) of the emerging "Tube."[109] While Duerden was a student, most of London's museums and art galleries still relied on natural light: lecture halls were still gaslit and underground cars were steam-driven. During the late 1880s, systems for public and domestic electrification were emerging. He probably did not ride an electrified subway car until his 1907 visit to Boston, as his New York City sojourn in 1903 was one year too early for him to avail himself of this new technology.[110] This brief comment on the history of transport and electrification makes a point concerning Duerden's professional life: as he moved from position to position (Table 3), his chances of availing himself of emerging research technologies changed constantly. Contemporaries who remained in one geographic location had the opportunity to learn how to work within its constraints: Massachusetts' climate permitted Davenport to collect Bryozoa during the long hot summers, and investigate their anatomy using "advanced microscopic techniques" when winter chills permeated Harvard's laboratories.[111] Throughout his early career in Ireland and Jamaica, Duerden lacked access to advanced research techniques: indeed had he had them, he would have lacked the physical environment to employ them.[112] Duerden's strategy was to become a professional exponent of the established, British, Natural History tradition – first in Ireland and later in Jamaica. He familiarized himself with prior research, concentrated on identifying new species of bryozoans and cnidarians, and accurately documented their distribution. He thus made himself indispensible as a collector assisting others who sought material for anatomical and physiological studies as he simultaneously ensured his own legacy in systematics, zoogeography and ecology. Did James Edwin want to be a "modern research zoologist"? In Jamaica, his "Philosophy of Biology" lectures suggest he was building on his Dublin experiences for interactions with amateur societies and the proselytization of science. His simultaneous excursions into anthropology, using material collected by the Governor General's wife, reveal scholarly interests and a social "savoire-faire" acquired beyond his formal university education: lauded 20 years after his death, this was work of high academic standard. Duerden's curatorial duties, begun *en passant* in Dublin, were developed in the Institute of Jamaica. His construction of a new exhibit at the American Museum of Natural History in 1903, using personally-collected coral specimens, suggests a natural talent for museology, a speciality first defined in the 1880s as museums assumed a role in public education.[113] When we examine Duerden's research output of approx 25 papers on cnidarians between 1902 and 1905, we should note that throughout this period he was teaching a diversity of topics in various universities. Once he had reached North America where he had greater access to equipment he added the microscopic examination of thin-sections to advance his coral studies.[114]

Did Duerden leave the United States in 1905 because he had been unsuccessful in finding a permanent position? Perhaps he and his wife chose to begin a new life in South Africa to ameliorate the loss of their infant son. It seems strange that James Edwin abandoned research on bryozoans and cnidarians having established a level of international renown in their biology. As a result of those studies and involvement in other areas of marine biology he had come into contact with many rising and senior American academics from whom he learned a lesson: the desirability of finding rich sponsors. Armed with social graces, administrative skills, and unflagging enthusiasm, within six months of his arrival in Grahamstown, he responded to enquiries from the rich ostrich farmers and thereafter followed paths of applied research that benefitted both him and Rhodes University.

James Edwin Duerden was a remarkably versatile researcher from Burnley, Lancashire whose range of interests covered invertebrates and vertebrate zoology from biogeography and marine diversity, to coral morphology and development to feathers and latterly wool. He is an example of a working-class Victorian who embraced educational opportunities and rose from humble origins to reach the top of his chosen academic field.

Acknowledgements

PNWJ first encountered Duerden when he embarked on a study of Irish bryozoologists over twenty years ago. We are grateful to Jim O'Connor (formerly of the Natural History Museum, Dublin) for permission to use some information contained in his 1991 paper. The authors also thank all those who have supplied information about Duerden and his work, copies of correspondence, or images: Mary Spencer Jones (Natural History Museum, London), Bill Burk, Michael McVaugh and Alan Feduccia (University of North Carolina, Chapel Hill), Adrian Craig, Alan Hodgson, Shirley Stewart (Rhodes University), Fleur Way-Jones (Curator of History, Albany Museum, Grahamstown), William Jervois

(Albany Museum), Antoinette Kelso (Trinity College, Dublin), Sylviane Vaucheret, Nigel Monaghan (National Museum of Ireland), Diarmaid Ó Foighil (University of Michigan), Sandy Baker (University of Leeds), and Tracy Commock (Institute of Jamaica). We are particularly grateful to Ray Duerden (Lancashire) who shared his findings about Duerden's early life and family and to Bill Burk who located Noel Edwin Duerden's gravestone when a prior search for it by the Wyse Jackson family while on a fleeting visit had failed to find it.

PNWJ's understanding of aspects of Duerden's ostrich and wool research was greatly enhanced in corresponding with, and subsequently meeting, PFAM. This current paper recalls Duerden's life and work from cotton-weaver to professor, and touches on areas of his early research, but we hope to expand our study in due course to include an in-depth critical analysis of the major facets of his later (ostrich and wool) output.

Endnotes

1 Document in the American Museum of Natural History, Bill Burk, personal communication 25 July 2004.

2 Duerden's date of birth is confirmed as 7 April 1865 on his birth certificate and the same date is also given on the family headstone. This memorial also provided the death dates of his parents and two sisters and the names of three siblings that died in infancy. http://www.briercliffesociety.co.uk/Grave%20Stones/Haggate%20Chapel/Duerden/Duerden9.htm (accessed 27 December 2013).

3 This church was erected in 1860 and could accommodate over 860 worshipers (*Barrett's Directory of Burnley and district*, 1896, p. 15). It is still in use today as a church.

4 Letter James E. Duerden [nephew] (Brierfield, Lancashire) to J. Omer-Cooper, 11 April 1965 (Cory Library, Rhodes University).

5 Possibly in Byerden Mill. This was burnt down on 22 October 1905 (see http://www.briercliffesociety.co.uk/Photo%20Archive/Local%20Disasters/Lodge%20Mill%20Fire.htm; accessed 17 January 2014)

6 Details of family largely provided by Ray Duerden, 7 September 2004. See also www.ancestry.co.uk.

7 In 1891 there were 6 mills in Briercliffe which contained 2,293 looms, while in the village of Brierfield half a mile away, seven mills operated 5,953 looms. Most produced printed cottons, with some capable of producing twills, jacconettes, denim, oxford cloth and striped mexicans (Details in *The Cotton Spinners and Manufacturers' Directory*, 8th edition, 1891, John Worrall, Oldham, pp. 77-79). Just 3 miles away in Burnley approximately one hundred cotton spinner and manufacturing firms were in business.

8 Rodgers, H.B. (1962) The changing geography of the Lancashire Cotton industry. *Economic Geography* **38** (4), 299-314.

9 Brown, J.C. (1995) Imperfect competition and the Anglo-German trade rivalry: markets for cotton textiles before 1914. *Journal of Economic History* **55** (3), 494-527 (Table 1, p. 496).

10 In the 1871 Census his occupation is given as 'Cotton Weaver' while in that of 1881 it is given as 'Market Gardener'. The market garden business remains in the 4th generation of the family, with John being joined in the business by his youngest sons Frank and John and then in turn by his grandson James Edwin, and latterly his sons (Census 1901; Letter J.E. Duerden [nephew]

(Brierfield, Lancashire) to J. Omer-Cooper, 11 April 1965 (Cory Library, Rhodes University). The business, known since 1900 as 'Duerden Brothers', was a well-known supplier of watercress which was moved out of the area by rail. The company quit Brierfield in 1986 but is still in operation at Great Eccleston, Preston in Lancashire.

11 Duerden was nominated for election to Fellowship between 1921 and 1925 (see Home, R.W. (2003) The Royal Society and the Empire: the Colonial and Commonwealth Fellowship Part 2. After 1847. *Notes and Records of the Royal Society of London* **57** (1), 47-84. Of the fifteen persons nominated between 1905 and 1932 six were elected (Home 2003, Appendix 4, pp. 78-79).

12 The Institute was similar to many around Britain at the time in that it provided an opportunity for further education for young working-class men, see Tylecote, M.P. (1957) *The Mechanics' Institutes of Lancashire & Yorkshire before 1851*. Manchester University Press. The Burnley Mechanics' Institute opened in 1834; the building now serves as a theatre.

13 While some mills in Lancashire had established on-premises schools for their child workers prior to 1840 (see Sanderson, M. (1967) Education and the Factory in Industrial Lancashire, 1780-1840. *Economic History Review*, new series, **20** (2), 266-279) there is no evidence that such an educational facility was available to Duerden or his siblings.

14 These bodies included the City and Guilds of London Institute for the Advancement of Technical Education (1878), Mechanics' Institutes (of many cities across Britain), the Normal School of Science (1881), and the Royal College of Science for Ireland (1867) funded in part from tax paid on hard liquor. See: Argles, M. (1962) English education for technology and science: the formative years. *History of Education Quarterly* **2** (3), 182-191; Gowling, M. (1977) Science, technology and education: England in 1870: The Wilkins Lecture, 1976. *Notes and Records of the Royal Society of London* **32** (1), 71-90; Donnelly, J.F. (1986) Representations of Applied Science: academics and chemical industry in late nineteenth-century England. *Social Studies of Science* **16** (2), 195-234.

15 Details of courses from letter H.R. Hewer to J. Omer-Cooper, 25 February 1965 (Cory Library, Rhodes University).

16 Howes was an excellent practical zoologist and teacher, and primarily interested in vertebrates. See *Proceedings of the Linnean Society*, 117th session (1904-1905), p. 36. Perhaps Howes influenced and fostered Duerden's early interest in invertebrates.

17 Census returns for 1901 (Margaret) and 1911 (Samuel).

18 Address given on his marriage certificate.

19 Why did Duerden turn his attention to bryozoans and hydroids? Perhaps he was influenced or encouraged to do so by staff members of the Museum of Science and Art, such as George Carpenter, who would nave recognised that such groups were largely under-studied in Ireland at the time. Duerden, being a junior staff member at the Royal College of Science for Ireland, probably was delighted to receive such encouragement.

20 For records of this work see Duerden, J.E. (1895) The rock pools of Bundoran. *The Irish Naturalist* **4**, 1-7; Duerden, J.E. (1896) Notes on the rock pools of Bundoran. *The Irish Naturalist* **5**, 153-155.

21 Praeger, R. Ll. (1903) Ten years' work of the Fauna and Flora Committee. *The Irish Naturalist* **12** (5), 124-131.

22 See Kelso, A. this volume.

23 See Duerden, J.E. (1894) Hydroids and Polyzoa collected between Laytown and the mouth of the Boyne. *The Irish Naturalist* **3**, 169-170; and Duerden, J.E. (1894) Notes on the marine

invertebrates of Rush, Co. Dublin. *The Irish Naturalist* **3**, 230-233.

24 *Crisia ramosa* was shown at the DNFC meeting held on 21 March 1893 (*The Irish Naturalist* **2**, 146) and the hydroids *Plumularia haleciodes* (new to Ireland) at the Dublin Microscopical Society meeting held on 20 October 1892 (*The Irish Naturalist* **1**, 193), *Canpanulina turrita* at the meeting held on 15 March 1894 (*The Irish Naturalist* **3**, 110), and *Plumularia similis* at the 21 June meeting of the same organisation later that year (*The Irish Naturalist* **3**, 201).

25 Swanston, W. and Duerden, J.E. (1893) Some north of Ireland Polyzoa. *The Irish Naturalist* **2**, 165-168.

26 Duerden, J.E. (1894) Hydroids and Polyzoa collected between Laytown and the mouth of the Boyne. *The Irish Naturalist* **3**, 169-170; Duerden, J.E. (1894) Notes on the marine invertebrates of Rush, Co. Dublin. *The Irish Naturalist* **3**, 230-233.

27 Duerden, J.E. (1893) Proceedings of Irish Societies: Dublin Microscopical Society. *The Irish Naturalist* **2**, 50.

28 Duerden, J.E. (1895) Survey of fishing grounds, west coast of Ireland, 1890-1891. Notes on the Hydroida and Polyzoa. *Scientific Transactions of the Royal Dublin Society*, new series, **8**, 325-336.

29 Duerden, J.E. (1895) *ibid.*; Duerden, J.E. 1896. Hydroids of the Irish coast. *Scientific Transactions of the Royal Dublin Society*, series 2, **8**, 405-420.

30 Schuchert, P. (2007) The European athecate hydroids and their medusae (Hydrozoa, Cnidaria): Filifera part 2. *Revue suisse de Zoologie* **114**, 195-396 (p. 323).

31 Schuchert, P. (2013) World Hydrozoa database. Accessed through: World Register of Marine Species at http://www.marinespecies.org/aphia.php?p=taxdetails&id=509903 (accessed 20 January 2014)

32 For an assessment of bryozoological research in Ireland see Wyse Jackson, P.N. (1991) Distribution of Irish marine Bryozoa, together with biographical notes relating to the chief researchers in the group. *Bulletin of the Irish Biogeographical Society* **14** (2), 129-184.

33 Aside from bryozoans and hydroids Duerden collected other invertebrate groups which he passed over to the Museum of Science and Art, Dublin or to colleagues expert in those groups. As such his collecting efforts found outlets in publications other than his own; see for example: Carpenter, G.H. (1894) Further Irish localities for pycnogons. *The Irish Naturalist* ***3*** (9), 202; Lyster Jameson, H. (1901) Notes on Irish worms: 1. The Irish Nemertines with a list of those contained in the Science and Art Museum, Dublin. *Proceedings of the Royal Irish Academy* **5**, 34-39.

34 Details from marriage certificate.

35 *Annual Report on the Institute of Jamaica, for the year ended 31st March, 1895*, p. 2.

36 Letter Thomas H. Farr (Kingston) to J. Omer-Cooper, 8 February 1965 (Cory Library, Rhodes University).

37 *Annual Report on the Institute of Jamaica, for the year ended 31st March, 1901*, p. 2; Farr, T.H. (1985) Early years of the Natural History Division. *Jamaica Journal* **18** (2), 19-28 (p. 22).

38 Letter J.E. Duerden (Kingston) to G.A.J. Cole, 12 April 1896 (Geological Museum, TCD).

39 Howard, R.R. (1956) The archaeology of Jamaica: a preliminary survey. *American Antiquity* **22** (1), 45-59.

40 Conklin, E.G. (1913) William Keith Brooks 1848-1908. *Biographical Memoirs of the National Academy of Sciences* **7**, 1-67.

41 Windle, W.S. (1894) Notes from a Marine Biological Laboratory. *Popular Science Monthly* **44**, 449-458; Brooks, W.K. (1897) The expedition of Jamaica, in the summer of 1897. *Johns*

Hopkins University Circulars **17** (132), 1-2; Brooks, W.K. (1897) Expedition of Jamaica of the students of the Johns Hopkins University. *Journal of the Institute of Jamaica* **2** (5), 465.

42 Brooks *ibid.* (1897) **17**, 2; Anon. (1897) Scientific News. *The American Naturalist* **31** (372), 1067. Several participants became seriously ill while in Jamaica or on the voyage home. Humphrey died at Port Antonio on 17 August and the leadership of the party was assumed by Conant but he died on 13 September the day after he had returned to the United States.

43 Duerden, J.E. (1903) A tropical marine laboratory for research. *Science* **17** (439), 862-864. In this correspondence Duerden was extoling the virtues of Jamaica as a site for a proposed marine research laboratory.

44 Leaflet *Conferring of Degrees at the close of the Twenty-fourth Academic Year, June 12, 1900*. The Johns Hopkins University of Baltimore, p. 4.

45 Andrews, E.A. (1933) *Peripatus* in Jamaica. *Quarterly Review of Biology* **8** (2), 155-163.

46 3 page manuscript catalogue dated 5 August 1895; Duerden to Grenville Cole [now in the Geological Museum, Trinity College, Dublin. The whereabouts of these rocks and thin sections cut from them is unknown. For Cole see Wyse Jackson, P.N. (1989) On Rocks and Bicycles: a biobibliography of Grenville Arthur James Cole (1859-1924) fifth director of the Geological Survey of Ireland. *Geological Survey of Ireland Bulletin* **4**(2), 151-163.

47 Letter J.E. Duerden (Kingston) to G.A.J. Cole, 5 August 1895 (Geological Museum, TCD).

48 Cole, G.A.J. (1897) Volcanic ash from Jamaica. *The Irish Naturalist* **6**, 136.

49 Note 47.

50 Note 37, p. 20, 22.

51 Clark, H.L. (1901, 7 February) The Museum of the Institute of Jamaica. *Nature* **63**, 347.

52 *Annual Report on the Institute of Jamaica, for the year ended 31st March, 1901*, p. 2.

53 Note 37, p. 20.

54 *The Daily Journal*, 5 June 1902, p. 1, Chapel Hill, North Carolina.

55 Personal communication from Michael McVaugh to PFAM, 24 April 2004.

56 Annual Report of the President for 1902, American Museum of Natural History, New York (1903), p. 23.

57 *Proceedings of the Board of Regents* (1901-1906), July meeting 1903, p. 220. www. http://quod.lib.umich.edu/u/umregproc/ACW7513.1901.001?rgn=main;view=fulltext; accessed 23 December 2013.

58 Letter Elaine D. Cline (Ann Arbor) to J. Omer-Cooper, 11 May 1965 (Cory Library, Rhodes University).

59 Note 57, May meeting 1904, p. 349.

60 Duerden, J.E. (1905) Marine Zoology in the Hawaiian Islands. *Science*, new series **21** (545), 897.

61 Information in Vaughan, T.W. (1907) Recent Madreporaria of the Hawaiian Islands and Laysan. *Bulletin of the United States National Museum* **59**, 1-427; Duerden, J.E. (1906) The role of mucus in corals. *Quarterly Journal of Microscopical Science* **49**, 591-614.

62 Note 61, p. 193.

63 http://www.marinespecies.org/aphia.php?p=taxdetails&id=741017 (accessed 29 December 2013)

64 Duerden, J.E. 1903. Some results on the morphology and development of Recent and fossil corals. *Report of the British Association for the Advancement of Science* 1903, 684-685.

65 Baker, R.A. and Bayliss, R.A. (1984) Walter Garstang (1868-1949): zoological pioneer and poet. *Naturalist* **109**, 41-53.

66 Hodgson, A.N. and Craig, A.J.F.K. (2005) A century of Zoology and Entomology at Rhodes University, 1905 to 2005. *Transactions of the Royal Society of South Africa* **60** (1), 1-18. Albany Museum dates to 1855 and is associated with Rhodes University.

67 *ad eundem* 'of the same rank'. It was common for universities to award such degrees (not based on submitted work) to staff or others who graduated from other institutions. See *Report of the University of the Cape of Good Hope for the year ended 31st December 1906*, Capetown, p. 8.

68 Parker, G.H. (1907) Preliminary list of Scientific Communications to be presented at the seventh International Zoological Congress, Boston, August 19 to 23, 1907, *Science*, n.s. **26** (657), 154-158.

69 Riddle, O. (1908). The genesis of fault bars in feathers and the cause of alternation of light and dark fundamental bars. *Biological Bulletin* **14**, 328-371. Riddle noted (p. 338) that Duerden had wrongly attributed his, Riddle's, experimental work on producing fault-bars in feathers to R.M. Strong and C.O. Whitman.

70 Number listed in manuscript 'A bibliography of the works of James Edwin Duerden' (compiled by M. Fouché, 1968) (Cory Library, Rhodes University, Grahamstown, South Africa, MS 17 756).

71 Text of the lecture was published in Duerden, J.E. (1920) Ostrich Farming in South Africa. *Journal of the Royal African Society* **20** (77), 19-24

72 For a full discussion of these issues see Pinto, R.G. (2011) *Activist globalization: how markets, societies and states empower cause-orientated action in transnational relations*. Ph.D. dissertation, University of Maryland; Stein, S.A. (2008) *Plumes: Ostrich Feathers, Jews, and a Lost World of Global Commerce*. Yale University Press, New Haven.

73 For a listing of recent research papers on wool from this institution see: http://gadi.agric.za/articles-agric.php

74 van Wyk, C.M. (1980) Wool research in South Africa conducted under the auspices of the Department of Agriculture. Part 1 - 1920-1950. *Karoo Agriculture* **1** (5), 17-20.

75 Oliver, W.J. and Oliver, W.J. (2005) The effect of nutritional stress on the wool production potential of strong and fine wool Merino sheep. *South African Journal of Animal Science* **35** (4), 273-281.

76 Duerden, J.E. (1908) The South African Association for the Advancement of Science. *Nature* **78**, 395-397.

77 Anon. (1922) Report of the nineteenth annual meeting of the South African Association for the Advancement of Science. *South African Journal of Science* **18**, xxiv.

78 Anon. (1932) Foreign guests of the British Association at York. *Nature* **130**, 303; BAAS, *Report of the annual meeting, 1932 (102nd Year), York*, p. xi.

79 Black, Edwin (2003). *War Against the Weak: Eugenics and America's Campaign to Create a master Race*. Thunders Mouth Press, New York, 550pp.

80 Riddle, O. (1948). Charles Benedict Davenport, 1866-1944. *Biographical memoirs of the National Academy of Sciences* **25**, 75-110.

81 See listing of Davenport's papers in Nickles, J.M. and Bassler, R.S. (1900) A synopsis of American Fossil Bryozoa including bibliography and Synonymy. *Bulletin of the United States Geological Survey* **173**, p. 482.

82 According to Black, note 76, page 46, Davenport pursued this profitable link with the Harrimans after meeting their undergraduate daughter Mary at a CSH summer school. Mary was:- "so enthusiastic about eugenics (that) her classmates at Barnard College had nick-named her 'Eugenia'.

83 Duerden wrote to Davenport irregularly over a period of fourteen years between 1907 and 1921 (letters in American Philosophical Society), and also sent him papers. For a listing of eighteen Duerden offprints (1906-1927) in Davenport's personal collection see: http://archives.cshl.edu/R/BMRVS2XE17X4J7QI878GDMU28N59NBHFHID6HILT58DE1JECXQ-00232; accessed 17/1/2014.

84 Duerden, J.E. (1921) Social anthropology in South Africa: problems of race and nationality. *South African Journal of Science* **18**, 1-31.

85 Information from Alan Hodgson, 22 August 2004.

86 Duerden, J.E. (c. 1917) *The betterment of the human race: a paper read before the Grahamstown Social Welfare League*. Grocott & Sherry, Grahamstown; Duerden, J.E. (1923) Genesis and reclamation of the poor white in South Africa. *Eugenics Review* **14** (4), 270-275.

87 See Dubow, S. (1995) *Scientific Racism in modern South Africa*. Cambridge University Press, pp. 137-140 for a fuller discussion of Duerden's views.

88 Duerden, J.E. (1925) Genetics and eugenics in South Africa: heredity and environment. *South African Journal of Science* **22**, 59-72.

89 www.ancestry.co.uk: UK, Incoming Passenger Lists, 1878-1960 (accessed 20 January 2014)

90 See Baker and Bayliss, note 65.

91 Maderson, P.F.A. (2004) Born in a follicle—a historical perspective. *Differentiation* **73**, 466-473.

92 See Maderson, note 91.

93 Paul Maderson, unpublished information.

94 See listing in Annual Reports of BAAS meetings, i.e. 1903 meeting, p. 39.

95 See Maderson, note 91.

96 J.E. Duerden and A.B.Wildman (1939). The arrangement of fibre follicles in some mammals, with special reference to the Ovidae. *Transactions of the Royal Society of Edinburgh* **59**, 763-771.

97 Details of accident and inquest from *Burnley Express* September 1937.

98 http://trees.ancestry.co.uk/tree/18153783/person/20005526089 (accessed 10 January 2014)

99 The chapel which had been erected in 1865 was demolished in about 2001. Source of image: http://www.briercliffesociety.co.uk/Grave%20Stones/Haggate%20Chapel/Duerden/Duerden9.htm (accessed 10 January 2014)

100 See note 2.

101 A Sidesman is a volunteer, generally in the Anglican tradition, whose would have included assisted the Church Warden in collecting the offerings of the congregation, and showing worshipers to their pew.

102 His estate is valued at nearly £489,861 in today's value. Of the bequests £1000 in 1937 is equivalent to £57,613 today; £500 = £28,806; and £250 = £14,403. See http://www.thisismoney.co.uk/money/bills/article-1633409/Historic-inflation-calculator-value-money-changed-1900.html (accessed 16 January 2014)

103 Anon. (1937) Prof. J.E. Duerden. *Nature* **140**, 576.

104 *Burnley Express*, September 1937.

105 See http://www.iucnredlist.org/details/133702/0 for information on *Pavona duerdeni*, and http://www.iucnredlist.org/details/132891/0 for *Porites duerdeni* (accessed 28 December 2013)

106 Alan Hodgson (Rhodes University) summed up Duerden's contribution in one research field thus: "Much of the research work initiated ... at Rhodes ... has been of inestimable value to the

sheep farmer and wool industry as a whole." (Personal communication to PNWJ, 22 August 2004).

107 In 1944-1945, when PFAM was a WWII evacuee living on a "modern estate", i.e., *circa* 1930, on the North-East corner of Brierfield, a 2 mile walk across open fields, traversed by streams, would have taken one to the Ebenezer Baptist Church in Briercliffe. In 2014, Google maps reveal new construction along the roads, but much open land remains. Duerden undoubtedly knew these fields still only yards from the sturdy stone terrace houses where he and his neighbours lived.

108 The time he spent studying at London University, 1885-1889, was a critical period in the history of the institution as the metropolis itself underwent a major reorganization, rebuilding and expansion. See Negley Harte (1986) *The University of London 1836-1986*. The Athlone Press Ltd., London, 303 pages. For overviews of the history of the metropolis in the second half of the 19th C, Linda Nead's (2000) *Victorian Babylon: people, streets and images in nineteenth century London*. Yale University Press, Newhaven and London, 251 pages, begins a story that culminates in Jonathan Schneer's (1999) *London 1900: The Imperial Metropolis*. Yale University Press, Newhaven and London, 336 pages.

109 http://en.wikipedia.org/wiki/Metropolitan_Railway#Inner_Circle, accessed 24 March, 2014.

110 http://en.wikipedia.org/wiki/History_of_rapid_transit, accessed 24 March, 2014.

111 Davenport's doctoral years (1889-1892) produced six papers containing exquisite illustrations of cell and tissue organization in bryozoans [see bibliography in Oscar Riddle's (1948) Charles Benedict Davenport: 1866-1944. *Biographical Memoirs National Academy of Sciences* **125**, 75-11).

112 As late as the early 1960s, PFAM experienced annual problems with histo-technique in a junior post in a Commonwealth University because "air-conditioning", while considered essential for efficient administration, was deemed an expensive luxury for research workers.

113 See Lewis. Geoffrey D. (2014) http://www.britannica.com/EBchecked/topic/398827/history-of-museums, down-loaded 24th March 2014.

114 See for example his papers 'Primary hexamerism in the Rugosa'. *Science* **15** (1902), 577, 'Aggregated colonies in madreporarian corals'. *American Naturalist* **36** (1902), 461-471, and ' The coral *Siderastrea radians* and its postlarval development'. *Carnegie Institution of Washington Publication* **20** (1904), 1-130.

115 Data derived from the Appendix herein, personal information, and 'A bibliography of the works of James Edwin Duerden', see note 70.

Biographical sources

Printed:

Anon. (1937) Prof. J.E. Duerden. *Nature* **140**, 576.

Currey, R.F. (1970) *Rhodes University 1904-1970: a chronicle*. Rhodes University, Grahamstown.

Duerden, J.E. (1941) Entry in *Who was Who*, volume 3, p. 389. Adam & Charles Black, London.

Hodgson, A.N. and Craig, A.J.F.K. (2005) A century of Zoology and Entomology at Rhodes University, 1905 to 2005. *Transactions of the Royal Society of South Africa* **60** (1), 1-18.

Omer-Cooper, J. (1972) Duerden, James Edwin, pp. 201-203. In W.J. de Kock (ed.) *Dictionary of South African Biography*. Volume 2. Human Sciences Research Council, Pretoria.

Praeger, R. Ll. (1949) *Some Irish Naturalists*. Dundalgen Press, Dundalk.

Shaw, W.B. (ed.) (1941) *The University of Michigan, an encyclopedic survey. Part IV. The College of Literature, Science and the Arts II - the Department of Zoology*. University of Michigan, Ann Arbor.

Wyse Jackson, P.N. (1991). Distribution of Irish marine Bryozoa, together with biographical notes relating to the chief researchers in the group. *Bulletin of the Irish Biogeographical Society* **14** (2), 129-184.

Webpages:

Biographical Etymology of Marine Organism Names. D: http://www.tmbl.gu.se/libdb/taxon/personetymol/petymol.d.html

http://www.ru.ac.za/academic/departments/zooento/history.html

Manuscript:

American Philosophical Society, Philadelphia, Pennsylvania, USA: Correspondence (seven items, 1907-1921) with Charles B. Davenport, the prime mover on eugenics in the USA until the 1940s (Catalogue number: B D27).

Geological Museum, Trinity College, Dublin: Catalogue of Jamaican materials sent by Duerden to Grenville Cole (Royal College of Science for Ireland), and three associated letters.

Cory Library, Rhodes University, Grahamstown, South Africa:

Biographical information (compiled by Joseph Omer-Cooper, 1970)

A bibliography of the works of James Edwin Duerden (compiled by M. Fouché, 1968) (MS 17 756)

Various letters, notes lectures, publications and newspaper cuttings relating to ostrich and feather research.

Smithsonian Institution, Washington, DC

Washington University of St Louis, Becker Medical Library: Mildred Trotter Papers, Bureau of Hair Research.

Appendix: J.E. Duerden's early publications largely on bryozoans, hydroids and corals

Duerden, J.E. 1892. [On *Plumularia haleciodes*, new to Ireland]. Proceedings of Irish Societies: Dublin Microscopical Society. *The Irish Naturalist* **1**, 193.

Duerden, J.E. 1893. On some new and rare Irish Polyzoa. *Proceedings of the Royal Irish Academy*, series 3, **3**, 121-136.

Duerden, J.E. 1893. Report on the hydroids collected by the Royal Irish Academy survey of the south-west coast of Ireland, 1885, 1886, and 1888. *Proceedings of the Royal Irish Academy* **3**, 137-150.

Duerden, J.E. 1893. [On *Triticella boeckii* and *Hippuraria egertoni*] Proceedings of Irish Societies: Dublin Microscopical Society. *The Irish Naturalist* **2**, 50.

Duerden, J.E. 1893. [On *Crisia ramosa* new to Ireland] Proceedings of Irish Societies: Dublin Naturalists' Field Club. *The Irish Naturalist* **2**, 146.

Duerden, J.E. 1893. [On *Bourgainvillia* sp. nov. from Bantry Bay] Proceedings of Irish Societies: Dublin Microscopical Society. *The Irish Naturalist* **2**, 196.

Duerden, J.E. 1893. [On *Tubiclava cornucopiae*] Proceedings of Irish Societies: Dublin Naturalists' Field Club. *The Irish Naturalist* **2**, 319.

Swanston, W. and Duerden, J.E. 1893. Some north of Ireland Polyzoa. *The Irish Naturalist* **2**, 165-168.

Duerden, J.E. 1894. [On *Campanulina turrita*] Proceedings of Irish Societies: Dublin Microscopical Society. *The Irish Naturalist* **3**, 110.

Duerden, J.E. 1894. Hydroids and Polyzoa collected between Laytown and the mouth of the Boyne. *The Irish Naturalist* **3**, 169-170.

Duerden, J.E. 1894. [On *Plumularia similis*] Proceedings of Irish Societies: Dublin Microscopical Society. *The Irish Naturalist* **3**, 201.

Duerden, J.E. 1894. Notes on the marine invertebrates of Rush, Co. Dublin. *The Irish Naturalist* **3**, 230-233.

Duerden, J.E. 1894. Beaumaris shark in Dublin Bay. *The Irish Naturalist* **3**, 262.

Duerden, J.E. 1895. Survey of fishing grounds, west coast of Ireland, 1890-1891. Notes on the Hydroida and Polyzoa. *Scientific Transactions of the Royal Dublin Society*, new series, **8**, 325-336.

Duerden, J.E. 1895. On the genus *Alicia* (*Cladactis*), with anatomical description of *A. costæ*, Panc. *Journal of Natural History*, series 6, **15** (87), 213-218.

Duerden, J.E. 1895. The rock pools of Bundoran. *The Irish Naturalist* **4**, 1-7.

Duerden, J.E. 1895. Jamaica Caves. *Nature* (London)

Duerden, J.E. 1895. The Actiniarian family Aliciidæ. *Journal of Natural History*, series 6, **20** (115), 1-15.

Duerden, J.E. 1895. Science Notes. *Journal of the Institute of Jamaica* **2** (2), 166-167.

Haddon, A.C. and Duerden, J.E. 1895. On some Actiniaria from Australia and other districts. *Scientific Transactions of the Royal Dublin Society*, new series, **6**, 139-172.

Duerden, J.E. 1896. Notes on the rock pools of Bundoran. *The Irish Naturalist* **5**, 153-155.

Duerden, J.E. and Haddon, A.C. 1896. On some Actiniaria from Australia and other districts. *Scientific Transactions of the Royal Dublin Society*, series 2, **6**, 139-172.

Duerden, J.E. 1896. Hydroids of the Irish coast. *Scientific Transactions of the Royal Dublin Society*, series 2, **8**, 405-420.

Duerden, J.E. 1897. The lizards of Jamaica. *Journal of the Institute of Jamaica* **2** (3), 263-265.

Duerden, J.E. 1897. The scorpions of Jamaica. *Journal of the Institute of Jamaica* **2** (3), 265-266.

Duerden, J.E. 1897. The myriapods of Jamaica. *Journal of the Institute of Jamaica* **2** (3), 266-267.

Duerden, J.E. 1897. Notes on the marine zoology of Kingston Harbour. *Journal of the Institute of Jamaica* **2** (3), 282-285.

Duerden, J.E. 1897. Zoanthids at Port Henderson. *Journal of the Institute of Jamaica* **2** (3), 285-287.

Duerden, J.E. 1897. Phases in Jamaican natural history. *Journal of the Institute of Jamaica* **2** (3), 288-291.

Duerden, J.E. 1897. A Jamaica drift-fruit. *Journal of the Institute of Jamaica* **2** (3), 291-292.

Duerden, J.E. 1897. Aboriginal Indian remains in Jamaica, with a note on the craniology of the aborigines of Jamaica by Professor A.C. Haddon. *Journal of the Institute of Jamaica* **2** (4), 1-52.

Duerden, J.E. 1897. James John Bowrey. *Journal of the Institute of Jamaica* **2** (5), 423-425.

Duerden, J.E. 1897. The Actiniaria around Jamaica. *Journal of the Institute of Jamaica* **2** (5), 449-465.

Duerden, J.E. 1897. Science Notes. *Journal of the Institute of Jamaica* **2** (5), 465-475.

Duerden, J.E. 1897. Relationships between the sea-anemones and corals. *Journal of the Institute of Jamaica* **2**, 500-502.

Duerden, J.E. 1897. P.H. Gosse. *Journal of the Institute of Jamaica* **2** (5), 574-581.

Duerden, J.E. 1898. Jamaican Actiniaria. Part I. Zoantheæ. *Scientific Transactions of the Royal Dublin Society*, series 2, **6**(14), 329-376.

Duerden, J. E. 1898. On the relations of certain Stichodactylinae to the Madreporaria. *Journal of the Linnaean Society of Zoology* **26**, 635-653.

Duerden, J.E. 1899. Jamaica fisheries. The operations in Jamaica of the Caribbean Sea Fisheries Development Syndicate Ltd. *Journal of the Institute of Jamaica* **2**, 608-614.

Duerden, J.E. 1899. Zoophyte collecting in Bluefields Bay. *Journal of the Institute of Jamaica* **2**, 619-624.

Duerden, J. E. 1899. The Edwardsia-stage of the actinian *Lebrunia*, and the formation of the gastro-coelomic cavity. *Journal of the Linnaean Society of Zoology* **27**, 269-316.

Duerden, J.E. 1900. Order of appearance of the mesenteries and septa in Madreporaria, *Johns Hopkins University Circular* **19** (146), 47-52.

Duerden, J.E. 1901. The Marine Resources of the British West Indies. *Journal of the Imperial Agriculture Department West Indies* **1901**, 121-141.

Duerden, J.E. 1901. Abundance of *Peripatus* in Jamaica. *Nature* **63**, 440-441.

Duerden, J.E. 1901. Report on the actinians of Porto Rico. *United States Fish Commission Bulletin for 1900* **2**, 321-374.

Duerden, J.E. 1902. Jamaican Actiniaria. Part II. Stichodactylinæ and Zoantheæ. *Scientific Transactions of the Royal Dublin Society*, series 2, **7**(6), 133-220.

Duerden, J. E. 1902. On the Actinian 'Bunodeopsis globulifera verrill'. *Transactions of the Linnaean Society of Zoology* **8**(9), 297-317.

Duerden, J.E. 1902. West Indian Madreporarian Polyps. *Memoir of the National Academy* **8**, 401-597. Reprinted 1903 *Memoirs from the Biological Laboratory of the Johns Hopkins University* **8**(7), 399-599.

Duerden, J.E. 1902. The morphology of the Madreporaria, I. Relationship of the Rugosa (*Tetracoralla*) to the living Zoantheæ. *Annals and Magazine of Natural History* (7), **9**, 381-398. Reprinted 1902. The morphology of the Madreporaria, I. Relationships of the Rugosa (Tetracoralla) to the living Zoantheae, *Johns Hopkins University Circular*, p. 19-25.

Duerden, J.E. 1902. The morphology of the Madreporaria, II. Increase of mesenteries in *Madrepora* beyond the protocnemic stage. *Annals and Magazine of Natural History* (7), **10**, 96-115. Reprinted 1902. The morphology of the Madreporaria, II. Increase of mesenteries in *Madrepora* beyond the protocnemic stage, *Johns Hopkins University Circular*, p. 59-66.

Duerden, J.E. 1902. The morphology of the Madreporaria, III. The significance of budding and fission. *Journal of Natural History* **10**, 382-393.

Duerden, J.E. 1902. Boring algae as agents in the disintegration of corals. *Bulletin of the American Museum of Natural History* **16**(25), 323-332.

Duerden, J.E. 1902. The development of septa in Paleozoic corals. *Science* **15**, 350.

Duerden, J.E. 1902. Primary hexamerism in the Rugosa. *Science* **15**, 577.

Duerden, J.E. 1902. Aggregated colonies in madreporarian corals. *American Naturalist* **36**, 461-471.

Duerden, J.E. 1903. West Indian sponge-incrusting actinians. *Bulletin of the American Museum of Natural History* **19**(18), 495-504.

Duerden, J.E. 1903. The morphology of the Madreporaria, IV. Fissiparous gemmation. *Journal of Natural History* **11**, 141-155.

Duerden, J.E. 1903. A method of studying the septal sequence in Paleozoic corals, *The Journal of the Elisha Mitchell Scientific Society*, p. 32-33.

Duerden, J.E. 1903. Some results on the morphology and development of Recent and fossil corals. *Report of the British Association for the Advancement of Science* 1903, 684-685.

Duerden, J.E. 1903. A tropical marine laboratory for research. *Science* **17** (439), 862-864.

Duerden, J.E. 1904. The morphology of the Madreporaria, V. Septal sequence. *Biological Bulletin of the Marine Biology Laboratory, Woods Hole* **7**, 79-104.

Duerden, J.E. 1904. Recent results on the morphology and development of coral polyps, *Smithsonian Miscellaneous Collections* **67**, 93-111.

Duerden, J.E. 1904. The antiquity of the zoanthid actinians. *Sixth Report of the Michigan Academy of Science*, 195-198.

Duerden, J.E. 1904. The development and relationship of the Rugosa (Tetracoralla), *Science* **19**, 217-218.

Duerden, J.E. 1904. The coral *Siderastrea radians* and its postlarval development. *Carnegie Institution of Washington Publication* **20**, 1-130.

Duerden, J.E. 1905. The morphology of the Madreporaria, VI. The fossula in rugose corals. *Biological Bulletin of the Marine Biology Laboratory, Woods Hole* **9**, 27-52.

Duerden, J.E. 1905. Studies of the morphology, physiology, and the development of recent and fossil corals with bibliography. *Annual Report of the Michigan Academy of Science* (1916) **1**(2), 3-4.

Duerden, J.E. 1905. Continuation of investigations on the morphology and development of recent and fossil corals and physiology of the Zoantharia. *Carnegie Institution of Washington D.C. Year Book* **4**, 277-278.

Duerden, J.E. 1905. Marine Zoology in the Hawaiian Islands. *Science* **21** (545), 897.

Duerden, J. E. 1905. On the habits and reactions of crabs bearing Actinians in the claws. *Journal of the Zoological Society of London* **2**, 494-511.

Duerden, J.E. and Ayres, S.A. 1905. The nerve layer in the coral *Coenopsammia* Lansing. *Report of the Michigan Academy of Science* **7**, 75-77.

Duerden, J.E. 1906. The morphology of the Madreporaria. VII. Intrapolypal tentacles. *Annals and Magazine of Natural History*, Series 7, **17**, 466-474.

Duerden, J.E. 1906. The primary septa in rugose corals. *Science* **24**, 246-247.

Duerden, J.E. 1906. The role of mucus in corals. *Quarterly Journal of Microscopical Science* **49**, 591-614.

Duerden, J.E. 1906. The morphology of the Madreporaria; VIII. The primary septa of the Rugosa, *Journal of Natural History* **18**, 226-242.

Duerden, J.E. 1906. The coral *Siderastrea radians* and its post-larval development. *Science* n.s. **23**, 497-498.

Duerden, J.E. 1906. The use of the word 'British'. *The Irish Naturalist* **15**, 135.

Duerden, J.E. 1908. The South African Association for the Advancement of Science. *Nature* **78**, 395-397.

Duerden, J.E. 1904. Recent results on the morphology and development of coral polyps, *Smithsonian Miscellaneous Collections* **67**, 93-111.

Duerden, J.E. 1904. The antiquity of the zoanthid actinians. *Sixth Report of the Michigan Academy of Science*, 195-198.

Duerden, J.E. 1904. The development and relationship of the Rugosa (Tetracoralla), *Science* **19**, 217-218.

Duerden, J.E. 1904. The coral *Siderastrea radians* and its postlarval development. *Carnegie Institution of Washington Publication* **20**, 1-130.

Duerden, J.E. 1905. The morphology of the Madreporaria, VI. The fossula in rugose corals. *Biological Bulletin of the Marine Biology Laboratory, Woods Hole* **9**, 27-52.

Duerden, J.E. 1905. Studies of the morphology, physiology, and the development of recent and fossil corals with bibliography. *Annual Report of the Michigan Academy of Science* (1916) **1**(2), 3-4.

Duerden, J.E. 1905. Continuation of investigations on the morphology and development of recent and fossil corals and physiology of the Zoantharia. *Carnegie Institution of Washington D.C. Year Book* **4**, 277-278.

Duerden, J.E. 1905. Marine Zoology in the Hawaiian Islands. *Science* **21** (545), 897.

Duerden, J. E. 1905. On the habits and reactions of crabs bearing Actinians in the claws. *Journal of the Zoological Society of London* **2**, 494-511.

Duerden, J.E. and Ayres, S.A. 1905. The nerve layer in the coral *Coenopsammia* Lansing. *Report of the Michigan Academy of Science* **7**, 75-77.

Duerden, J.E. 1906. The morphology of the Madreporaria. VII. Intrapolypal tentacles. *Annals and Magazine of Natural History*, Series 7, **17**, 466-474.

Duerden, J.E. 1906. The primary septa in rugose corals. *Science* **24**, 246-247.

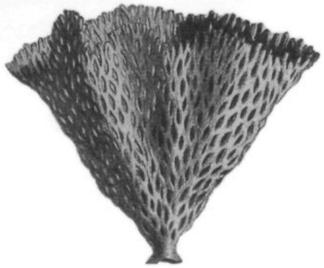
Duerden, J.E. 1906. The role of mucus in corals. *Quarterly Journal of Microscopical Science* **49**, 591-614.

Duerden, J.E. 1906. The morphology of the Madreporaria; VIII. The primary septa of the Rugosa, *Journal of Natural History* **18**, 226-242.

Duerden, J.E. 1906. The coral *Siderastrea radians* and its post-larval development. *Science* n.s. **23**, 497-498.

Duerden, J.E. 1906. The use of the word 'British'. *The Irish Naturalist* **15**, 135.

Duerden, J.E. 1908. The South African Association for the Advancement of Science. *Nature* **78**, 395-397.

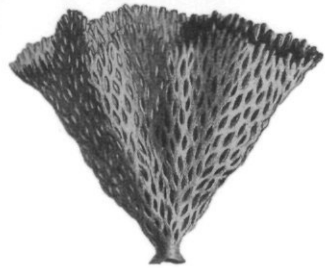


This volume contains twelve papers on various aspects of the history of research on Fossil and Living Bryozoans.

- Bryozoology in South Africa
- Jeremy Jackson, Bryozoa & Punctuated Equilibrium
- Bryozoans and climate change research
- Kluge Collection at Perm University
- Albert Russell Nichols
- Ehrhard Voigt type material & Hermann Brandes
- The earliest colour image of Bryozoa
- Benjamin Harrison Grave: American zoologist
- Conservation of W.D. Lang's bryozoan slides
- Bryozoans of the Krusenstern Expedition 1803-06
- Mary Dora Rogick
- James Edwin Duerden: zoological polymath

ISBN 978-0-9543644-4-1

International Bryozoology Association



THIS VOLUME CONTAINS TWELVE PAPERS ON VARIOUS ASPECTS OF THE HISTORY OF RESEARCH ON FOSSIL AND LIVING BRYOZOANS.

- BRYOZOOLOGY IN SOUTH AFRICA
- JEREMY JACKSON, BRYOZOA & PUNCTUATED EQUILIBRIUM
- BRYOZOANS AND CLIMATE CHANGE RESEARCH
- KLUGE COLLECTION AT PERM UNIVERSITY
- ALBERT RUSSELL NICHOLS
- EHRHARD VOIGT TYPE MATERIAL & HERMANN BRANDES
- THE EARLIEST COLOUR IMAGE OF BRYOZOA
- BENJAMIN HARRISON GRAVE: AMERICAN ZOOLOGIST
- CONSERVATION OF W.D. LANG'S BRYOZOAN SLIDES
- BRYOZOANS OF THE KRUSENSTERN EXPEDITION 1803-06
- MARY DORA ROGICK
- JAMES EDWIN DUERDEN: ZOOLOGICAL POLYMATH

ISBN 978-0-9543644-4-1

INTERNATIONAL BRYOZOOLOGY ASSOCIATION