Ideas made glass: Blaschka glass models at Canterbury Museum

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In 1882, Canterbury Museum purchased a series of intricate glass models of invertebrates made by Dresden artisan Leopold Blaschka (1822–1895) and his son Rudolf Blaschka (1857–1939). This article considers both the historic context and scientific theories that are likely to have shaped this purchase. With museums around the world seeking to assemble encyclopaedic collections, the Blaschka models were a way of ensuring that even difficult to preserve aspects of the natural world could be displayed and used for education. The Museum's founding director Julius von Haast (1822–1887) was particularly interested in communicating science to the Canterbury community. This article examines Haast's purchase by comparing and contrasting Canterbury Museum's Blaschka collection with two other collections (at University College Dublin and Otago Museum) as a way of exploring the possible influence of their scientific-educational context. This comparison provides evidence for the influence of several evolution-based theories as a preference bias for certain taxonomic categories amongst Canterbury Museum's collection of Blaschka models. In order to make the Museum's Blaschka models more accessible, this article concludes with a comprehensive illustrated catalogue of the collection.

Keywords: Blaschka, collecting, evolutionary biology, glass models, invertebrates, Julius von Haast.

Introduction

In the latter half of the nineteenth century, intricate and expertly-crafted glass models made their way into university and museum collections around the world. Universities and museums were keen to collect, describe and to educate people about the natural world. But not all animals could be dried, skinned or satisfactorily preserved in alcohol. Dresden based father and son duo, Leopold and Rudolf Blaschka (1822–1895 and 1857–1939, respectively) produced thousands of glass models of invertebrate and botanical specimens. Inspired by technical drawings produced by leading biologists and live organisms, the Blaschka models were prized for their fine detail. Although now revered for their craftsmanship and artistry, the scientific context behind the models deserves closer scrutiny (Brill and Huber 2016). Blaschka models were one of many foreign objects and specimens that were collected for Canterbury Museum by its founding director Julius von Haast (1822–1887). This article examines previous research on Blaschka models, describes the museological approach adopted by Haast and his connection to scientific circles, and assesses whether particular scientific viewpoints and approaches may be reflected in the composition of Haast's Blaschka order.

Museums of the 1880s were generally intended to present comprehensive collections depicting natural and human history. By viewing select examples of a wide range of subjects, visitors would be able to draw conclusions about both culture and nature (Fyfe 2010). High value was placed on encyclopaedic collections showcasing material from around the world (Haacke 1882). Haast followed this encyclopaedic model, collecting a range of local and overseas specimens, believing that foreign and rare material would increase Canterbury Museum's prestige and educational value. Based on the resulting attendance numbers it seems the Christchurch public agreed with his approach (Fyfe 2010).

Apart from the drive for comprehensive coverage, there was also at this time the dramatic rise of evolutionary theory (Darwin 1859; Haeckel 1874a) and of marine biology (Thomson 1878). Together these influences amounted to a new importance for soft-bodied marine invertebrates. However, these same animals also represented a glaring gap in traditional museum exhibits. Displaying these as specimens was rarely an option since satisfactory preservation of form and pigmentation presented many difficulties in the 1880s (and still does today) (Parker 1882; Lendenfeld 1885; Moore 1989). With an encyclopaedic vision in mind, Haast would have looked to fill this gap; and the Blaschkas' reputation among scientists would have appealed to Haast's educational goals.

By 1878, the Blaschkas produced 630 different models (Ward 1878) that would later grow to become a repertoire of over 700, including special commissions (Ward 1888; Brill and Huber 2016). Using a combination of flameworking, melting and bending glass with hand tools, the Blaschkas captured the detail and essence of their zoological subjects (Sigwart 2008; Brill 2016; Harvell 2016). Some of the more complex works delved into mixed media, blending real mollusc shells with glass bodies (see, for example, Canterbury Museum accession number (CMA) 1884.137.86) or simulating the dwelling tubes of annelids by coating these with sand (see CMA 1884.137.22). Working primarily at low temperatures, the Blaschkas manipulated glass into layers, sometimes thinner than an eggshell (Harvell 2016). Colours were added using a mixture of techniques; sometimes the glass was painted, sometimes enamelled and other times coloured glass was used (Bertini et al 2016; Brill 2016). The Blaschkas' technical expertise is admired both for its scientific accuracy and its artistry (Harvell 2016; Brill 2016).

Canterbury Museum's purchase of a series of glass invertebrate models was inspired by a previous order of Blaschka models by Frederick Wollaston Hutton (1836–1905) who was Otago University Museum Curator until 1880. Although a date is not known for when this order was made, these models were displayed when that museum opened in 1877 (Hutton 1878a; Crane 2015a). Correspondence between Leopold Blaschka and Haast reveals that while the idea of purchasing models for Canterbury Museum was first mooted in 1879, an order was not placed until 1882 and the models did not arrive until October 1883 (Blaschka 1879, 1882; *Press*, 27 October, 1883: 3, 1 November, 1883: 3). Haast initially indicated that he wanted to duplicate Hutton's order but this did not eventuate. Leopold encouraged Haast to choose his own set; primarily as he did not recall the details of Hutton's order (Blaschka 1879; Crane 2015a). When Haast finally made his order in 1882, it was ultimately a larger one than Hutton had made for Otago Museum and its overall composition was significantly different (see Systematic Comparison). Unfortunately, the list of what Haast ordered no longer survives. In later correspondence, Leopold indicated that he substituted a few models and added some additional "worms and corals" free of charge (Blaschka 1883). These were to be released in the Blaschkas' next catalogue (Blaschka 1883). These free samples appear to be the enlarged heads of the marine annelids *Eunice norvegica*, *Nereis margaritacea* and *Phyllodoce parettii* (CMA 1884.137.90, 1884.137.20, 1884.137.18), and a soft coral polyp (CMA 1884.137.136) (Fig. 1). The relevant taxonomic nomenclature at the time of Haast's order is found in the Ward (1878) catalogue and reflected in Canterbury Museum catalogues. This is used here too as the most historically relevant and practical nomenclature

Figure 1. Free Blaschka model samples. **A,** *Eunice novegica* (CMA 1884.137.90). **B,** *Nereis margaritacea* (CMA 1884.137.20). **C,** *Phyllodoce parettii* (CMA 1884.137.18). **D,** a soft coral polyp (CMA 1884.137.136).

to use when comparing Blaschka collections.

Newspaper articles announcing the new acquisition note that the models were displayed in the Technological Room as examples of industrial art applied to science (*Star,* 16 February, 1882: 4). The articles clarified that in future the models would be catalogued taxonomically amongst relevant specimens (*Press*, 27 October, 1883: 3, 1 November, 1883: 3) and, as early as 1885, echinoderms and cuttlefish in spirits of wine were displayed with Blaschka models (Mosley 1885). By the time the first edition of the *Guide to the Collection in the Canterbury Museum* was printed in 1895, the Technological Room had been dismantled and the Blaschka models had been integrated taxonomically among the zoological displays (Hutton 1895).

Most of the literature regarding Blaschka models focuses on how the items were acquired, how they were displayed in the nineteenth century (Hackethal 2008; Swinney 2008; Callaghan et al 2014; Rossi-Wilcox 2015; Doyle et al 2016) and the artistic or scientific merit of the models (Reiling 1998, 2014; Hackethal 2008; Rossi-Wilcox 2008). While the models are generally interpreted as educational aids (Dyer 2008; Sigwart 2008; Swinney 2008; Hackethal 2008; Reiling 2014), what particular aspects of zoology they were being used to teach has been largely neglected. Various authors have intimated that theories from this period did influence Blaschka acquisitions (Reiling 1998; Swinney 2008; Brill and Huber 2016), but exploration of this topic is sparse.

More specifically, Reiling (2014) relates the production of one subset of Blaschka models to the direct influence of Ernst Haeckel (1834–1919) and two of his theories (biogenetic law and colonial theory). Overall, however, exploration of what Blaschka models were being used to teach, the underlying scientific motivations and how these factors may have influenced purchasing decisions of the Blaschkas' clientele, is largely absent from the literature. This is surprising because the theories being considered in this period engendered intense interest and debates. Further, some of the biologists devising prominent new theories (Haeckel 1874b; Lankester 1880; Dohrn 1875 in Dohrn and Ghiselin 1994) were highly aware of Blaschka models. Sometimes they were ordering Blaschka models themselves (Lankester 1877) or as in the case of German biologists Ernst Haeckel and Anton Dohrn (1840–1909), they were assisting the Blaschkas directly with information, books or specimens (Harvell 2016).

There would be a variety of factors in determining the composition of many Blaschka orders. For some larger institutions, with several curators and more specialised responsibilities and interests, some Blaschka orders might simply match the particular taxonomic interest of whatever segment of the collection was being addressed (e.g. Ridley's intended order of sponges for the Natural History Museum; Miller and Lowe 2008). In such cases an answer would be already apparent. But for other cases, the answer for why certain Blaschka models were ordered could include: to fill gaps in an otherwise comprehensive natural history display, to provide aesthetic pleasure, to minimise total cost, and/or to address scientific-educational themes.

Most Blaschka orders consisted of a broad spread of taxonomic groups. However, this does not necessarily mean that the general drive for comprehensive coverage was the only relevant motivation. An interplay of factors for most Blaschka collections can be expected. What interests us is the possibility that the signal from a single factor might still be present. Of the several possible factors, scientific-educational interest is the most amenable to analysis and discovery. Thus where curatorial interests are known, preference statistics can be used to test for a skew in a predicted direction. Even with an interplay of factors, if a collection was assembled with a particular scientific or educational bent, this is expected to be detectable as a skew towards those particular taxonomic groups and/or themes. Suitable collections to evaluate would be ones where the influence of a single curator with known scientific outlook and educational aims was dominant. The major Blaschka collections in New Zealand, at Canterbury and Otago Museums, provide useful groups for such analysis given the distinctive (and contrasting) scientific-educational contexts they were ordered within. Another collection suitable for analysis is University College Dublin, which was acquired in a single order and initiated by a professor whose scientific and teaching concerns are well-documented (Parker 1885; Haddon 1887; Callaghan et al 2014).

The factor of cost has sometimes been identified as a strong consideration in Blaschka orders. However, we think this is a largely moot point, as while cost is expected to influence the choice of models within a taxonomic group, it is not usually expected to determine which groups were ordered (at least when a broad range of Blaschka models are being ordered). Further, it is worth noting that most taxonomic groups contained both cheap and expensive examples and that the expensive models are distributed between various themes. Thus the most expensive models include ones that would be primarily useful for display and/or identification (e.g. certain anemones, echinoderms, cephalopods) while other expensive models were a focal point of academic and textbook interest (e.g. embryology models of tiny plankton unfamiliar to most observers). In this context it is worth pointing out that investments in expensive embryological models provide examples where the intent is clearly scientific and educational.

Although 133 extant glass invertebrate models have been in the collection of Canterbury Museum since the 1880s (counted according to the Ward 1878 catalogue), the items have received little attention. This paper is the result of a recent cataloguing project and explores the scientific context that is likely to have influenced Haast as Director of Canterbury Museum. In particular, this article considers the educational aims, their theoretical underpinnings and Haast's diverse relationships with local, visiting and foreign scientists. Here, Canterbury Museum's model collection is systematically compared with those of Otago Museum and University College Dublin to identify any significant model preferences.

The article concludes with a comprehensive illustrated catalogue of Canterbury Museum's models.

The scientific context

The latter half of the nineteenth century saw traditional natural history or "inventory science" (Crane 2014) contested by the rise of new theory-driven approaches (Farber 2000).

Several zoological subjects came to new prominence in the 1870s with advances in evolutionary theory and concomitant changes in zoological teaching. Earlier field guides, while broad in taxonomic scope, concentrated mainly on what could be readily observed (e.g. Gosse 1865) and emphasised identification and classification. This emphasis, along with a great gathering of other zoological evidence, was also seen in textbooks such as Nicholson (1873) as favoured by Hutton (*Clutha Leader*, 15 August, 1879: 6). However, the newer textbooks, informed by what we are here generally designating as more modern evolutionary thinking (Gegenbauer 1878; Huxley 1878; Parker 1891), taught that whole animal orders could most profitably be understood by concentrating on 'types': exemplary invertebrates that revealed basic groundplans (Crane 2015b). These animals tended to be small and have a relatively humble appearance such as plankton, hydrozoans and the simplest of annelid worms. Such textbooks featured fine details of their anatomy and most particularly their development or embryology. The new zoological teaching reflected an extraordinarily rich time for new evolutionary theories in the decade after 1875, that had arisen from the implications of *The Origin of Species* (Darwin 1859) being expanded by the first generation of post-*Origin* biologists (Asma 2001; Reiling 2014).

This new thinking entered precipitously and directly to New Zealand in 1880–1881 and provides a highly distinctive scientific context, and a reason to believe Haast developed a truly contemporary evolutionary outlook by the time he placed his Blaschka order. Between Haast's initial contact with the Blaschkas in 1879 and his order being placed in 1882, three evolutionary biologists started work in the South Island. This was significant because New Zealand had few formally-trained academic biologists at this time (Haacke 1881; Crane 2015c). All the new arrivals had strong interests in not just promoting evolutionary theory but advancing it. The first, Englishman Thomas Jeffery Parker (1850–1897), was a self-proclaimed disciple of the famous comparative anatomist and evolutionist Thomas Huxley (1825–1895) and arrived in the South Island in 1880. Parker worked as Professor in Biology at Otago University and replaced Hutton as Curator at Otago University Museum in 1880 (Crane 2015c). Parker was a notable proponent of some of Haeckel's theories, including biogenetic law (Crane 2015c), which hypothesised that during development from embryo to adult, animals go through stages that resemble successive stages in the evolution of their remote ancestors. Parker also used evolutionary branching tree diagrams (phylogenies) to illustrate the results of evolution (Parker 1885).

Two other biologists worked closely with Haast at Canterbury Museum. Dr Johann Wilhelm Haacke (1855–1912), a recent graduate from the University of Jena in Germany (and student of Haeckel) arrived in Dunedin in 1881. Although Parker was unable to provide employment for Haacke, he recommended him to Haast who hired him for a cataloguing project (Haacke 1881; Parker 1881; Haast 1882). Haacke's role involved creating "ticket catalogues" for hydrozoans, echinoderms, and other animal groups for seven months (Haacke 1881; Parker 1881; Haast 1882, 1948). Haacke was profoundly concerned with theory as his later writing makes clear (Haacke 1893; Levit and Olsson 2006) and his correspondence with Haeckel suggests he was developing his theories while in New Zealand (Haacke 1881). Austrian biologist, Dr Robert von Lendenfeld (1858–1913), also arrived in New Zealand in 1881 with a letter of introduction from Thomas Huxley (Lendenfeld 1883a). Lendenfeld had studied at the University of Graz, Austria (Lendenfeld 1883b, Hösch 1972), and eventually took a part-time teaching position at the Agricultural College in Lincoln, Canterbury, in 1883. According to *New Zealand Journal of Science* (Anonymous 1882a), he also studied under Ernst Haeckel. Haast provided Lendenfeld space at Canterbury Museum where he set up his own part-time research laboratory with his wife as his assistant (Anonymous 1883c; Lendenfeld 1883b; Haast 1883). Many of his results were from studies of aquaria reared animals (e.g. hydrozoan development), so his work at Canterbury Museum may have had this experimental aspect too.

These three connections highlight the strong links Haast had with the scientific community generally. Haast also corresponded with scientists abroad, including Darwin, Joseph Hooker and Haeckel, and kept abreast of local scientific debates (Haast 1883; Stenhouse 1984). Although not zoologically trained (Haacke 1881; Nolden 2016), Haast's correspondence with Lendenfeld and Parker strongly suggests he was cognisant of fine zoological details himself, including coelenterate embryology and crayfish anatomy (Parker 1881). According to Haacke (1881), Parker, Haacke and Haast probably held the only three copies of Haeckel's (1866) *Generelle Morphologie* in New Zealand. Overall, the three newly-arrived biologists were largely aligned with the teaching approach and theories expounded by the likes of Haeckel and Huxley (Crane 2013).

A modern evolutionary view of nature at this time would include an emphasis on annulated worms, particularly annelids, which became prominent during this period. In the early 1880s, the Gehyrea (spoonworms, peanut worms, priapulids) were thought to be related to annelids (earthworms, bristleworms, leeches) as both showed external rings or annulations (Gegenbauer 1878). The new importance of worms in evolutionary teaching as exemplars of segmented animals is epitomised by Haast's contemporary, Parker, who devoted two lengthy lessons in his earliest published textbook (Parker 1891) to a simple marine annelid worm (*Polygordius*) to teach the basic body plan for all the "higher" animals. For Parker's New Zealand zoology students, this seminal lesson was delivered theoretically via textbook only, because *Polygordius* was a native of the Bay of Naples! This example highlights Parker's emphasis on the teaching value of distinct morphological types in line with Huxley's approach.

The Blaschkas would have been aware of the increasing profile of annelids in zoological teaching and judging by drawings held by the Corning Museum of Glass, Corning, New York, they planned a developmental series for *Polygordius*. Although this did not happen, they did later produce one of their most expensive models, a developmental series for another marine annelid *Autolytus* (Agassiz 1862; Ward 1888). The Blaschkas' awareness of annelids is hardly surprising given that Anton Dohrn sent live invertebrates from Naples to the Blaschkas in Dresden (Harvell 2016). Dohrn (1875 in Dohrn and Ghiselin 1994) was one of two researchers who had newly interpreted the segmented body plan of annelids as evidence that they were the closest relatives to the backboned animals. Although the relationships between annelids and other groups remained controversial, it is nonetheless clear that contemporary zoological teaching in the 1880s included a new emphasis on annelids. This adds another hypothesis that can be tested with respect to Blaschka models; institutes imbued with contemporary zoological thinking could be expected to order relatively more annulated worm models. For Canterbury Museum it seems relevant that Haast ordered Blaschka models of both the adult (CMA 1884.137.22) and the developmental series of the marine annelid worm *Terebella conchilega* (CMA 1884.137.110).

Our brief discussion of the scientific and educational context of this period requires mention of the heightened interest in the study of animal embryos. The dawning recognition of the importance of developmental stages at this time is well illustrated by Perrier's reflections (1880), and also by Bateson's reminiscences on his zoological youth in 1883 when "every aspiring

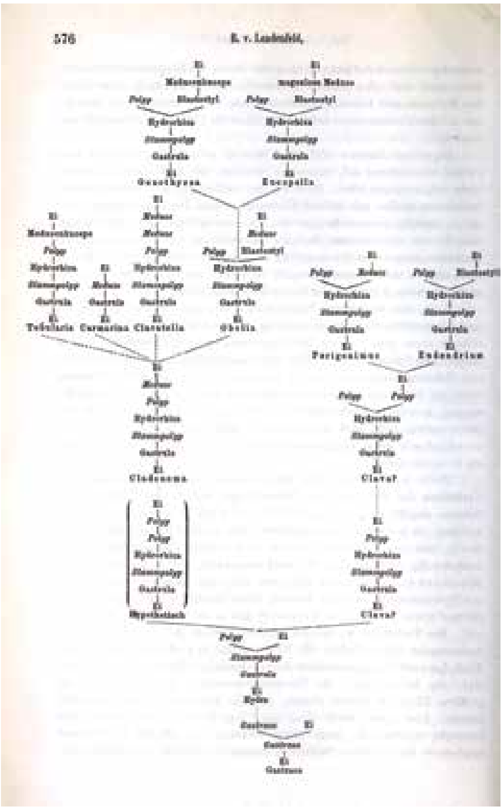

Figure 2. Copy of diagram showing combined phylogeny and development. Three of the hydroid genera on this diagram were ordered for Canterbury Museum as Blaschka developmental models. Lendenfeld (1883a).

zoologist was an embryologist, and the one topic of professional conversation was evolution" (1922: 56). Prominent among the relevant theories here is Haeckel's version of biogenetic law (Gould 1977; Hall 2003), which was his most famous (and ultimately controversial), and of which Haast would have been aware. These new evolutionary theories increased interest in embryology and hence demand for Blaschka 'stages of development' models (Sigwart 2008; Reiling 2014). The general interest in embryology should not be solely equated with biogenetic law, however. Another embryology-based evolutionary theory that is worth considering as an influence on Blaschka model production and demand is *Gastraeatheorie* [Gastraea Theory] (Haeckel 1874b, 1877). *Gastraeatheorie* postulated a general uniformity of structure in the early developmental stages of animals in widely separated groups. While this theory was controversial (Agassiz 1876), it did have impact (Huxley 1875) and was a driver for further investigations (Robinson 2016), including those of the phylogenetic relations between simple coelenterates (e.g. Lendenfeld 1883c) and also between coelenterates, protozoa and sponges.

A vestige of interest in *Gastraeatheorie* may be present in Canterbury Museum's Blaschka collection. Lendenfeld's principal research centred on coelenterates and sponges. Lendenfeld's (1883c) detailed study of South Sea hydroids (small, moss-like animals that grow on kelp, mussels and other substrates) features a tree diagram showing their phylogeny combined with development (Fig. 2) and the tree is rooted with the hypothetical Gastraea animal as ancestor. This research had been produced and publicised by 1882 (Anonymous 1882a). Lendenfeld's research shows an intriguing correlation with Haast's Blaschka order. Three of the genera represented in his phylogenetic-developmental diagram (*Carmarina*, *Tubularia*, and *Obelia*) (Lendenfeld 1883c) are also represented in Haast's order as developmental series (CMA 1884.137.41-42, CMA 1884.137.63, CMA 1884.137.108, CMA 1884.137.109, CMA 1884.137.126).

A systematic comparison of the composition of three Blaschka collections

If Haast left a discernible scientific-educational mark on Canterbury Museum's Blaschka collection, it is anticipated that Canterbury Museum's Blaschka collection would be skewed towards more developmental models, non-anemone coelenterates and annulated worms. These categories are the ones expected to reveal contemporary evolutionary theory and teaching based on Haast's selections, and have a chance of contrasting against a background of other possible influences. In order to investigate this possibility, three Blaschka collections were assessed for possible differences in model preferences and potential selection bias: Canterbury Museum (CM; Christchurch, New Zealand), Otago Museum (OM; Dunedin, New Zealand), and University College Dublin (UCD; Dublin, Republic of Ireland). OM was included in the study as Haast initially aimed to copy Hutton's order there and Hutton published his views on teaching (1880a). University College Dublin was included because the details of their purchase has been carefully researched (Callaghan et al 2014), and it was acquired in a single order initiated by Professor Alfred Cort Haddon (1855–1940) whose scientific and teaching concerns are well-documented. Haddon was a friend of both Parker and Huxley, who had similar interests in phylogeny (Parker 1885), and embryology (Haddon 1887) and was directly involved in modern evolutionary teaching. The Natural History Museum (London) collection was not included in the analysis as that collection was acquired in four separate acquisitions (Miller and Lowe 2008; Bertini et al 2016). The collection at the Museum of Comparative Zoology at Harvard University was not included as the current model holdings there are representative from a once broader set of models (Linda Ford pers. comm. 2 March 2016) and research might be required to gauge how well the existing collection reflects its original composition.

Primarily because the aim of the analysis was to make inferences about underlying curatorial interests, but also to make groups of models sufficiently large enough for meaningful testing to occur, some catalogue-based groups were split or combined to create groups that could be expected to reveal particular zoological themes from the 1880s. Thus, coelenterates were divided into two groups as true sea anemones and non-anemones. Sea anemones were a favoured group for natural historians (Gosse 1860) whereas non-anemone coelenterates were the object of vigorous study by leading academic evolutionary biologists including Huxley and particularly Haeckel. Interest in annelid worms is expected to overlap with that for other annulated worms so these groups are combined as one zoological theme. Molluscs, echinoderms and flatworms (MEF), which were subjects of mostly traditional natural history interest at this time, were combined and treated as one zoological theme for the purpose of our analysis.

Overall, there were 133 models in the CM collection, 139 in the UCD collection and 57 at OM (Table 1). Each museum contained a number of models that were not found in the other two collections, and only 11 models were purchased for all three collections (Fig. 3). Fifty four models occurred in both the CM and UCD collections. Hierarchical clustering analyses (Bray-Curtis Distance Measure and Group Averaging clustering method) based on the numbers or proportion of models in each taxonomic category suggested that the

Table 1. Number and proportion of models of each taxonomic category in the collections held in each museum (UCD - University College Dublin; CM - Canterbury Museum; OM - Otago Museum). Adjusted residuals were calculated based on the expected values obtained from a 3 x 5 contingency table, using formula provided by Sharpe (2015).

	Number of Models			Proportion of collection (%)			Adjusted residuals		
	UCD	CM	OM	UCD	CM	OM	UCD	CM	OM
Mollusca/Echinodermata/Flatworms	59	56	24	42.4	42.1	42.1	0.06	-0.04	-0.02
Anemones	7	18	10	5.0	13.5	17.5	-2.82	1.40	1.86
Chordata	6	10	6	4.3	7.5	10.5	-1.47	0.50	1.28
Coelenterates (other)	54	37	13	38.8	27.8	22.8	2.42	-1.22	-1.57
Worms (annulated)	13	12	4	9.4	9.0	7.0	0.29	0.11	-0.53
Total	139	133	57	100	100	100			

Table 2. Actual number (N) of models of each taxonomic category in the collections held in each museum, and expected number (Exp.) based on the proportion of models of each taxonomic category in the appropriate catalogue. Residuals (Res.) are standardised residuals calculated using the formula provided by Sharpe (2015). P values are derived from the calculated χ2 value for 4 degrees of freedom.

		UCD			CM			OM	
	N	Exp.	Res.	N	Exp.	Res.	N	Exp.	Res.
Mollusca/Echinodermata/Flatworms	59	73.0	-1.64	56	67.7	-1.42	24	29.0	-0.93
Anemones	7	20.6	-2.99	18	20.4	-0.53	10	8.7	0.43
Chordata	6	7.0	-0.38	10	6.9	1.16	6	3.0	1.76
Coelenterates (other)	54	32.5	3.78	37	32.2	0.86	13	13.8	-0.21
Worms (annulated)	13	5.9	2.90	12	5.9	2.52	4	2.5	0.93
χ2		34.5			10.7			5.04	
P		<0.001			0.030			0.283	

compositions of the model collections at CM and UCD were more similar to each other than to the collection at OM (Fig. 4).

An initial examination of the proportions of models in the different taxonomic categories in the three collections involved a chi-square (χ2) test of association using the counts of models in each group (Table 2). Deviations from the number of models expected by chance (if all the collections contained the same model composition) were assessed by adjusted residuals using the formula provided by Sharpe (2015):

where, O = observed counts; E = expected counts;

$$Adj\ Residual = \frac{(O - E)}{\sqrt{E\ (1 - Row\ Total\ /\ n)(1 - Column\ Total\ /\ n)}}$$

n = total number of models

There was moderate evidence that the proportions of models in the five taxonomic categories differed among the three museums (χ2 = 14.8, P = 0.062, df = 8). The proportion of MEF models in each collection was very similar over the three museums, ranging from 42.1% to 42.4% (Table 2). Similarly, the proportions of models represented by annulated worms were also fairly consistent, ranging from 7% at OM to 9.4% at UCD. The major discrepancies, as revealed by adjusted residuals > |2|, were observed in the proportions of models in the anemones and coelenterates (Table 1). Non-anemone coelenterates were under-represented at OM (22.8%) compared to UCD (38.8%), whereas the anemones were under-represented at UCD (5.0%) compared to OM (17.5%). The models represented by Chordata were much lower at UCD (4.3%) compared to OM (10.5%). This analysis suggests that the collections at UCD and OM were distinct, and the model collection at CM was somewhat intermediate between that of the other two museums. However, the adjusted residuals indicated that models of anemones might be under-represented and those of other

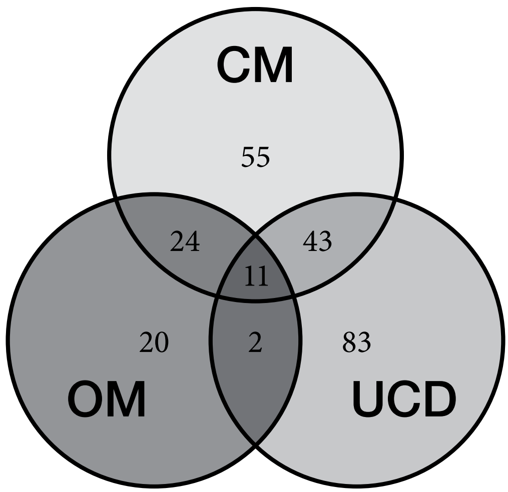

Figure 3. Venn diagram illustrating the numbers of models the collection at each museum contains and what proportions of models were unique to each museum or shared among collections (CM - Canterbury Museum; OM - Otago Museum; UCD - University College Dublin).

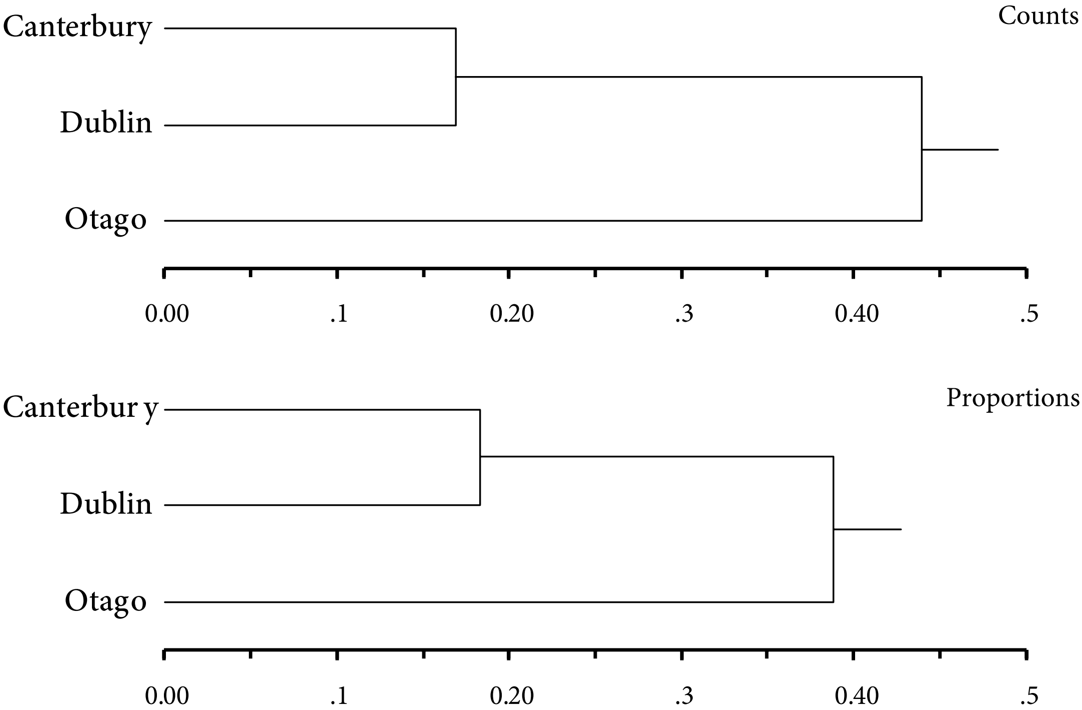

Figure 4. Dendrograms based on hierarchical clustering indicating the similarity of the compositions of the model collections at three institutes. Clustering was based on either the actual counts of models or the proportions of models in each taxonomic category in each collection.

coelenterates over-represented in the collection at CM, although not to the extent of that in the UCD collection (Table 1).

Selection bias of models was assessed using a chi-square goodness of fit test. The observed numbers of models in each taxonomic category in each collection were compared to the numbers expected to occur if selection had occurred from the appropriate catalogue at random (Table 2). Biases were determined using standardised (or Pearson) residuals, as calculated using the formula provided by Sharpe (2015):

$$Std\ Residual = \frac{(O - E)}{\sqrt{E}}$$

This analysis suggested that model selection had occurred non-randomly at UCD and CM ($P < 0.05$ in both cases), but that there was little evidence of a strategy for model selection at OM ($P = 0.283$) (Table 2). The residuals indicated that the CM collection was under-represented by MEF and over-represented by models of annulated worms (Table 2). The bias away from purely natural history models was even stronger at UCD, where the residuals suggested a strong deviation away from MEF and anemone models and towards models of coelenterates and annulated worms.

Summary of systematic comparison

The goodness of fit (Table 2) and clustering analyses (Fig. 4) indicate that the CM and UCD collections could reflect similar model selection biases. Despite many different models being ordered (Fig. 3), when the preferences for whole groups are considered, there appeared a collection composition matching ‘modern’ zoological teaching reflecting an interest in the phylogenetic questions of the time. Both UCD and CM collections feature a small but significant bias for annulated worms and a relative disinterest in anemones. Tellingly, both UCD and CM collections feature many embryological models while OM have none.

In comparison with the results from CM and UCD, which showed a skew towards models suitable for zoological teaching, the OM collection appears to reflect a relatively ad hoc assortment of models available in the catalogue. The form of the collection at OM appears to reflect Hutton's predispositions. Based on the comparison with two other Blaschka collections, the OM collection reflects Hutton's deep and practical engagement with inventory catalogue natural history, as revealed by his extensive cataloguing of New Zealand fauna (Hutton 1878b, 1880b). While Hutton was a famously ardent Darwinist (Stenhouse 1984), who included basic coelenterate development in his public lectures (*Clutha Leader*, 15 August, 1879: 6), his order for Otago does not imply a strong connection with contemporary European theories. Rather it matches Hutton's convictions on the subject of zoological teaching. His laboratory manual (Hutton 1880a) is explicitly designed to be practical and features larger animals that are easier to observe and dissect. There is a strong emphasis on the student developing observation and practical skills in identification. In stark contrast to Thomas Parker's textbook (1891), Hutton chooses earthworms over marine annelids, large anemones over tiny hydrozoans, and devotes four whole lessons to mollusc dissection. Similarly his practical stance contrasts with the theoretical leanings of Lendenfeld and Haacke. Although biographies of Hutton sometimes refer to his adoption of Huxleyan methods, this is only partly true. His forthright views included dissatisfaction with the increasing use of some post-Darwin theories in zoological education (Hutton 1880a; Stenhouse 1990). The composition of New Zealand Blaschka orders might then be seen as a small window into debates ably reviewed by Stenhouse (1990) that were being acted out in New Zealand at this time, in which Haeckel's influence played no small part (Anonymous 1882b). Hutton's views on teaching are crystal-clear from several comments in his preface (Hutton 1880a) and summarised in his opening quote: "The progress of science corresponds to the time of practical teaching; the stationary, or retrograde period of science, is the period when philosophy was the instrument of education". (Whewell in Hutton 1880a)

Conclusion

The reasons for selecting specific Blaschka models are rarely known. In the absence of declared motivations for assembling Blaschka collections, there has been a default tendency to see Blaschka models as essentially filling gaps in an inventory of nature left by many difficult-to-preserve marine invertebrates. While the drive to achieve comprehensive coverage is certainly a feature of late Victorian natural history collections, this period was also one of intense intellectual exploration and new approaches to zoological teaching allied to new theories. Analysis of the composition of the Blaschka collection at Canterbury Museum, relative to the Otago Museum collection, finds a small but significant preference towards models that we deem more suitable for 'modern' evolutionary teaching. Moreover, looking at overall composition, of the three collections compared, Canterbury Museum's collection is most like that of the University College Dublin, a collection subject to comparable influences. The overall composition is similar despite less than half of the same models being represented. Based on this, it appears that Haast, like many of his scientific colleagues, was looking beyond inventory science. Haast maintained links with many key scientists, including two German-speaking coelenterate specialists with strong connections to Ernst Haeckel. It is likely that Haast was sympathetic to the new theories that promised to provide new foundations for biology and reform zoological teaching.

This fresh perspective on why various models were ordered might allow us to see these models in a similar fashion to their nineteenth century audience. Haast intended the collection at Canterbury Museum to be a cathedral of science and an encyclopaedia of the world. Haast's approach fitted his drive to stimulate local science. It also anticipated the large and impressive zoological teaching laboratory that later emerged at Canterbury College, which boasted many embryological models (*Press*, 13 March, 1896: 3). We hope that audiences of Blaschka models may gain a sense of the potent ideas that seem to have circulated around and through them and, for the first time in many decades, see these models made accessible once more.

Acknowledgements

We are grateful to Moira White and Otago Museum staff who generously shared data. Dr Linda Ford and Johnathan Woodward, Museum of Comparative Zoology, Harvard University, assisted identifications by comparing their collection with photos. Thanks to Lynette Hartley for photographing the Blaschka models and to Frances Husband for cataloguing them. We thank the Ernst Haeckel archive and the Alexander Turnbull Library for allowing copies to be made of valuable correspondence.

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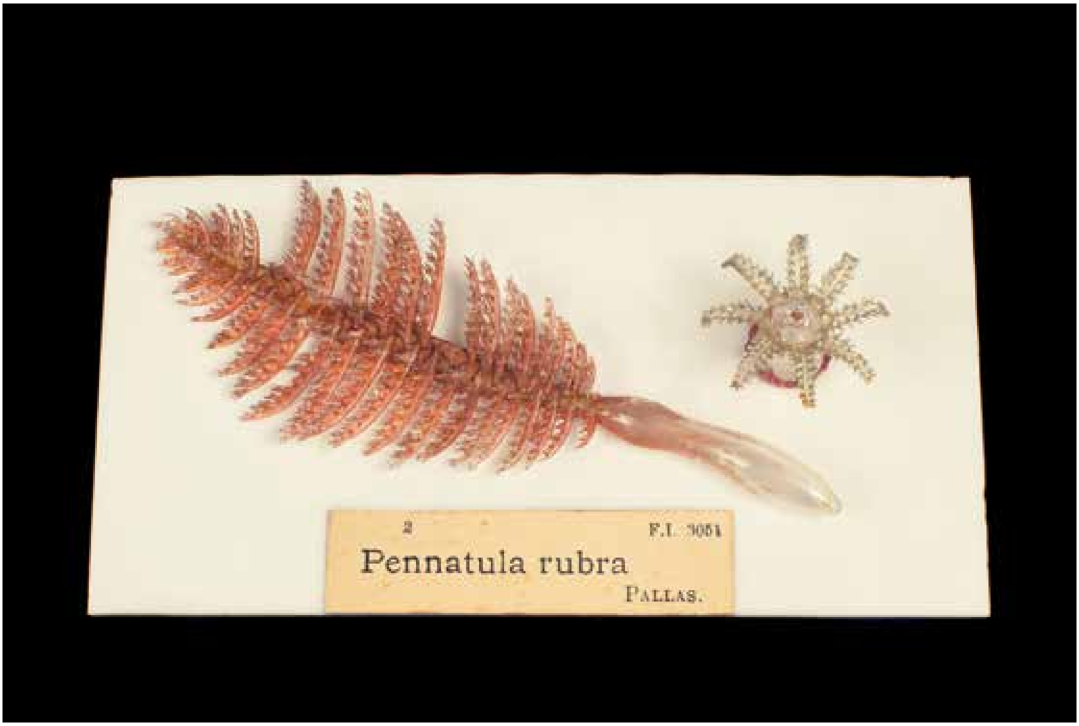
Illustrated catalogue of the Blaschka collection at Canterbury Museum

Blaschka models are fragile and, over the 135 years of their care at the Museum, some of the models have suffered damage through the natural decay of adhesives, the nature of materials used and the fact the models were acquired for the purpose of teaching and display. Some models are currently awaiting conservation following the Canterbury earthquake of 22 February 2011. So that a comprehensive picture of the collection is provided, larger detached pieces of models are included in the photographs in this catalogue. Smaller pieces are not included. Each model is labeled with the original Blaschka number (from Ward 1878, 1888), a taxonomic identification and Canterbury Museum accession number.

Blaschka Number 1. *Alcyonium digitatum* 1884.137.57

Blaschka Number 5. *Corallium rubrum* 1884.137.21

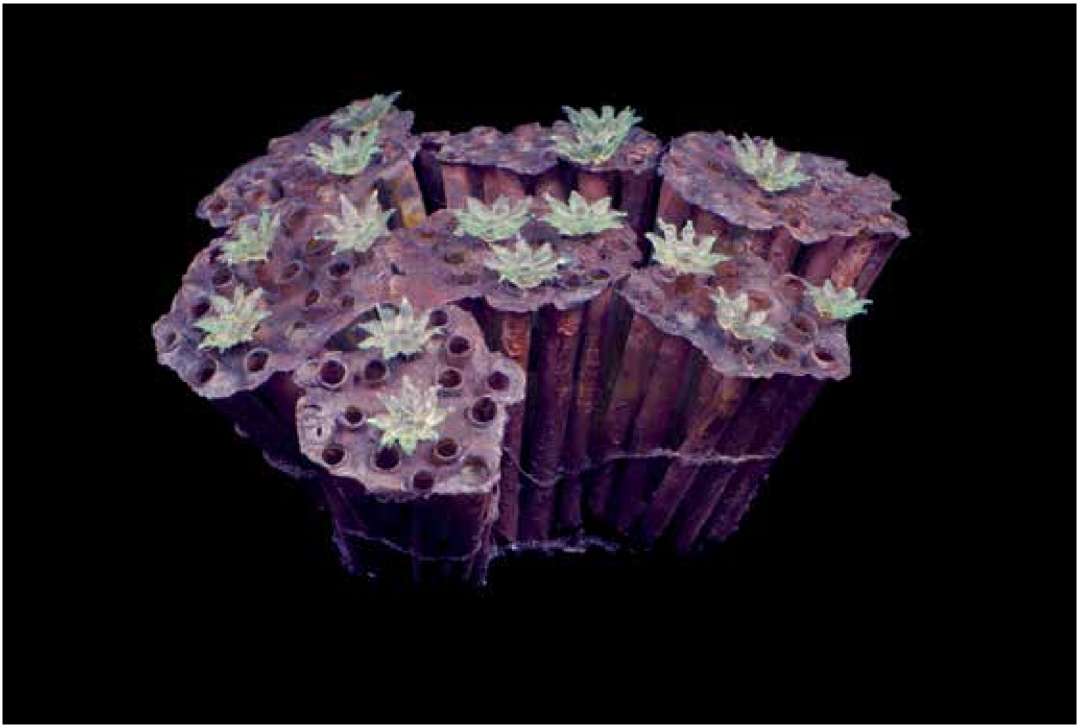
Blaschka Number 6. *Gorgonia verrucosa* 1884.137.81



Blaschka Number 10. *Pennatula rubra* 1884.137.121

Blaschka Number 12. *Renilla violacea* 1884.137.118

Blaschka Number 14. *Sympodium caeruleum* 1884.137.71



Blaschka Number 16. *Tubipora hemiprichii* 1884.137.31

Blaschka Number 20. *Actineria hemprichi* 1884.137.115

Blaschka Number 36. *Anthea cereus* var. *maxima* 1884.137.56

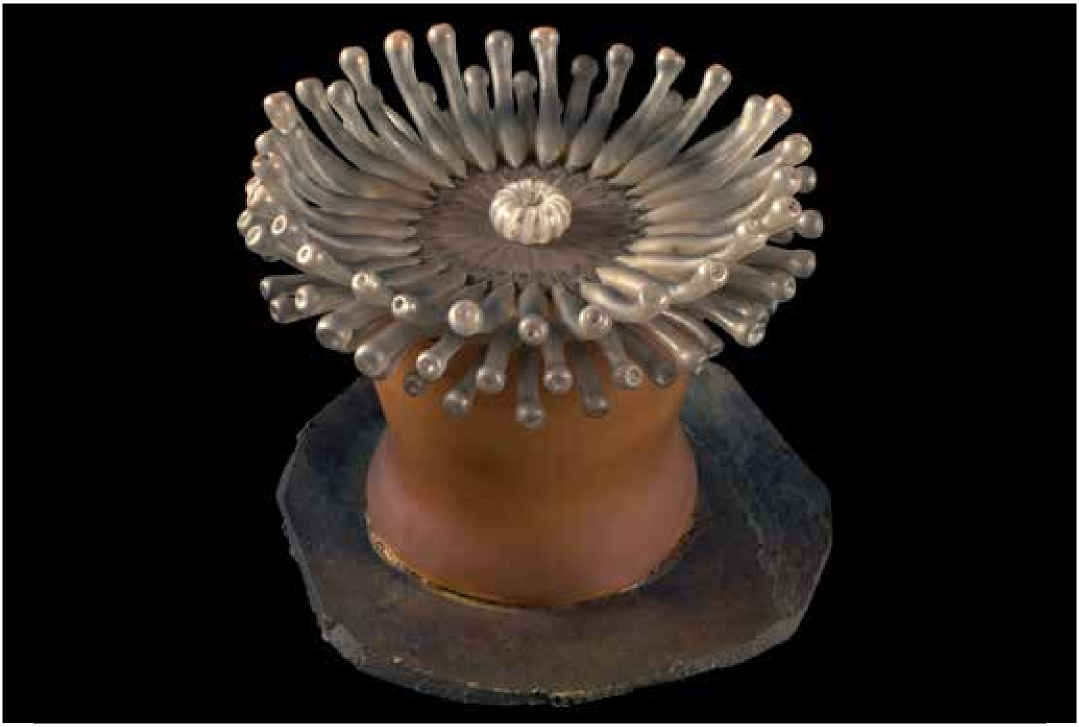
Blaschka Number 22. *Actinia mesembrianthemum* 1884.137.5

Blaschka Number 27. *Actinoloba dianthus* 1884.137.29

Blaschka Number 41. *Bolocera eques* 1884.137.74

Blaschka Number 48. *Bunodes gemmacea* 1884.137.123

Blaschka Number 54. *Cerianthus membranaceus* 1884.137.64

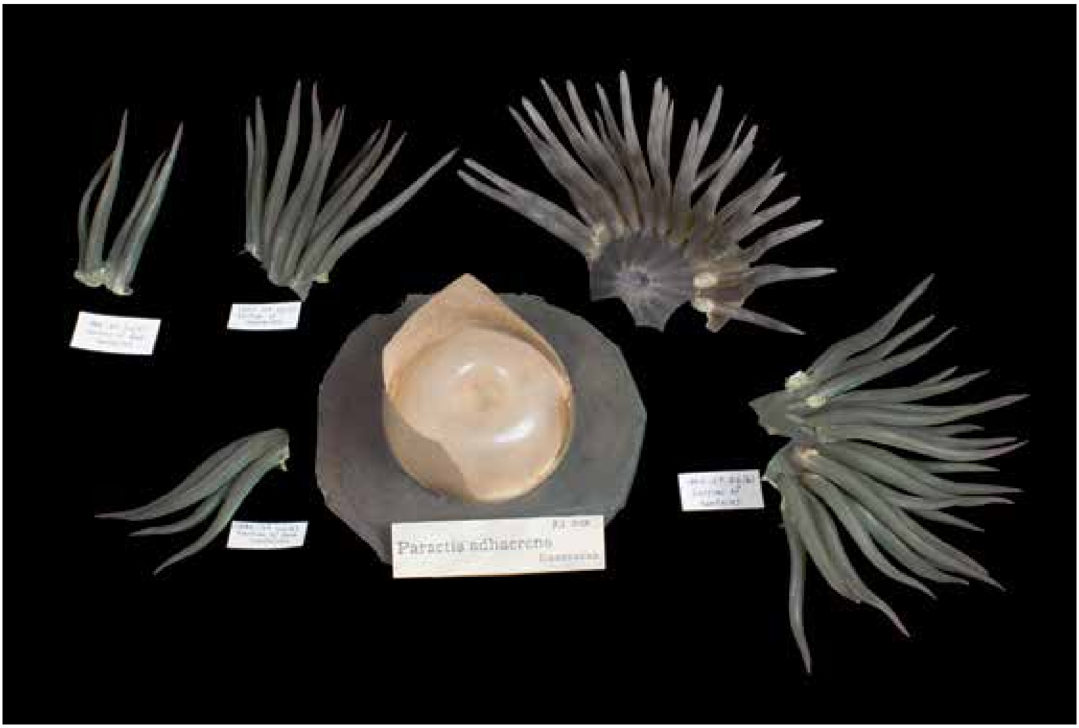


Blaschka Number 55. *Corynactis clavigera* 1884.137.34

Blaschka Number 63. *Halcampa chrysanthellum* 1884.137.96

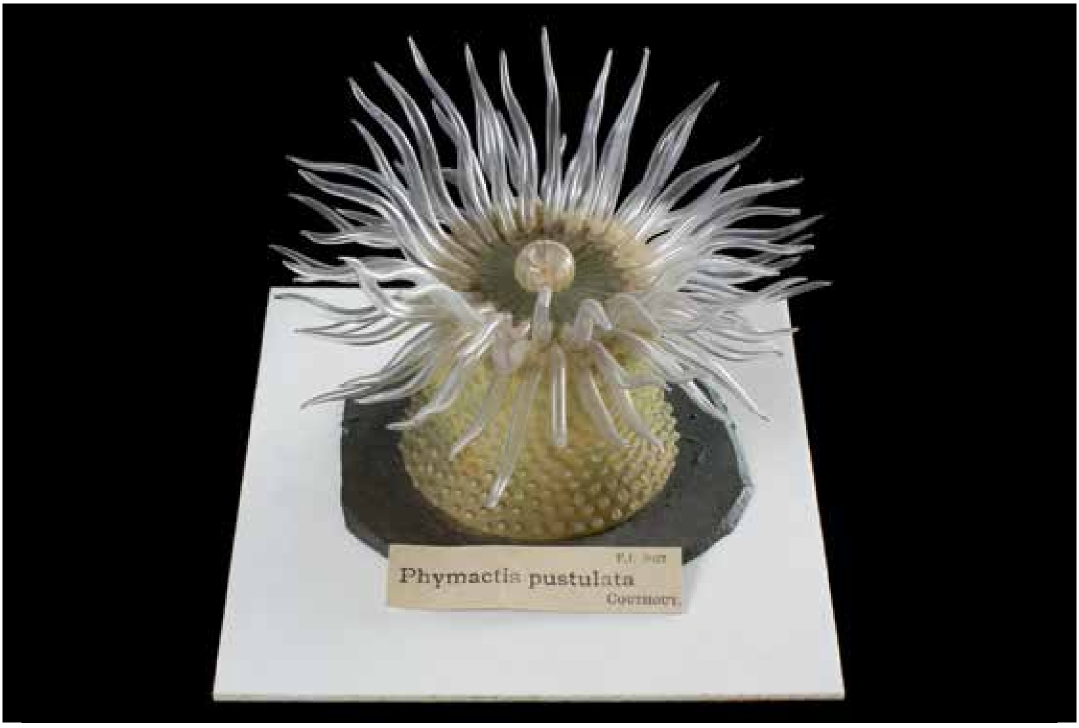
Blaschka Number 67. *Ilanthos scoticus* 1884.137.26

Blaschka Number 68. *Nemactis primula* 1884.137.124



Blaschka Number 70. *Paractis adhaerens* 1884.137.55

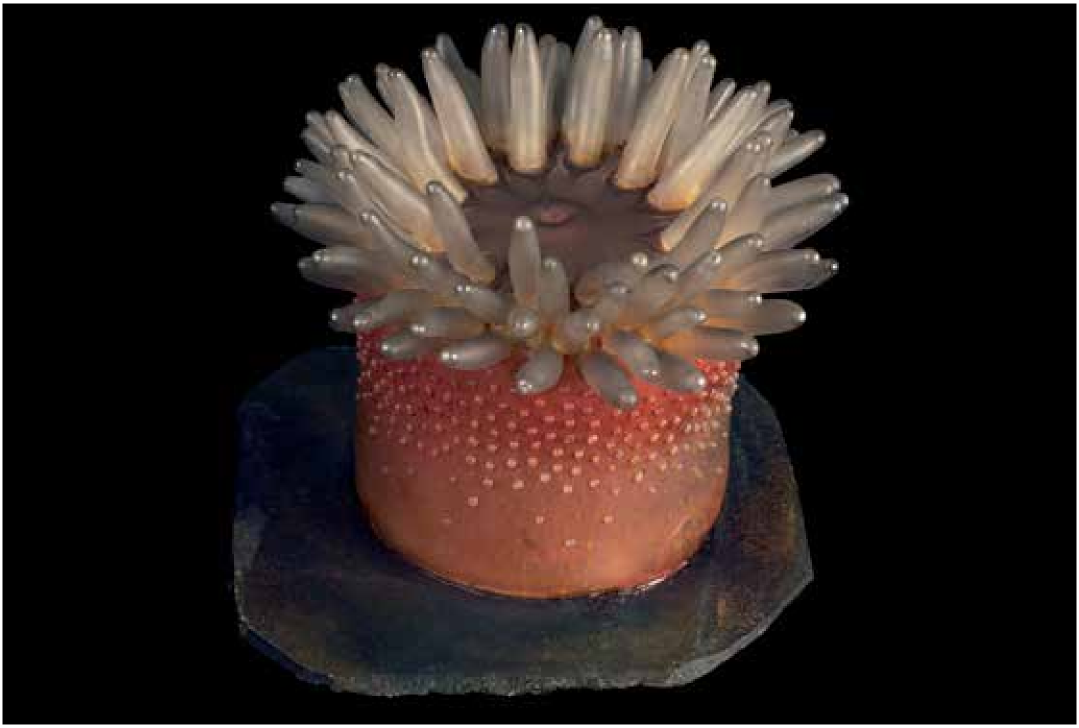
Blaschka Number 73. *Peachia hastata* 1884.137.28



Blaschka Number 83. *Phymactis pustulata* 1884.137.65

Blaschka Number 85. *Phymanthus loligo* 1884.137.30

Blaschka Number 88. *Sagartia bellis* var. *tyriensis* 1884.137.122



Blaschka Number 109. *Tealia crassicornis* var. *purpurea* 1884.137.27

Blaschka Number 115. *Thalassianthus aster* 1884.137.62

Blaschka Number 117. *Zoanthus couchii* 1884.137.70

Blaschka Number 119. *Astroides calycularis* 1884.137.73

Blaschka Number 138. *Carmarina hastata,* female 1884.137.41

Blaschka Number 139. *Carmarina hastata,* male 1884.137.42

Blaschka Number 140. *Carmarina hastata,* stages of development 1884.137.108

Blaschka Number 157. *Lafoea calcarata* 1884.137.107

Blaschka Number 167. *Obelia dichotoma,* male polyps and medusa 1884.137.109

Blaschka Number 169. *Oceania phosphorica* 1884.137.113

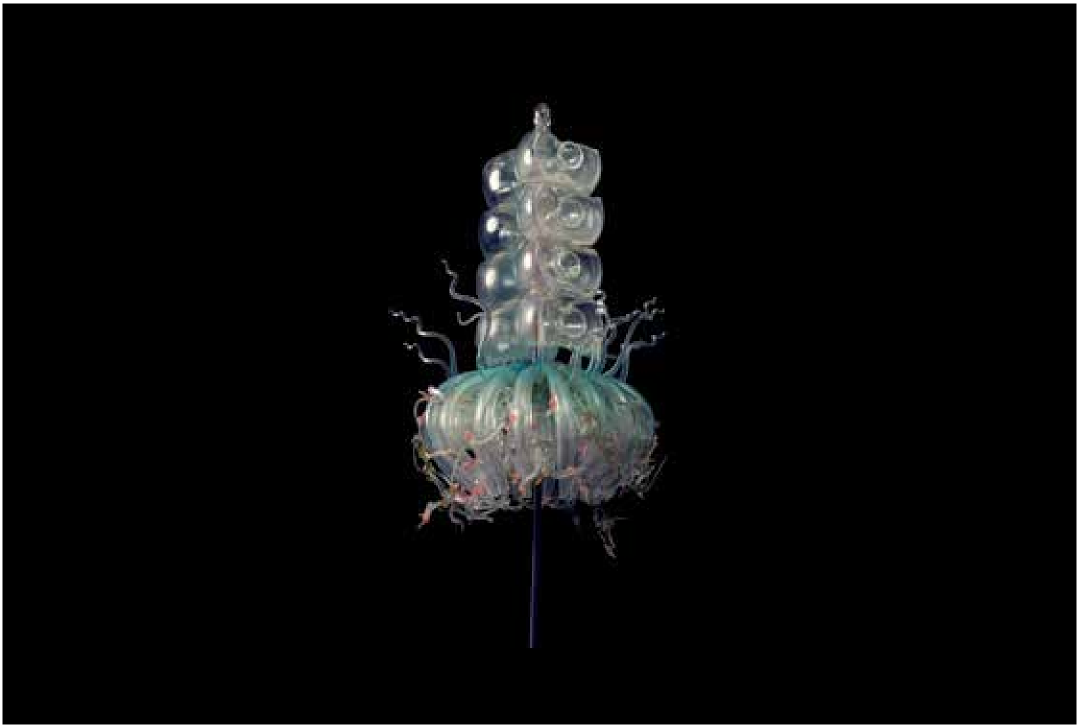
Blaschka Number 191. *Tubularia indivisa,* stages of development 1884.137.63

Blaschka Number 191a. *Tubularia indivisa,* male 1884.137.126

Blaschka Number 196. *Zygodactyla crassa* 1884.137.44

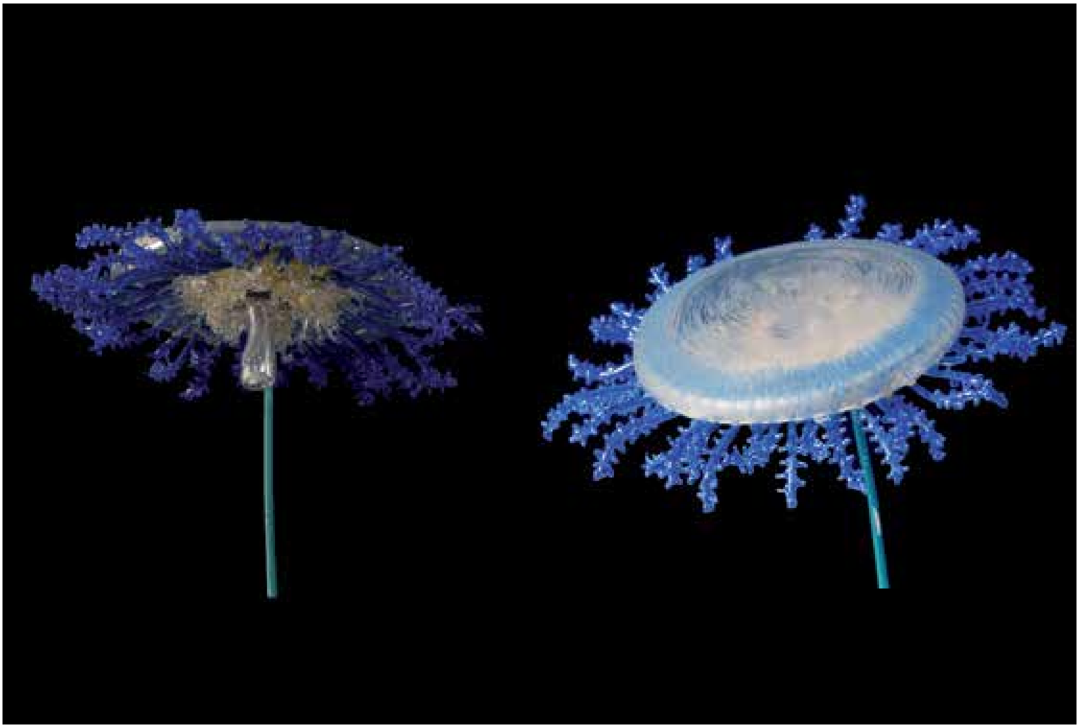
Blaschka Number 203. *Diphyes sieboldii* 1884.137.114

Blaschka Number 211. *Physalia pelagica* 1884.137.33



Blaschka Number 213. *Physophora magnifica* 1884.137.61

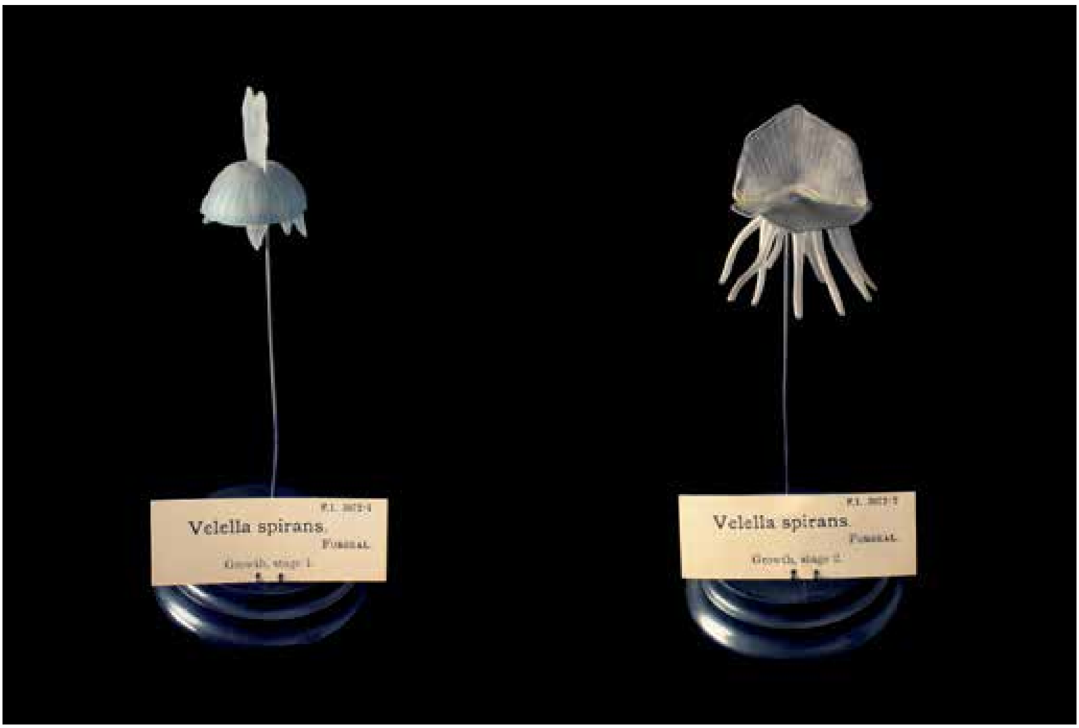
Blaschka Number 214. *Physophora magnifica,* stages of development 1884.137.40



Blaschka Number 216. *Porpita mediterranea* 1884.137.59

Blaschka Number 220. *Stephanomia canariensis* 1884.137.36

Blaschka Number 222. *Vellela spirans* 1884.137.54



Blaschka Number 223 . *Velella spirans,* stages of development 1884.137.111

Blaschka Number 224. *Aurelia aurita,* adult 1884.137.32

Blaschka Number 225. *Aurelia aurita,* stages of development 1884.137.24

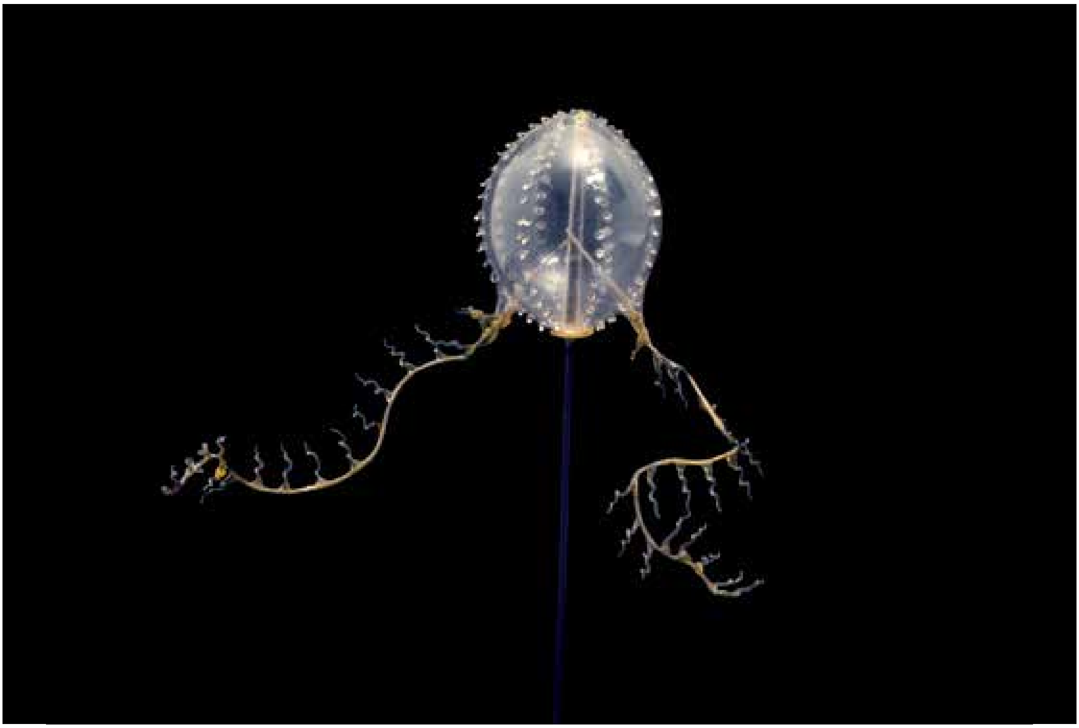
Blaschka Number 227. *Chrysaora hysoscella* 1884.137.104

Blaschka Number 235 . *Pelagia noctiluca* 1884.137.105

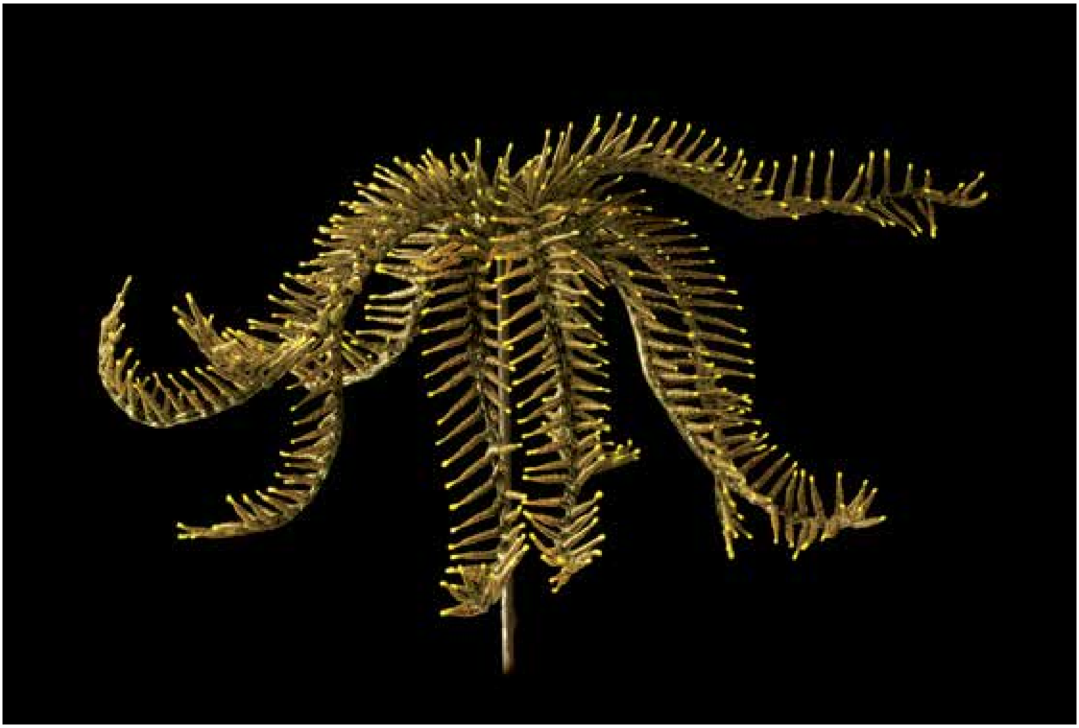
Blaschka Number 238. *Rhizostoma pulmo* 1884.137.68

Blaschka Number 241. *Beroë punctata* 1884.137.52

Blaschka Number 242. *Cestum veneris* 1884.137.127



Blaschka Number 247. *Pleurobranchia pileus* 1884.137.53



Blaschka Number 249. *Comatula hamata* 1884.137.13

Blaschka Number 252. *Amphiura filiformis,* stages of development 1884.137.25

Blaschka Number 267. *Cucumeria hyndmannii* 1884.137.84

Blaschka Number 274. *Holothuria tubulosa* 1884.137.75

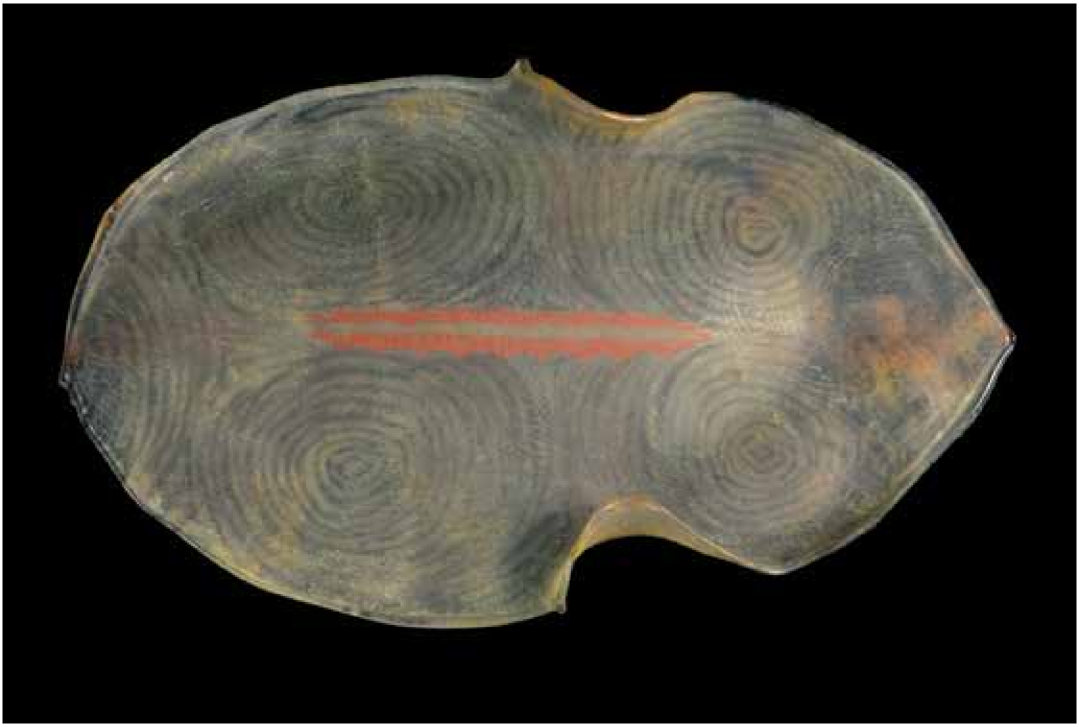
Blaschka Number 277. *Psolus phantapus* 1884.137.2

Blaschka Number 282. *Synapta beselii* 1884.137.23

Blaschka Number 289. *Synapta oceanica* 1884.137.3

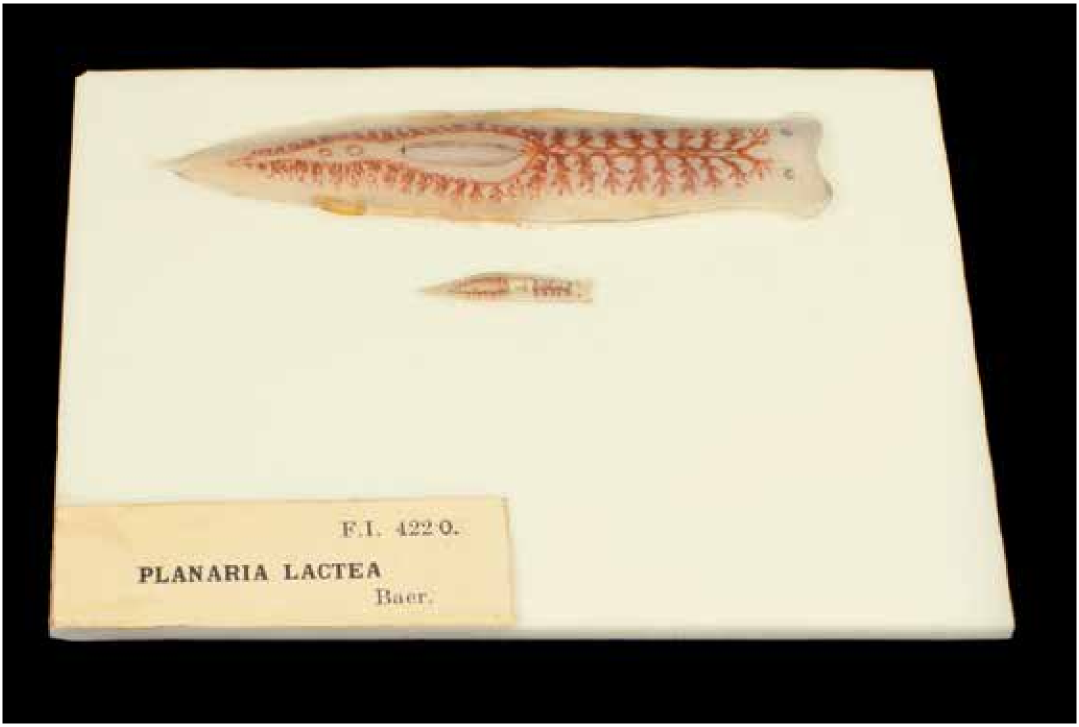
Blaschka Number 291. *Thyone fusus* 1884.137.82

Blaschka Number 295. *Borlasia trilineata* 1884.137.49

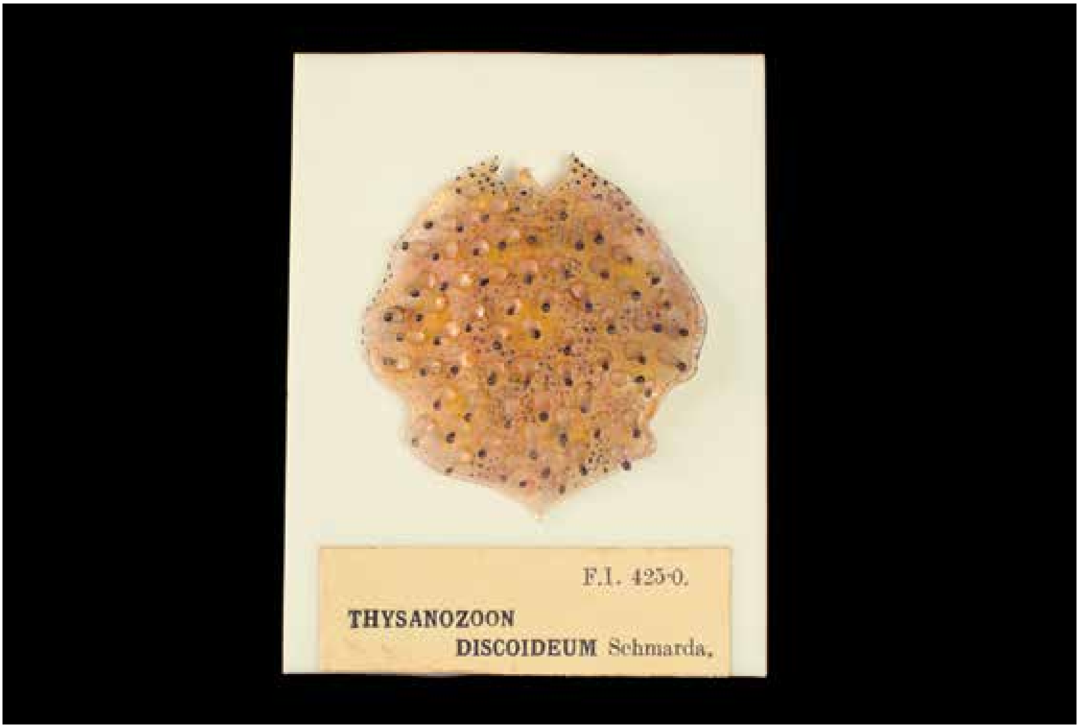


Blaschka Number 297. *Centrostomum polycyclium* 1884.137.97

Blaschka Number 306. *Neckelia macrorrhochma* 1884.137.37



Blaschka Number 308. *Planaria lactea* 1884.137.128



Blaschka Number 320. *Thysanozoon discoideum* 1884.137.112

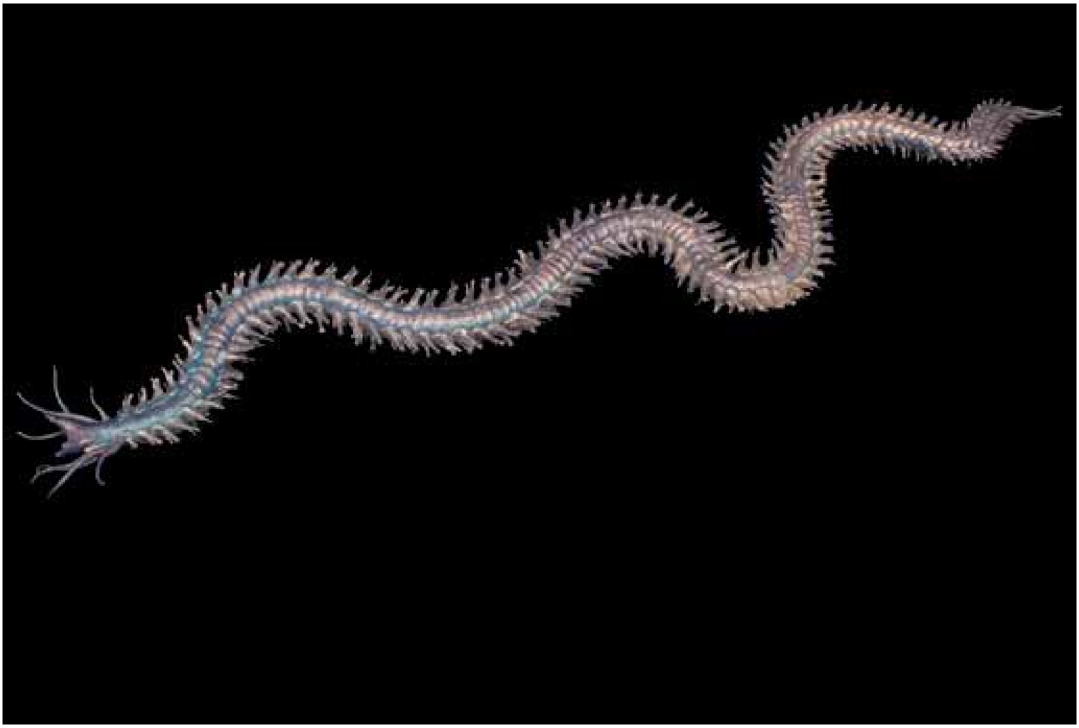
Blaschka Number 324. *Bonellia viridis* 1884.137.48

Blaschka Number 326. *Priapulus caudatus* 1884.137.125

Blaschka Number 328. *Clepsine marginata* 1884.137.35

Blaschka Number 331. *Arenicola marina* 1884.137.9

Blaschka Number 334. *Eunice norvegica* 1884.137.90



Blaschka Number 337. *Nereis margaritacea* 1884.137.20

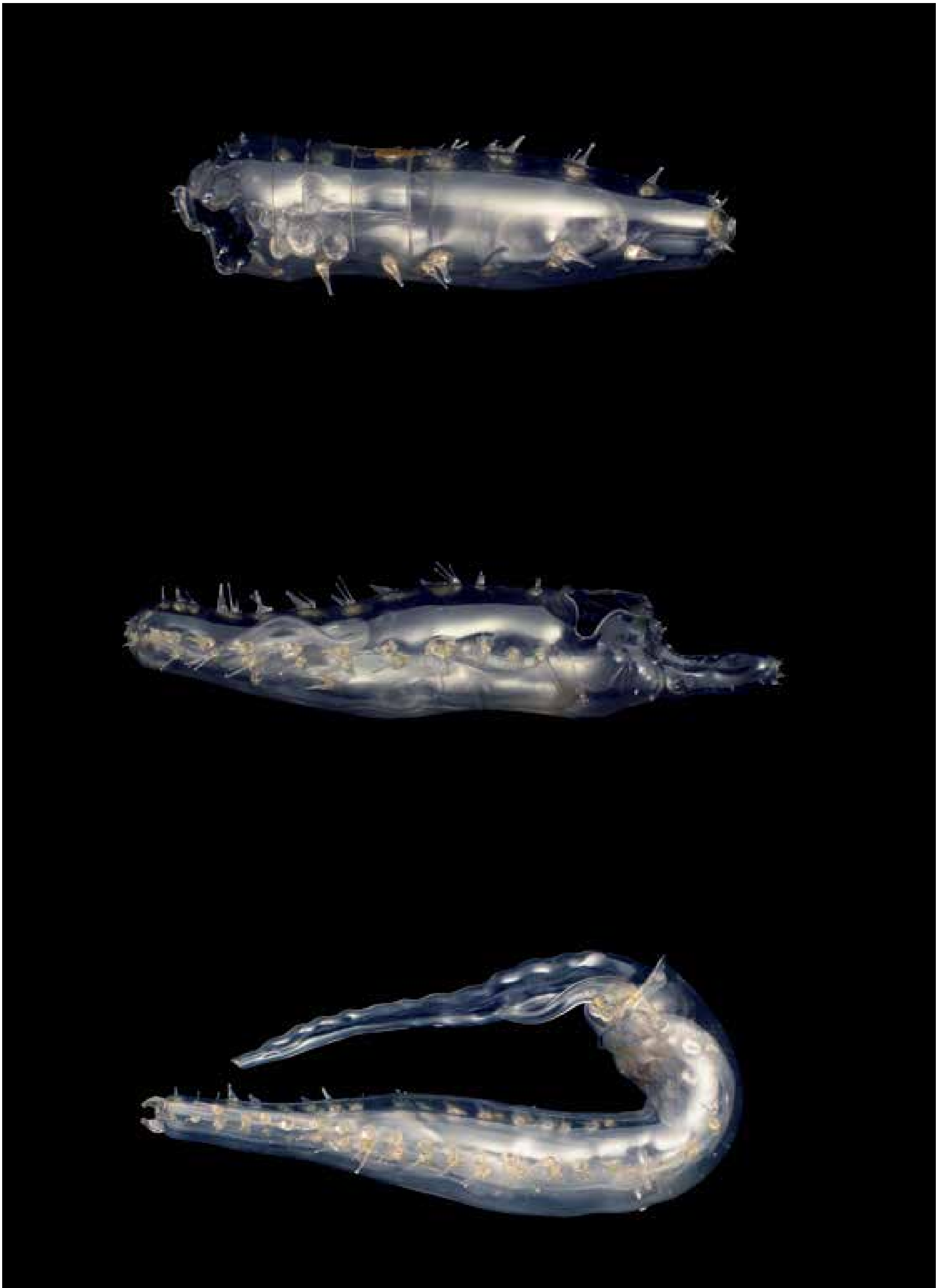
Blaschka Number 339. *Phyllodoce parettii* 1884.137.18

Blaschka Number 342. *Sabella penicillus* 1884.137.98

Blaschka Number 343. *Serpula contortuplicata* 1884.137.15

Blaschka Number 344. *Siphonostoma diplochaitos* 1884.137.91

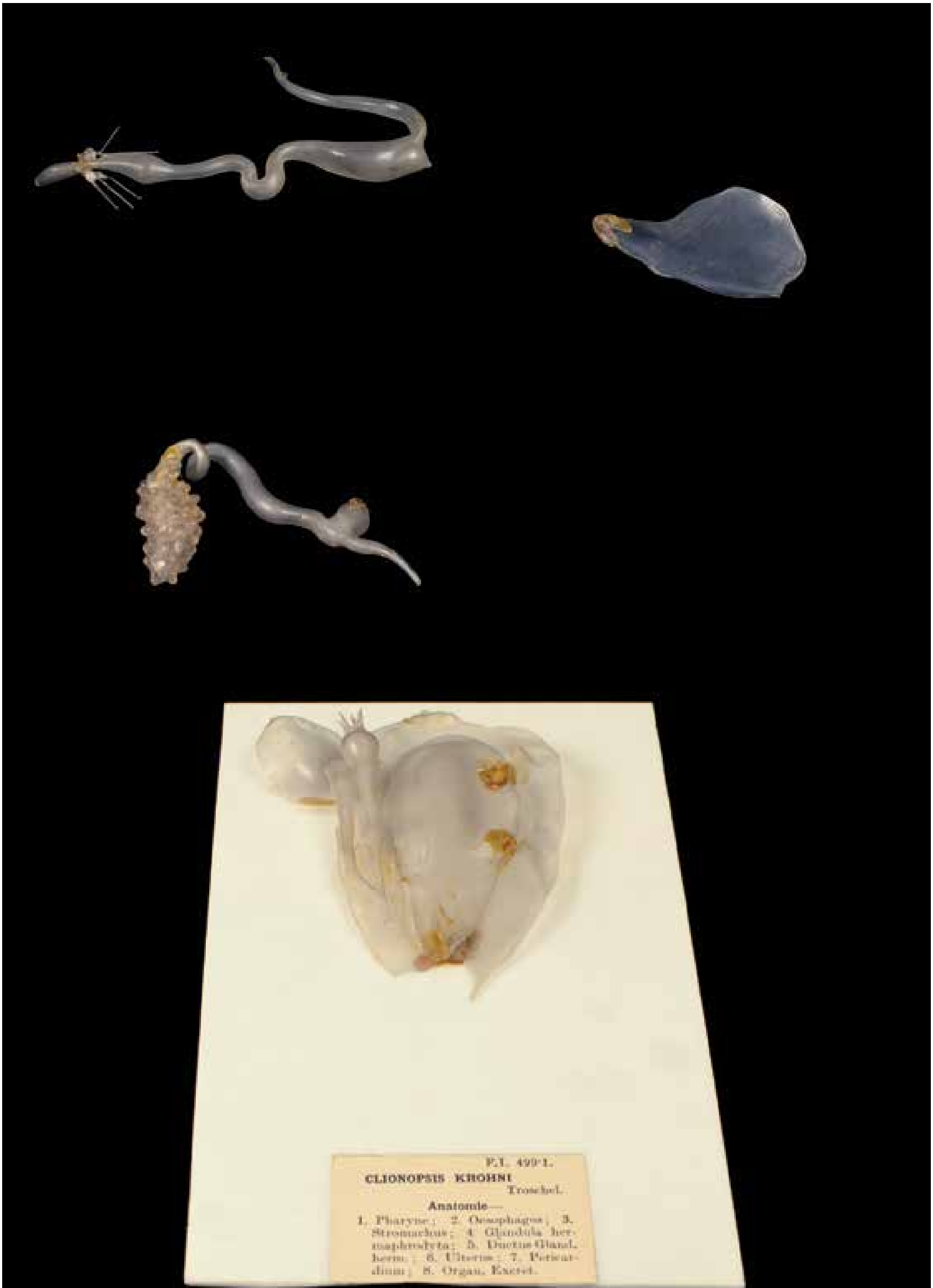
Blaschka Number 348. *Terebella conchilega* 1884.137.22



Blaschka Number 349. *Terebella conchilega*, stages of development 1884.137.110

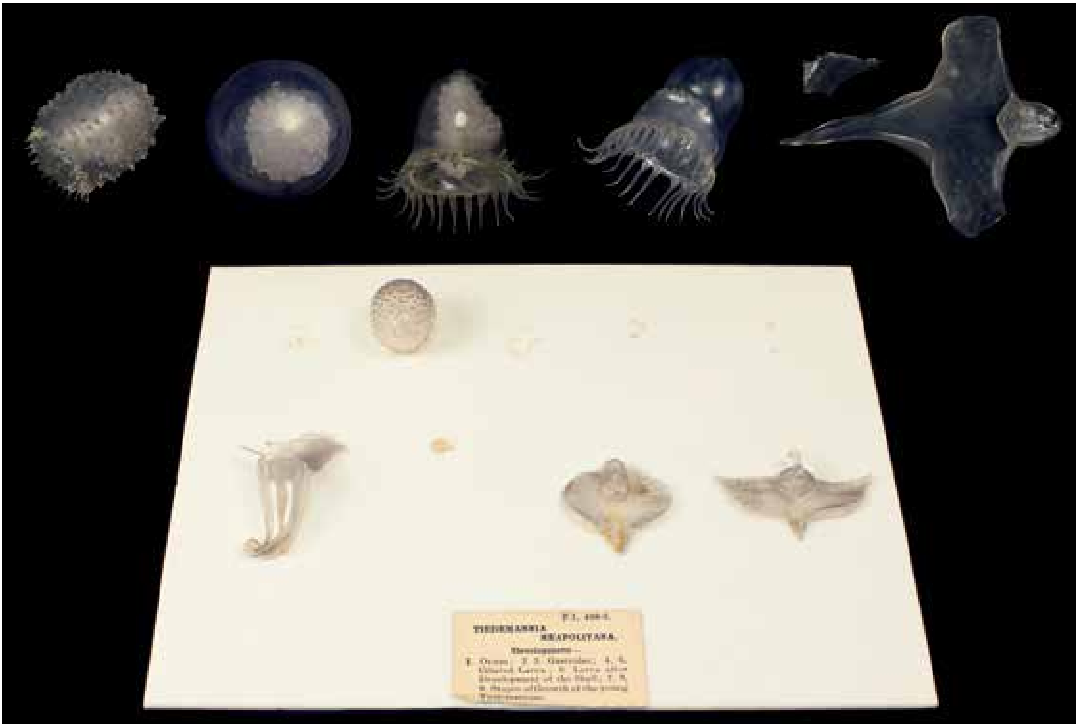
Blaschka Number 352. *Clio borealis* 1884.137.78

Blaschka Number 353. *Clionopsis krohnii* 1884.137.100



Blaschka Number 354. *Clionopsis krohnii,* anatomy 1884.137.103

Blaschka Number 359. *Tiedemannia neapolitana,* adult 1884.137.99

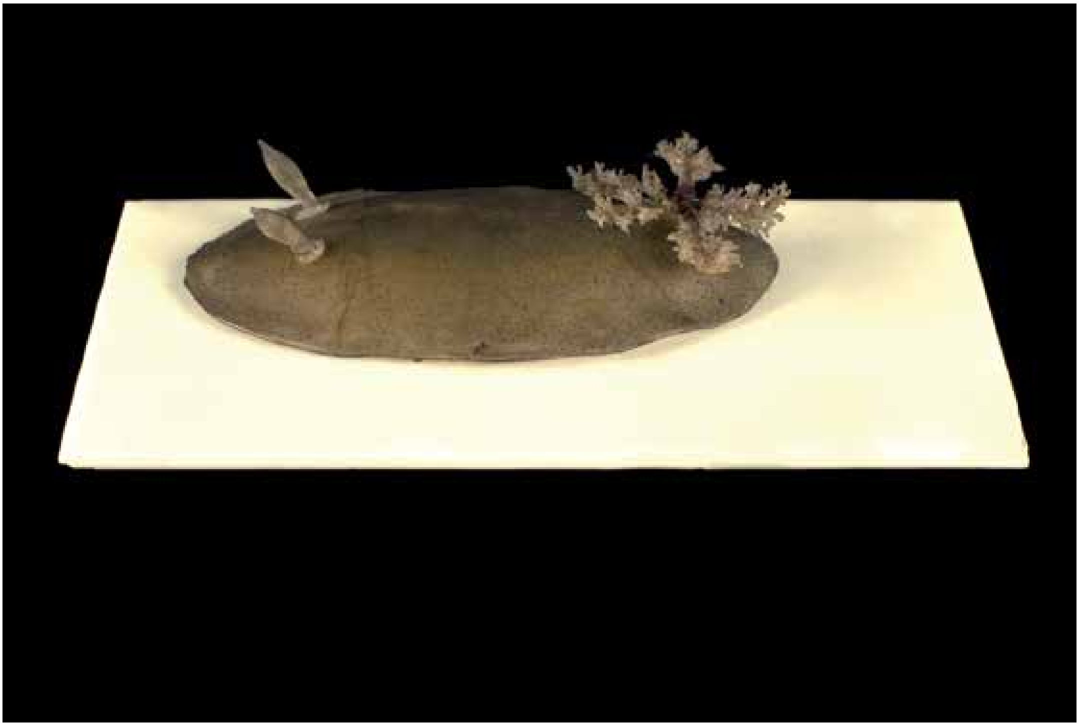


Blaschka Number 360. *Tiedemannia neapolitana,* stages of development 1884.137.95

Blaschka Number 361. *Actinodoris australis* 1884.137.93

Blaschka Number 365. *Aeolis exigua* 1884.137.89

Blaschka Number 395. *Dendronotos arborescens* var. *carneus* 1884.137.7

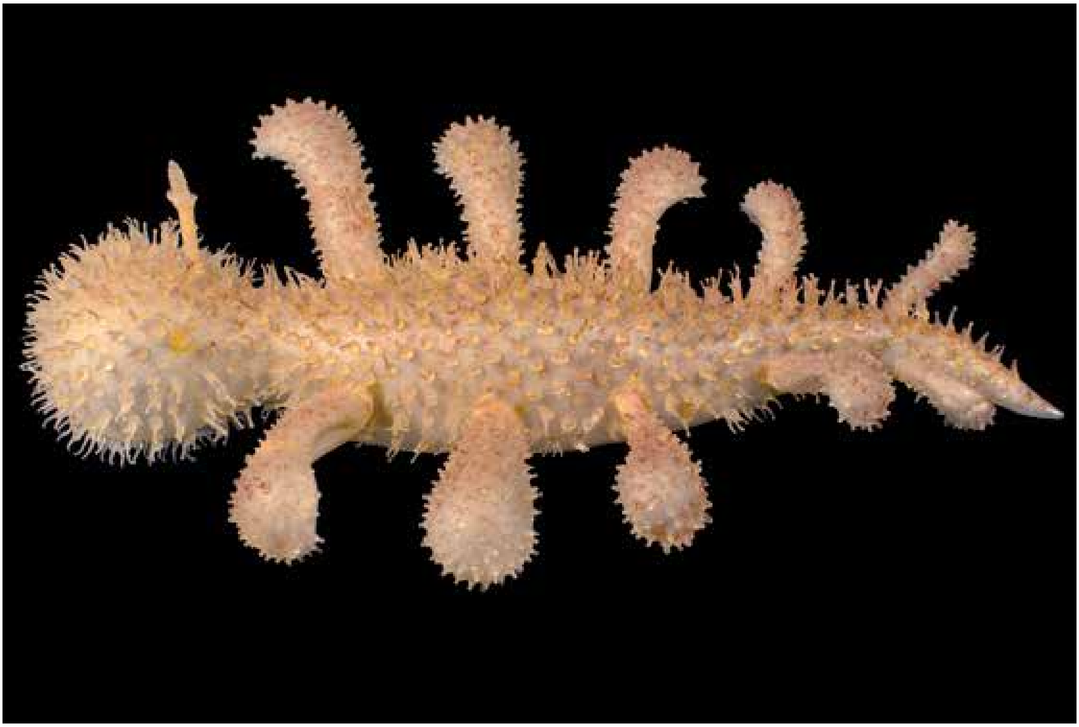


Blaschka Number 415. *Doris formosa* 1884.137.46

Blaschka Number 431 . *Doto coronata* 1884.137.88

Blaschka Number 432. *Elysia chlorotica* 1884.137.76

Blaschka Number 455. *Goniodorus verrucosa* 1884.137.117



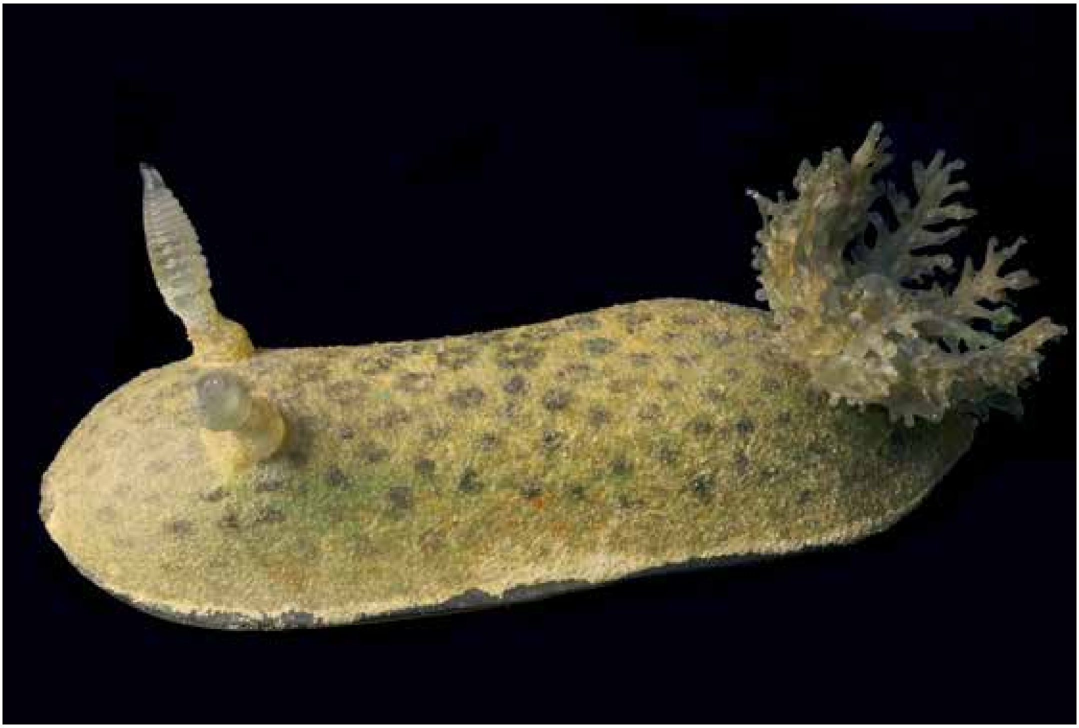
Blaschka Number 460. *Melibe fimbriata* 1884.137.8

Blaschka Number 467. *Plocamophorus imperialis* 1884.137.116

Blaschka Number 482. *Tethys leporina* 1884.137.12

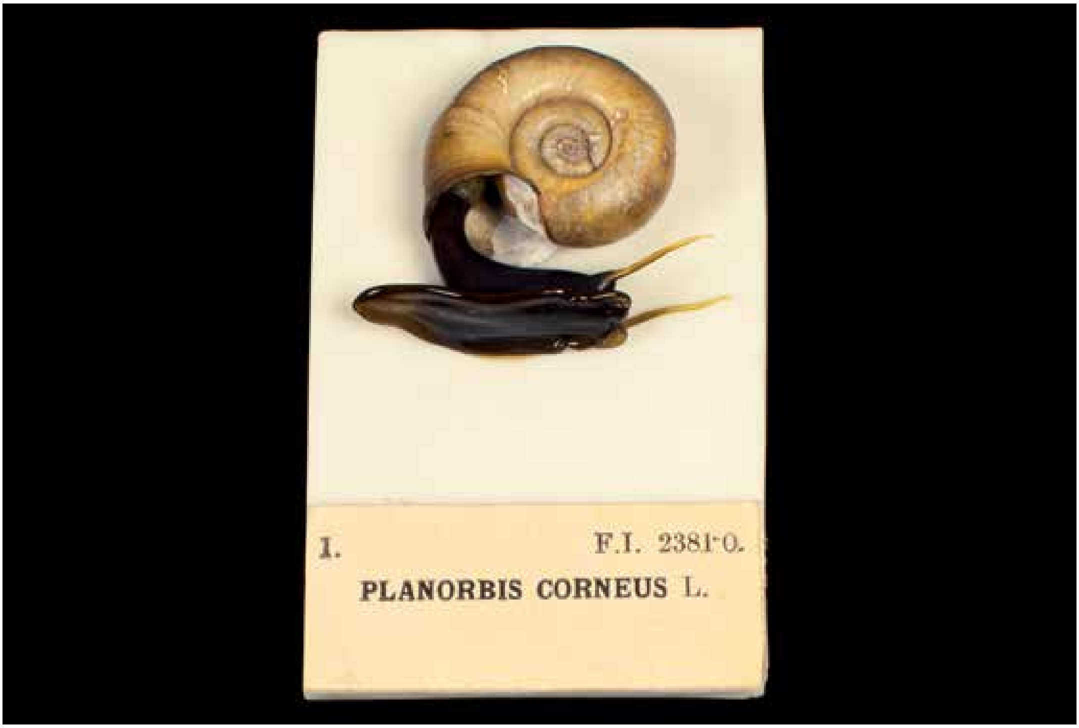
Blaschka Number 489. *Aplysia inca* 1884.137.11

Blaschka Number 491. *Dolabrifera fusca* 1884.137.94



Blaschka Number 423. *Doris pantherina* 1884.137.60

Blaschka Number 464. *Phyllobranchus orientalis* 1884.137.87



Blaschka Number 507. *Planorbis corneus* 1884.137.83. Note the unorthodox shell.

Blaschka Number 510. *Arion empiricorum* var. *ater* 1884.137.45

Blaschka Number 513. *Arion empiricorum,* anatomy 1884.137.50

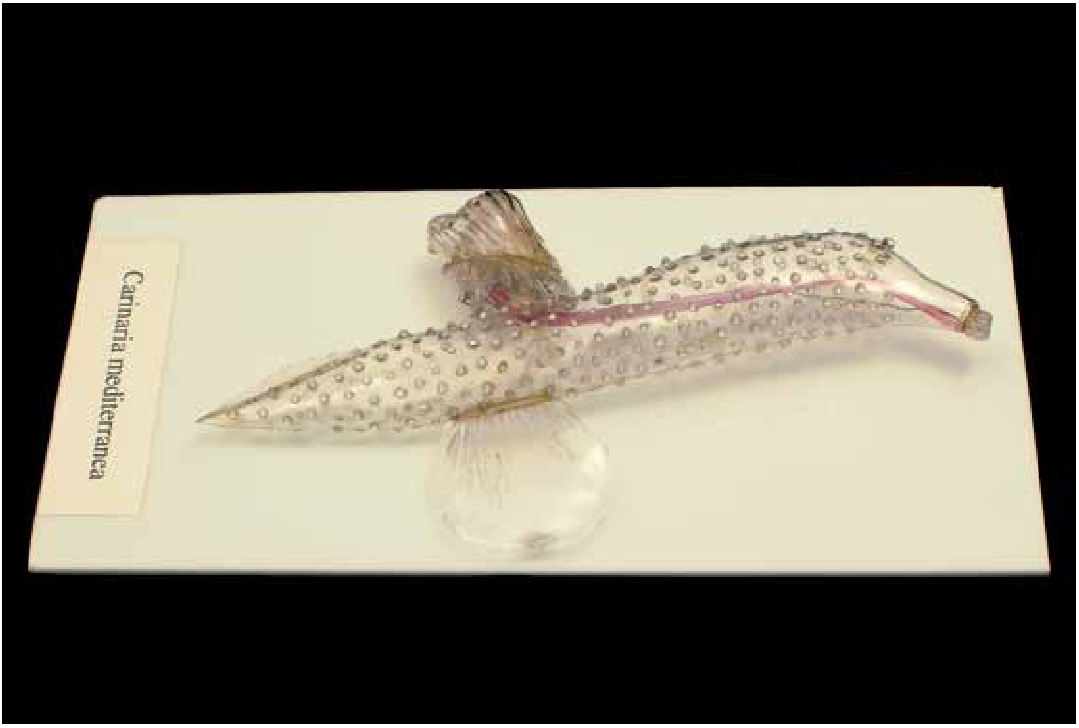
Blaschka Number 525. *Helix ?pomatia* 1884.137.86. Note the body appears to represent *Testacella haliotidea*

Blaschka Number 526. *Helix pomatia*, anatomy 1884.137.69

Blaschka Number 527. *Limax agrestis* 1884.137.77

Blaschka Number 529. *Limax arborum* 1884.137.19

Blaschka Number 534. *Limax maximus* 1884.137.1



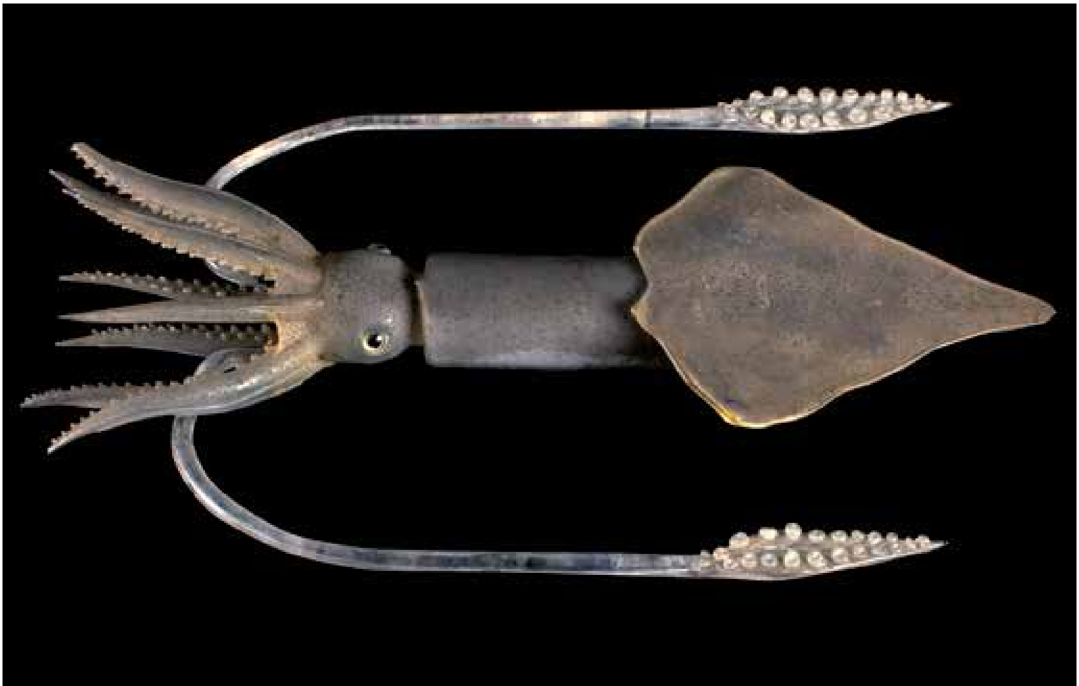
Blaschka Number 526. *Carinaria mediterranea* 1884.137.14

Blaschka Number 549. *Argonauta argo,* female 1884.137.10

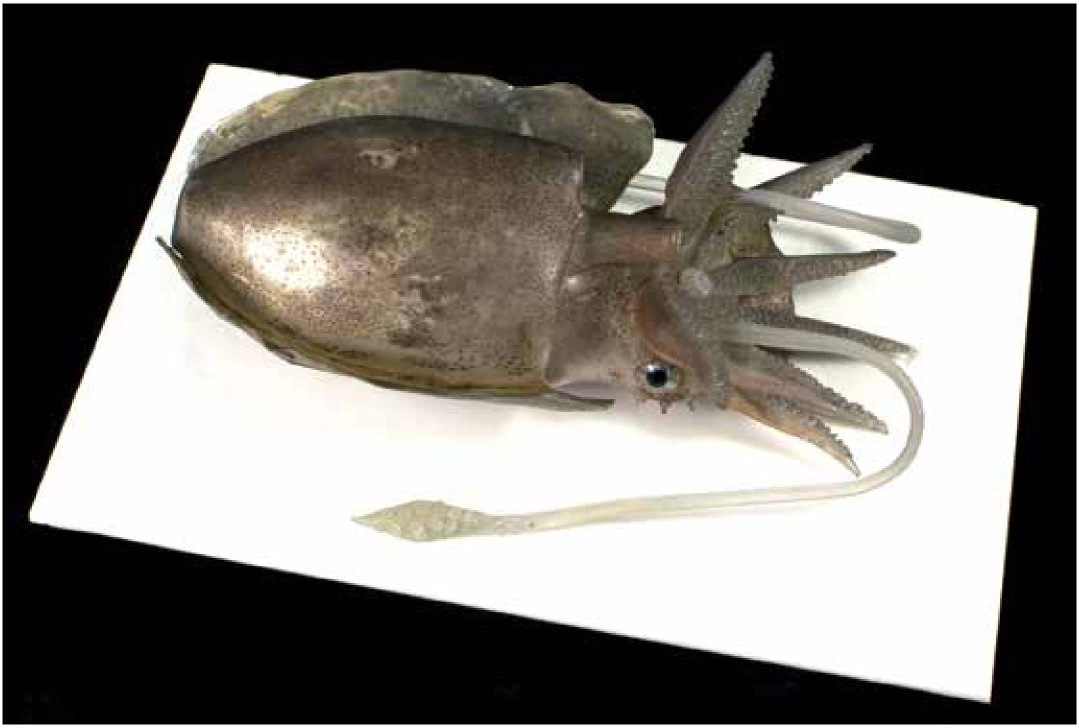
Blaschka Number 550. *Argonauta argo,* males, 2 stages 1884.137.16

Blaschka Number 556. *Histioteuthis bonelliana* 1884.137.39

Blaschka Number 558. *Loligo vulgaris* 1884.137.6



Blaschka Number 583. *Onychoteuthis lichtensteinii* 1884.137.17



Blaschka Number 589. *Sepia officinalis* 1884.137.38

Blaschka Number 592. *Sepiola rondeleti* 1884.137.67

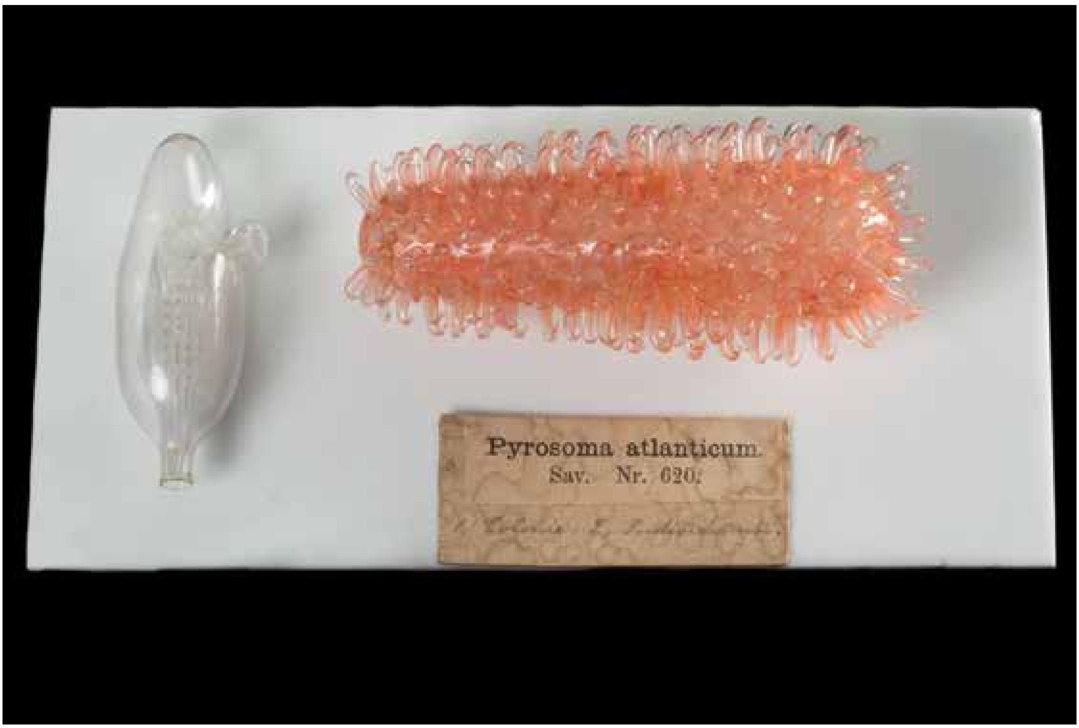
Blaschka Number 599, *Appendicularia flagellum* 1884.137.80

Blaschka Number 602. *Botryllus gemmeus* 1884.137.129

Blaschka Number 609. *Boltenia rubra* 1884.137.85

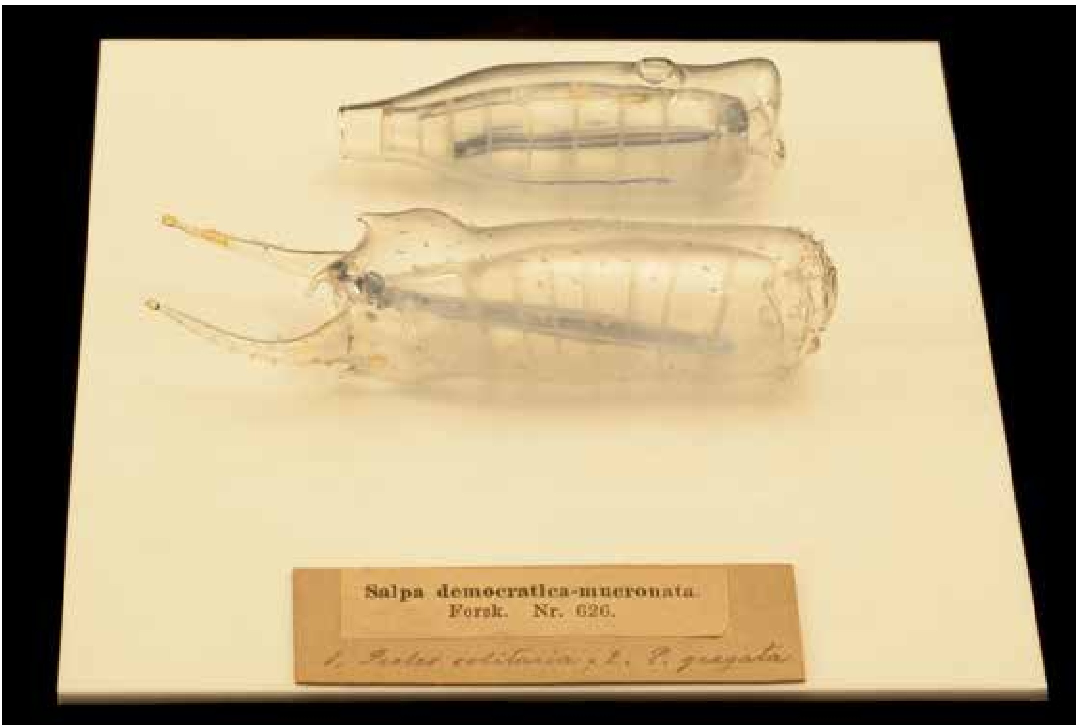
Blaschka Number 613. *Clavellina lepadiformis* 1884.137.119

Blaschka Number 615, *Cynthia pyriformis* 1884.137.4



Blaschka Number 620. *Pyrosoma atlanticum* 1884.137.66

Blaschka Number 621. *Doliolum Ehrenbergii-Troschelii* 1884.137.79



Blaschka Number 626. *Salpa democratica-mucronata* 1884.137.51

Blaschka Number 627, *Salpa pinnata* 1884.137.47

Blaschka Number 618. *Phallusia pustulosa* 1884.137.58