New Results from the Study of Coelenterate Nematocysts

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The early anaphases (figure 5) show the separation of the chromosomes of this heteromorphic pair. When the anaphase chromosomes are seen in polar view (figure 4), they are similarly arranged in the two groups on the same spindle. In one group the large chromosome (*H*) is found in the same relative position as the small one (*h*) in the other group. In the homeotypic division the chromosomes are so closely packed together that it is difficult to make an accurate count, and still more so to make a comparison of relative sizes. The homeotypic division seems to be regular, and typical pollen tetrads are formed. At the time of dispersal the pollen grains appear to be normal.

The observations of unequal homologous chromosomes in plants thus far reported are in dioecious species in which the inequality of the chromosomes of one pair could or might be associated with sexual differentiation. Miss Carothers,[1] however, has found heteromorphic pairs of homologous chromosomes distinct from the sex chromosome in both male and female individuals of several orthoptera.

When it was found that these species of *Buginvillaea* do not produce seeds, an attempt was made to germinate the pollen grains in order to determine the percentage, if any, of viable grains. Pollen from some 200 flowers was placed in sugar solutions of concentrations varying from 2% to 20%. The pollen was examined at the end of 24 hours and again at the end of the second day, and no germination had taken place. The introduction of a portion of the stigma into the drop of sugar solution did not stimulate germination.

[1] Carothers, E. E., *J. Morph.*, **24**, 487–511 (1913); **28**, 445–494 (1916–1917); **35**, 457–474 (1921).

NEW RESULTS FROM THE STUDY OF COELENTERATE NEMATOCYSTS
(Preliminary Note)

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Through the aid of a Fellowship of the *International Education Board* I have been enabled to continue, under favorable conditions and on material of particular interest, my researches on the nematocysts of Coelenterates, which I have already studied for several years. After a study, chiefly physiological, I had recognized the importance and the necessity of a systematic morphological investigation of these organites in the various groups of this phylum; and as this required living material, I particularly appreciated the opportunity of collecting and studying non-European

species also, many of which seemed to be indispensable for forming a general idea of the evolution of these strange structures.

Through this aid I have been able to collect extremely interesting material at widely separated stations: at the *Marine Biological Station* of Nhatrang-Cauda (Oceanographic Service of Fisheries), Annam, French Indo-China (February–May, 1928); at the *Marine Biological Laboratory*, Woods Hole, Mass. (July–September, 1928); at the *Hopkins Marine Station*, Pacific Grove, Cal. (November, 1928–January, 1929); and lastly at the *Bermuda Biological Station for Research* and the *Bermuda Government Aquarium* (January–April, 1929). The material was of particular interest and abundance especially in Indo-China and in Bermuda, owing to the classical wealth and the fascinating variety of the coral reefs. I am greatly indebted to the Directors of these laboratories, Dr. A. Krempf, Prof. M. H. Jacobs, Prof. W. K. Fisher, Prof. E. L. Mark, and Mr. L. L. Mowbray, and their staffs, for their kind hospitality and for the many facilities they let me have, without which this work could not have been done.

During this study 52 species, previously unknown to me, have been investigated, thus raising to 109 the total number of species I have examined. The list of these species, the technique which has been used, and the results obtained, will be fully reported in an extensive monograph now under way. Yet it may be useful to give here a short preliminary account of the main results obtained during this last year, embracing the data establishing some new ideas, but not those which merely confirm observations made previously by other authors.

I. MORPHOLOGY OF THE NEMATOCYST.—As a general result of my observations there have been established nineteen types of nematocysts characterized by the structure of the everted thread. These nineteen types constitute an almost uninterrupted series, ramified in several parallel directions: there are six fundamental types, characterized by the more or less complicated shape of the everted thread, each of which leads, through identical variations in the armature of the thread, to several highly and differently specialized forms. This series shows all the features interpreted as Orthogenesis and Adaptation in the comparative study of the living species, but opens here a problem of particular interest and complexity: this series is not autonomous, but is only part of, though causally connected with, the evolutionary line pursued by the Coelenterates themselves. So that here we have to deal with two independent, but simultaneous, evolutionary lines, showing the same characteristics (orientation, orthogenesis, adaptation), the extent of parallelism between which is to be investigated. The question is still further complicated by the fact that, first, most of the Cnidaria bear simultaneously several types of nematocysts, representing several stages of nematocyst evolution, within the

same animal, and, secondly, that the same animal can bear different cnidoms (1) in the various stages of its life-history. It would be out of place to discuss here all the data connected with this question, but it appears from a study of them that the two evolutionary lines (Coelenterate, nematocyst) are not always parallel, and that in the case of the nematocysts, as in many others, the interpretations of Orthogenesis and Adaptation originate merely from a subjective fallacy.

From a more technical point of view, it has been possible to make a first attempt at a general classification of nematocysts, and to furnish an appropriate terminology; it is believed that this classification and terminology will have the same usefulness in the study of the Cnidaria as have those of the spicules in the study of the Sponges.

II. TAXONOMIC VALUE OF THE NEMATOCYST.—The composition of the cnidom has been established with accuracy for all the collected species. Its taxonomic value, which theoretical considerations permitted one to affirm beforehand, has been corroborated by the facts. In a large number of cases, the nematocysts have allowed me to foretell anatomical or embryological features of the Coelenterate exhibiting them, which subsequently have been confirmed when these features were studied. For instance, it has been possible, through the study of the nematocysts alone, to conclude that the incompletely known *Clava krempfi* Billard (2) is very different from the true *Clava*, and to foretell that its gonozooid must be a free medusa, belonging to the family Pteronemidae. This conclusion has been confirmed (see under VI, c).

In a certain number of cases the relationships thus demonstrated do not agree with the ideas hitherto advocated. Particularly in the classification of the Leptolida, the many resulting contradictions and incompatibilities permitted one to foresee that the characters usually considered important were here of little or no value. The nematocysts, however, always gave precise and concordant indications, which therefore seem to show more adequately the natural relationships of the species.

So far as nematocysts indicate relationships:

(a) The Hydrides are not the simplest, but among the most complicated Hydrozoa; they are closely connected with the Tubularians.

(b) The Calyptoblasts/Leptomedusae are a rather homogeneous group; on the contrary the Gymnoblasts/Anthomedusae include very dissimilar forms, and it will be impossible to maintain this group. To be removed are particularly the (medusae) Pteronemidae, usually budded from *Coryne*-like polyps, and the gen. *Eudendrium*, the relationships of which are, in fact, with the Calyptoblasts.

(c) The Siphonophora include at least two different groups, as already stated by Haeckel on other grounds and in a different interpretation; one group (Siphonantha) is related with the true "Anthomedusae," re-

stricted as stated above, the other (Disconantha) is to be connected rather with the Scyphomedusae.

(d) The Milleporida constitute a homogeneous group, not related to the "Gymnoblasts" s. str., but perhaps to the Pteronemidae.

(e) The Trachylida (Tracho- and Narcomedusidae) constitute a homogeneous, probably primitive, group (3), the affinities of which are doubtful.

(f) The "spirocysts" (4, 5), supposed to be characteristic of all the Anthozoa, are lacking, in fact, in all the Octocorallia; in certain Hexactinidae (*Actinotryx*, *Lebrunia*, *Zoanthus*) a quantitative reduction of these structures (spirocysts) has been observed, going almost as far as their complete disappearance.

(g) The Hexacorallia constitute a well-delimited group, separated from the Actiniaria. The Stichodactylina, considered to be a homogeneous group, include, in fact, two categories of species, one belong to the Hexacorallia, the other to the Actiniaria; an identical conclusion had been reached by Krempf (6) through the study of their anatomical and embryological features.

(h) The gen. *Lebrunia* on the one hand, and the family Sagartiadae on the other, bear each a special kind of nematocyst not found anywhere else.

The observations here recorded have been extended, it is true, to only a very few species, representing a very small part of this large phylum. Yet, they have been so concordant, that it seems worth while to state them, without prejudging, of course, the degree of generality they will be found later to deserve. At best, conclusions of this kind can never be definitive; their purpose can be only to account for the present state of our knowledge, to connect the observed facts, and to prepare the field for further researches.

III. PHYSIOLOGY OF THE NEMATOCYST.—(a) In the large nematocysts with isodiametrical and regularly armed tube, found in the Hexacorallia (see II, g), the capsular content, stained with neutral-red, is soluble in seawater, while in the other kinds of nematocysts it is insoluble. Thus there exists here a relation between the structure of the tube and the physicochemical properties of the capsular content.

(b) However, contrary to what would have been expected according to the theories of Adaptation, there is not always a fixed relation between the structure of the nematocyst and its toxicity: e. g., in the nematocyst of the tentacles of *Physalia arethusa* Brown, well known for their great power of urtication, the armature of spines is almost entirely lacking, and the everted thread is incapable of penetrating into any tissue; the poison must be effective by simple contact. In other cases, strongly armed nematocysts are destitute of any chemical efficiency, and are sometimes located in tissues and organs far away from the surface of the body. In still other

forms of nematocysts, the tube is closed at its tip, or prevented, by accessory structures, from completely everting itself. All these facts are against a too adaptavistic interpretation of these structures and of the enigmatic forces out of which they originated.

(c) The nematocysts found in the mesenteries of *Actinotryx sanctithomae* Duch. & Mich. and of *A. macropapillata n. sp.* (see VI, b) provide a most favorable object for physiological research; their perfectly regular shape is convenient for volumetric measurements; their exceptional size (up to 70 × 250μ, with a thread attaining a length of 6 mm.!) easily permits manipulation of isolated capsules and experimentation with them.

A nematocyst can be isolated in a small drop of water; the thread-eversion can then be produced by pressure on the cover-glass and the everting thread directed in such a way as finally to cause its tip and the final ejaculation of the capsular content to lie outside of the drop; thus it is possible to measure the surface occupied by the capsular content after its spreading out on the slide, and, its volume having been measured previously, to calculate approximately its viscosity and thus the amount of energy necessitated for the eversion of the thread.

(d) It is possible to measure the variations in volume resulting from (or perhaps responsible for) the thread-eversion: the volume of the capsule decreases, but the total volume of the nematocyst (i.e., capsule plus everted tube) increases with the thread-eversion. The length of the capsule decreases twice as much as its width.

IV. DEVELOPMENT OF THE NEMATOCYST.—(a) In a still undetermined species of Siphonophore (collected at Pacific Grove) the development of the nematocyst begins remote from the tentacular knobs, within the manubrium of a peculiar kind of medusozooid, resembling the male gonozooid, which apparently has not yet been described.

(b) In *Tubularia marina* Torrey, contrary to what had been observed in three other species of the same genus (1), the "specific" nematocysts of the adult do not result from the transformation of the "larval" ones.

(c) The polyp of "*Clava*" *Krempfi* Billard bears two categories of nematocysts; only one of them migrates into the medusa (see VI, c), which, in addition, develops a third kind.

V. COMPARATIVE ANATOMY OF THE ANTHOZOA.—The study of the nematocysts shows that the marginal tubercles of *Bunodes* are homologous with the "cnidorrhags" of *Actinia equina* L.; but the wall-tubercles of *Bunodactis* are to be considered merely as ectodermic proliferations, not homologous with the former.

VI. FAUNISTIC NOTES.—(a) Through the study of the cnidom it is possible to separate the sp. *Alcyonium krempfi* Hickson (7) into two forms (varieties[2]).

(b) In Bermuda has been found a new Actinian, belonging to the gen.

Actinotryx, and characterized chiefly by the location and the remarkable size of its disc tubercles.

(c) In Indo-China has been observed the sexual phase of the Gymnoblastic Hydroid *Clava krempfi* Billard (2); it consists in a free medusa belonging to the family Pteronemidae. All other species of this family are known to be budded by *Coryne*-like polyps; therefore a new genus has to be created for this species.

(d) Concerning the parasites of Coelenterates, I have found, in some Indo-Chinese Actinians, an Infusorian, *Foettingeria actiniarum* Caull. & Mesn., observed hitherto only in European seas, and in an Alcyonidian (*Nephthya* spec.), a Microsporidium, which is the first of the Cnidosporidia to be discovered in a Cnidarian.

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AN INTERFEROMETER METHOD OF OBSERVING THE VIBRATIONS OF AN OSCILLATING QUARTZ PLATE

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The work here reported involves a somewhat novel use of the Michelson interferometer in the investigation of the modes of vibration of an oscillating quartz crystal. One interferometer mirror is replaced by the crystal which is so mounted that reflection occurs at the surface to be examined. If parallel fringes are produced as usual by tilting one of the reflecting surfaces, a vibration of the quartz surface will produce a disturbance of the fringe system. The straight fringes are localized; hence from the variation in the appearance of the fringes from point to point, one can draw conclusions as to the corresponding variation of amplitude of vibration of the quartz surface.

The effect of a normal oscillation of a surface element of the plate will be to impart lateral oscillations to the corresponding fringe system. The brightness of the non-oscillating fringes is given by the equation