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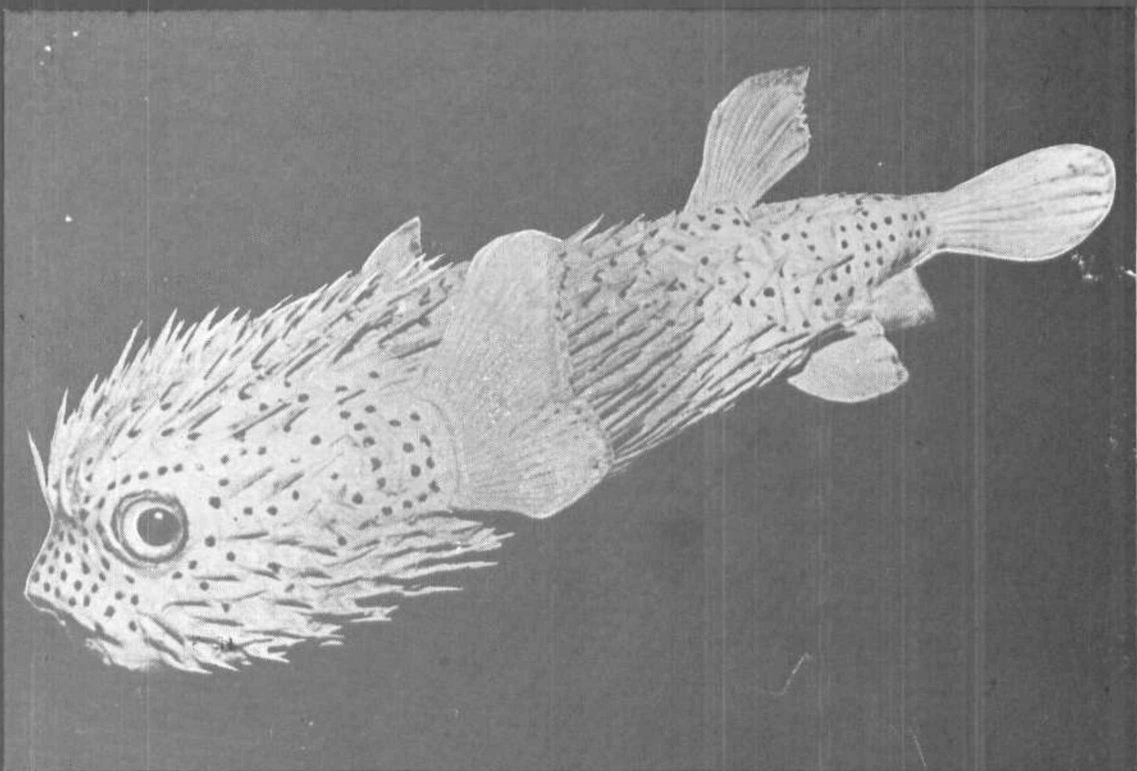

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AN APPRAISAL OF THE BIOLOGICAL AND BIOCHEMICAL DIVERSITY IN SPONGES

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Introduction

The isolation of two unusual nucleosides from the Jamaican sponge *Tethya crypta* (de Laubenfels) by Bergnann and Feeney in 1950 (*J. Amer. Chem. Soc.*, **72**) has stimulated a world wide interest in sponges as a potential source of many new bioactive compounds. These nucleosides which occur free rather than as components of nucleic acids were later named spongouridine (Ara-U) and spongothymidine (Ara-T). Impressed with the clinical possibilities in treating tumours and viral diseases, a lot of interest has been evinced in different parts of the world on the biochemistry of marine organisms in general. These studies have shown that invertebrate animals are not only a rich source of novel chemical structures, but many of these naturally occurring compounds exhibit what is termed biological activity. This area of research has thus proved highly rewarding in several instances, notably in the discovery of prostaglandin precursors in gorgonaceans (Weinheimer and Spraggins, 1969, *Tetrahedron Lett.*, 59) the isomers of which have potential use in the treatment of asthma to cardiovascular diseases, to name a few.

It has been proved through experiments that these novel compounds are used by many animals as a part of chemical defence mechanism since they have no other mechanism to protect themselves from predators, invadors like microorganisms including pathogens or the larvae of foulers, etc. It is indicated in literature that sponges with clean surface exhibit greater antimicrobial activity than those with biofouled surfaces. Ecologically, specimens of *Tethya crypta* grow buried in fine sand with only the oscular complex jutting out of sand. The 'tissue' of sponge especially of the buried part, hence operate anaerobically. If the reason behind the formation of arabinose nucleosides is attributable to this peculiar ecological aspect there is sufficient reason to believe that all sponges (even of different genera) growing in similar ecological conditions should contain arabinose nucleosides or some related compounds. So, on the basis of ecological conditions the chemical compounds used by them may show some affinity and hence a study in this line may prove highly rewarding.

Since various chemicals elaborated by animals have an ecological bearing, sponges from different eco-profiles such as exposed, cryptica, boring, burrowing and also those in relation to various types of symbiotic relationships, have to be dealt with separately for understanding the fundamental mechanism of ecological interactions. Hence, it is hoped that interdisciplinary studies between ecologists and chemists within the frame work based on ecological and evolutionary theories would be more meaningful in the field of Marine Product Chemistry.

Indian sponges - some faunistic considerations

Phylum Porifera (Sponges) is an ancient group with an evolutionary history of about 570 million years and is represented in the extant seas by about 5000 species referable to 790 genera in 80 families. This group is world wide in distribution mostly marine but a few species are seen in freshwater realms world over. In course of this long evolutionary history starting from the Cambrian period, sponges have developed many metabolic, physiological and ecological alternatives within the group (Bergquist, 1978, Sponges).

Eventhough sponges are included under multicellular organisms (metazoa) they are very much different from advanced metazoa and are hence included under a separate subkingdom - the Parazoa. Cell layers are only two for this group and the cells of 'ectosome' and 'endosome' form a loose aggregation and hence cannot be compared to the ectoderm and endoderm seen in advanced metazoans. Individual cells of sponges can be sieved out using bolting silk or fine-meshed cloth and this phenomenon is unique for sponges. Cells thus sieved out when kept in fresh seawter, may aggregate gorming a new individual and this also is specific to sponges. Thomas (1992, CDRI Workshop on the use of chemical techniques for the study of marine products), has given in detail the other physical and physiological peculiarities of sponges.

Though the sponges are classified under 4 classes, species of the Class Demospongiae (or silicious sponges) dominate numerically with about 88.8% of the total. Hence any collector, interested in marine animals may come across Demospongean species in plenty in the nearshore areas of the sea. In places like Maldives or Seychelles Bank, it may be possible to pick up a few massive specimens of the Class Calcarea (or calcareous sponges); but their number is considerably less in the Indian seas (only 14 species). The Class Hexactinellida or glass sponge includes deep water forms and hence getting a massive specimen is only a remote possibility. The Class Sclerospongiae has only limited number of specimens known till date and is not represented in our seas.

A summary of the approximate number of the Indian animal species and its share in the world fauna recently published by the Zoological Survey of India (Jairajpuri, 1991, Z.S.I., Pub.) indicates that the total number of sponge species occurring in India is 519 and this when compared to the world's total forms only 10.1%. Another assessment on the level of our qualitative knowledge on the sponge fauna of the Indian seas recently published by Rao (1990, IGCAR Workshop, Kalpakkam) indicates that only 60% of our fauna is documented till date and hence much more effort has to be put in for getting a complete picture of our sponge fauna. The number of new species and new distributional records that emerge from newly investigated areas indicate that the above claim is only a reasonable one. The same condition prevails with regard to almost all invertebrate groups in our waters. The paucity of active workers in the various fields may be attributed to the present lacuna in our knowledge on the systematics of these groups. Hence some rectifying measures in this regard are necessary before it is too late.

Sponges are distributed from intertidal to hadal depths and form a major component of the benthic community in some places. Though many species of sponges co-exist in their overall range in distribution, the abundance of each species may vary both in time and space. Easy availability of sufficiently larger specimen is possible only along the areas of their optimum growth, while stray occurrence of smaller specimens may be noted along zones of their marginal distribution. Hence a sound knowledge on their availability along the above two zones is a must in formulating any meaningful investigation on a 'particular species and it is possible only through a well planned survey of our coastal realms.

Body form and colour are highly variable even for different specimens of the same species collected from the same area. Hence, general morphology cannot be taken as an identifying character. Spicules, their size, shape, arrangement, etc. are the only dependable characters in identifying the species of sponges.

The ever increasing human activity in recent years has damaged many of our natural ecosystems and their biota considerably. Over exploitation of target species or bycatch for export has degraded or depleted many of our erstwhile rich beds of gorgonids, corals, etc., which are beyond any level of replenishment. In some instances it is even difficult to assess the damage caused to the biota as no assessment, either quantitative or qualitative, is available for the period prior to the commencement of their commercial exploitation or ecosystem damage. This situation further reiterates the need for adequate survey and assessment of our inshore areas.

Adequate knowledge on the natural resources is a prerequsite for the economic and technological development of any country. Since many of the animal groups/species are coming to limelight day by day on account of peculiar chemical compounds elaborated by them, it is necessary to obtain first hand information on their identity, availability, population structure, etc. for their judicious exploitation and utilization. Attempts may be initiated to revamp the lost vigour of our erstwhile rich beds and side by side, efforts may be made in conserving the areas which are not much tampered by human interference.

Sponges - some ecological considerations

Sponges have several physical and physiological peculiarities which are not exhibited by other animal groups and hence they are used extensively in physiological studies. Cellular aggregation and totipotent nature of archaeocytes, peculiar mode of fertilization through carrier cells, presence of 'protonervous system', symbiotic relationship with bacteria, zooxanthellae, zoochlorellae, higher algae, etc. have given an unique position for sponges in the animal kingdom. When scientists from different disciplines started looking at sponges as mighty tools in their areas of research these 'humble' animals have become quite popular, and in India also several Institutions have initiated investigations on sponges especially on the isolation of various chemical compounds and their structural elucidation, synthesis, etc. as major 'thrust areas' in their respective fields.

Boring sponges play a decisive role in the destruction of calcium carbonate skeleton of corals, molluscs, etc. and hence they pose a serious threat to coral reefs and economically important molluscan beds of the Indian seas. Boring sponges (34 species) are wide spread in the Indian seas and hence a study in this line may be taken up on a long term basis. Sponges etch out minute particles (microchips) from the calcium carbonate substrata whether shell or coral, by enzymatic and physical means but the biochemistry involved in this process is poorly documented with reference to many species endemic to Indian seas. Wide spread deterioration of hard coral substrata through the activity of sponges may prove to be a dearer subject to geologists as all the atolls are formed by the activity of corals.

Freshwater sponges might be used as indicators of pollution. By virtue of the restricted physicochemical parameters within which only sponge can normally survive it is obvious that this fixed relationship can be of very useful significance in assessing the physicochemical conditions of the surrounding water and this monitoring value has been clearly revealed in many works (Soota, 1991, *Rec. Zool. Surv. India, Occ. Pap.*, No. 138). The usefulness of marine sponges in this area of research may be explored from some selected centres.

Many sponges grow in association with higher algae, microalgae, bacteria. It is not known whether the chemicals synthesised by sponges are produced by sponge itself, or by the symbionts or through a combined action by both. It can even be related to the dietary habit of the host. This aspect has to be investigated in detail.

Chemical diversity in sponges

Availability of suitable substratum for attachment is an important factor which governs the abundance and distribution of marine sedentary organisms. Having settled comfortably amidst several generations of foulers the sponge larva has to grow to its adulthood. While competing for food it has to protect itself from both predators and other invadors such as algae, larvae of other animals, and in this struggle the various chemicals produced by them become so handy.

Predators are wide spread in the marine environment and they pose a serious threat to the adult sponges which live exposed and are with no mechanism developed for defence. So they resort to overcome this situation by growing in protected areas, growing rapidly, burrowing, boring, developing chemical defence or by entering into symbiotic association with animals and plants. For chemical defence the sponges develop a variety of antibiotic substances, pigments, toxins, antiinflamatory and antiarthritic compounds. Most of these chemicals are either ichthyotoxic or antimicrobial in nature. Many of the compounds known in the past from sponges have great pharmaceutical potentials as they have respiratory, cardiovascular, gastrointestinal, antinflamatory and antibiotic activities. Already three derivatives (Ara-A, Ara-T and Ara-U) of arabinose nucleosides from *Tethya crypta* have been patented as antiviral and anticancer drugs. There is every reason to expect that the next few years will see many more patents on compounds of sponge origin. Systematic screening backed up by synthetic chemistry, pharmacology, microbiological testing and clinical trials has only been applied to marine organisms since the early 1970's and is a long and costly road from active crude extract to nontoxic pure synthesised compound (Bergquist, *Coll. Internat. C.N.R.S.*)

The different chemicals isolated from sponges and their ecological relationships in a few are outlined below:

I. **Sterols:** Amazing structural diversity is seen in sterols of Demospongiae (Silicious sponges). 14 different sterols are known from *Spirastrella inconstans*, a common sponge in our seas.

1. Cholesterol accounts to 82% of the mixture in *Phyllospongia foliascens*.
2. Poriferasterol is common in many species.

3. Chondrillasterol is common in *Chondrilla* spp., but present in many other species also.

4. Strongylosterol is common in *Strongylophora durissima*, a common sponge in the Gulf of Mannar.

II. Compounds with biological activity

A. TERPENOIDS

1. Sesqueterpenes:
   - Picrotin, known from *Spirastrella inconstans* — Ichthyotoxin
   - Picrotinin, known from *S. inconstans* — Ichthyotoxin
2. Furanosesqueterpenes:
   - Herbacin, from *Dysidea herbacea* — Ichthyotoxin
   - Variabilin, from *Ircinia variabilis* — Ichthyotoxin
   - Latrunculin, from *Latrunculia magnifica* - Cytotoxic to epithelial carcinoma of larynx (HEP-2)
3. Norsesterterpenes:
   - Signosceptrellin A, B, C, from *Sigmosceptrella laevis* — Ichthyotoxin
4. Sesterterpenes, from *Heteronema erecta*, *Dysidea herbacea*, *Phyllospongia foliascenes*, *P. dendyi*, *P. radiata*, *Spongia officianalis*, *Cacospongia scalaris* & *C. mollior* — Ichthyotoxin
5. Diterpenes:
   - Spongia compound 1, 5, 7 from *Spongia officinalis* - Antifungal
6. Meroditerpenoids:
   - Strongylophorin 1, 2, 3 from *Strongylophora durissima* - Activity not known

B. BROMOPYRROLE COMPOUNDS

1. Oroidin, from *Agelas oroides* - Activity not known
2. Dibromophakellin, from *Phakellia flabellata* - Activity not known

C. COMPOUNDS DERIVED FROM DIBROMOTYROSINE

1. Aerothionin, from *Verongia aerophoba* — Antibiotic
2. Aeroplysinin, from *Verongia aerophoba* — Antibiotic

D. PRENYLATED BENZOQUINONES

1. Compound - A, from *Ircinia spinulosa* - Confuses the olfactory system in predators

III. Sponge pigments

1. Spongeoporphyrin, from *Cliona* spp. and *Spirastrella* sp. - Royal purple
2. Uranidine, from *Verongia* sp. - Yellow pigment
3. Renieratene, from *Reniera japonica* — Brilliant colour
4. Isorenieratene, from *Reniera japonica* — Brilliant colour

IV. Halogen compounds

1. Bromine and Iodine, from *Chrotella australiensis*, *Axinella* sp., *Spongia officianalis*, *Dysidea fragilis*, *Callyspongia fibrosa*, *Tedania anhelans*, *Phyllospongia foliascens* and *Aurora globostellata*

V. Nucleosides and Nucleic acids

1. Spongouridine, from *Tethya crypta* — Antitumour and antiviral
2. Spongothymidine, from *Tethya crypta* — Antitumour and antiviral
3. Spongosine, from *Tethya crypta* — Antitumour and antiviral

Some sponges with known bioactive properties

Petrosia seriata	Petrosin-A, B	-	Ichthyotoxin
Haliclona pigmentifera	-	-	Diuretic activity
Suberites carnosus	-	-	Spasmogenic
Microciona prolifera	-	-	Antiviral
Tedania ignis	8 fractions	-	All antibiotic
Haliclona viridis	-	-	Bacteriostatic
Toxadocia violacea	-	-	Hypotensive & Paralytic
Halichondria panicea	-		Antimicrobial
Cliona celata	-		Antimicrobial
Oligaceras hemorrhages	-		Antimicrobial
Dysidea etheria	-		Antimicrobial
Haliclona sp., *Agelas* sp. *Axinella* sp., *Verongia* sp. *Homaxinella* sp., *Plakortis* sp. *Callyspongia* sp.			All bacteriostatic
Verongia cauliformis	-		Antibacterial
V. fistularis	-		Antibacterial
Plakortis sp.	-	-	Antiyeast
Dysidea herbacea	-	-	Bacteriostatic

The above list indicates that the various chemical compounds synthesised by sponges help in protecting them from predatory organisms and also from others which might attach to their surface.

For understanding the fundamentals of ecological interaction which are at play in nature a clear picture of chemistry involved is quite essential. This shows that chemists can help the ecologists a lot in interpreting the complicated ecological principles founded on an evolutionary frame work.

Conclusion

Eventhough the origin and biological pathways of many of these diverse compounds elaborated by sponges are not well documented, many of the chemicals isolated till date have definite ecological bearing and hence such studies in future, may be oriented in such a way to link with chemical ecology on one hand and with drug industry on the other. A multidisciplinary approach in this line is the only answer.