MARINE SPONGE SYMBIOSES: DIVERSITY WITHIN DIVERSITY (Poster)
Borowitzka, MA
Algae Research Group, School of Biological Sciences & Biotechnology, Murdoch University, Murdoch, WA 6150. Australia. E-mail: borowitz@possum.murdoch.edu.au.

Sponges are very common and very diverse benthic marine invertebrates throughout the world's oceans. They are also a very popular Phylum for bioprospecting due to the high proportion of novel compounds they produce.

Many marine sponges, especially tropical sponges, contain symbionts including bacteria, cyanobacteria, red algae, green algae, diatoms and dinoflagellates and possibly even fungi (see Table 1). In some cases, the sponge may contain several different types of symbionts at the same time. The biomass of these symbionts can in some cases also equal or exceed the biomass of the sponge tissue, as for example in the symbiosis between Dysidea herbacea and the cyanobacterium Oscillatoria spongeliae or the sponge Haliclona cymiformis and the red alga Ceratodictyon spongiosum. As well as these symbionts, sponges also contain a number of other organisms such as polychaetes in their aquiferous systems. Each sponge can therefore be its own diverse mini-ecosystem.

Table 1. Summary of marine sponge symbionts. Bacterial symbionts, other than cyanobacteria, are not shown as these are almost ubiquitous symbionts of sponges.

<table>
<thead>
<tr>
<th>Symbiont</th>
<th>Location in sponge</th>
<th>Symbiont Taxa</th>
<th>Sponge Taxa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyanobacteria</td>
<td>Mesohyl, archaeocytes or pinacocytes</td>
<td>Oscillatoria, Aphanocapsa, Synechocystis</td>
<td>Dysidea, Verongia, Neofibularia, Jaspis, Theonella</td>
</tr>
<tr>
<td>Rhodophyta</td>
<td>Extracellular</td>
<td>Ceratodictyon, Phyllophora, Thamnoclonium</td>
<td>Haliclona, Gellius</td>
</tr>
<tr>
<td>Chlorophyta</td>
<td>Extracellular, in sponge fibres or in spicules</td>
<td>Cladophoropsis, Ostreobium</td>
<td>Mycale, Tethya</td>
</tr>
<tr>
<td>Dinophyta</td>
<td>Mesohyl</td>
<td>Gymnodinium sp.?</td>
<td>Cliona, Spheciospongia</td>
</tr>
<tr>
<td>Chrysophyta</td>
<td>Mesohyl</td>
<td>Nitzschia</td>
<td>Unidentified</td>
</tr>
</tbody>
</table>

The degree of association between the sponge and its symbionts varies. Most of the available data are limited to ultrastructural studies1-3, and almost nothing is known of the degree of metabolic, biochemical and possibly genetic integration. Structurally the symbionts may be (a) intracellular either in a cell vacuole or in the cytoplasm, (b) intercellular in the sponge mesohyl or (c) extracellular where the sponge grows over the symbiont, often changing the growth form of the symbiont. Such diversity in the structural integration between host and symbiont is not found in any other symbiotic system. It is therefore quite probable that an equivalent diversity exists in the level of metabolic integration between host and symbiont.

One of the difficulties this presents is what to call the organism. Is it really correct to call it a sponge, when much of the biomass may not be sponge? At least one analogous symbiotic system, the lichens, which are a symbiosis between fungi and algae, has its own classification. Do we need a separate classification for these "symbio-sponges"?
Another problem relates to the monitoring and conservation of these organisms. Do we consider those with photosynthetic symbionts as animals or plants? This question is not trivial as our approach to the study of organisms, their biology and ecology, and ultimately their conservation, is often different whether we deal with animals or plants. In our studies of these organisms our thinking at times has been mis-focused (at least temporarily) because we have thought of the sponges as animals. It is important to be aware of the complexity of these organisms when considering their conservation.

The chemistry of sponges reflects both the diversity of this Phylum and probably also the diversity of their symbionts. One of the major questions in sponge chemistry in recent years has been: "What is the role of the various symbionts of sponges in the biochemical diversity of these sponges?" The biosynthetic origin of most "sponge" secondary metabolites is not known, however several recent studies which have shown that at least some of them are synthesised by the sponge symbiont and not the sponge. For example, the bioactive 13-dimethylisodysidenin and the chlorinated dipiperazines of Dysidea herbacea have been shown to be produced by the symbiotic cyanobacterium, Oscillatoria spongiae. Similarly, a fungus associated with the sponge Jaspis sp. has been shown to be the source of the chlorinated metabolites, chloriolin A-C. The situation is even more complex in the sponge Theonella swinhoei which contains both unicellular and filamentous heterotrophic bacteria as well as cyanobacteria. The macrolide, swinholide A, has been found only in the unicellular heterotrophic bacteria and as antifungal cyclic peptide was found only in the filamentous heterotrophic bacteria. The cyanobacteria on the other hand produced no major secondary metabolites. Uriz and coworkers have observed that cytotoxic activity in sponges was correlated with the presence of cyanobacteria. This is not surprising since cyanobacteria have been shown to have a high incidence of cytotoxic compounds. Further research is certain to find that many more "sponge" metabolites are actually produced by the symbionts.

The above serves to demonstrate that diversity exists not only at the community level, but also at the organismal level.

Acknowledgements
Much of our work on sponge/algal symbiosis has been funded by the Australian Research Council. In particular I would like to thank my co-worker, Rosalind Hinde and our research students and Post-Doctoral Fellows: Adrienne Grant, Francoise Pironet, Grant Roberts and Donelle Trautman. Thanks also go to Pat Berquist who first introduced me to the world of sponges.

References