BIOACTIVITIES IN MARINE GENERA
OF ATLANTIC CANADA:
THE UNEXPLORED POTENTIAL

MARK A. RAGAN

Atlantic Research Laboratory
National Research Council of Canada
1411 Oxford Street, Halifax, N.S. B3H 3Z1

One hundred sixty genera of marine algae, invertebrates and tunicates represented in Atlantic Canadian waters are known to contain chemically uncharacterized bioactive metabolites of potential chemotherapeutic or marine-ecological interest. These include antiviral, antifungal, antibacterial, antitumor, cytotoxic, cardiovascular, hormonal, antifeedant, chemoreception, chemotransdunctant, and ichthyotoxic principles.


Introduction

At present marine organisms are being viewed as potential sources of new biologically active (bioactive) products. This interest is based on three areas of research:

Marine pharmacology

Fleming’s discovery of penicillin (1929), and the subsequent successes of screening programs for novel systemic antibiotics in culture media of fungi and actinomycetes, inspired pioneering surveys for antibacterial principles in seaweeds, unicellular algae and marine animals (Pratt et al. 1951; Kamimoto 1955, 1956; Chesters & Stott 1956; Roos 1957; Allen & Dawson 1960; Li 1960; Jørgensen & Steemann Nielsen 1961). Such studies were eventually expanded to encompass more organisms and bioassays, and beginning in the 1960s gave rise to pharmacologically oriented reviews (Der Marderosian 1969a; Grant & Mackie 1977; Kaul 1979), monographs (Baslow 1969; Hashimoto 1979), and symposia (Nigrelli 1960, 1962; Freudenthal 1968; Youngken 1960; Webber & Ruggieri 1976; Kaul & Sindermann 1978; Hoppe et al. 1979; Fuhrman & Jacobs 1981). It is probable that the recent appearance of literature on the traditional medicinal and religious utilization of marine plants and animals by indigenous cultures of China, Japan, southeast Asia, India, Hawaii and elsewhere (Anon. 1978; Diaz-Pifferer 1979; Hoppe 1979; Misra & Sinha 1979; Nisizawa 1979) will stimulate these investigations.

Marine biology and ecology

The production of antibacterial or autoinhibitory substances by phytoplankton has been known since the early days of culture studies (e.g. Waksman et al. 1937; Levring 1945; Harder & Oppermann 1953). A growing awareness that marine organisms face special biological problems (chemoreception, detoxification, predation, fouling, reproduction, nutrition, symbiosis, competition), and the development of

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theories of response and adaptation which emphasize chemical mediators (Nigrelli 1958; Lucas 1961), have promoted ecologically oriented studies of bioactive marine natural products (Green 1977; Herring 1979; Bakus 1981).

**Taxonomy and phylogenetics**

Modern concepts of taxonomy and phylogenetics (Copeland 1938; Whittaker 1969; Ragan & Chapman 1978; Margulis & Schwartz 1982) are placing increasing emphasis on the great phyletic (hence, potentially, chemical: Phinney 1969) diversity of "lower" marine organisms which formerly were considered often as merely underdeveloped members of the two great (and largely terrestrial) kingdoms of Animals and Plants.

These parallel fields have motivated large-scale surveys for bioactive principles in marine organisms. Many diverse and chemically unique natural products exhibiting antiviral, antifungal, antibacterial, antitumor, cytotoxic, cardiovascular and other bioactivities have been characterized (Wright 1984). In addition, there exist numerous reports of biological effects produced by chemically uncharacterized metabolites of marine organisms.

The present paper reviews chemically uncharacterized bioactivities which have been reported in genera of marine organisms represented in Atlantic Canadian waters (Table I). Excluded were prokaryotes, vascular plants (see Harrison 1982), chordates (except tunicates), and complex assemblages of species such as the dinoflagellate-containing sea anemone *Zoanthus* (Welch 1962). The inclusion of phytoplankton genera occurring in the area in question was necessarily complicated by a number of hydrographical, physiological (e.g., salinity tolerance) and taxonomic variables. Therefore, all marine or saline-tolerant phytoplankton genera were included in the compilation, whether or not they have been reported specifically from the northwest Atlantic. Authorities consulted for lists of marine flora and fauna of Atlantic Canada include Lambe (1896), Whiteaves (1901), Taylor (1957), MacFarlane & Milligan (1965), Gosner (1971), Marine Research Associates (1973), South (1976), Caddy et al. (1977), Linkletter et al. (1977), and Wilson et al. (1979). A few important genera of benthic organisms represented in the Gulf of Maine but not reported from Atlantic Canada have also been included.

The bioactivities listed here include a wide range of antibiotic, pharmaceutical, allelopathic and ectocrine activities. All relatively unambiguous examples of hormones, internally active growth- or reproductive regulators, antigens (e.g., Yazykov 1966), vitamins, chelators, general nutrients, odor- or taste-factors, and enzyme activities were excluded. Also excluded, with some reservations, were the numerous cases in which a certain bioactivity has been "explained" by reference to a known compound or group of compounds; in many such instances the cause-and-effect relationship itself and/or the chemical identification of the compound(s) is incomplete or unconvincing. Finally, numerous ecological observations, such as the frequent association of *Polysiphonia lanosa* and *Ascophyllum nodosum*, or species succession in phytoplankton blooms, have been excluded for the most part owing to a lack of sufficiently specific information on the chemical mediators involved. Even after these exclusions, a lengthy list of uncharacterized bioactivities remains, and this undoubtedly represents only a small fraction of the largely untapped potential of marine bioactive compounds.
Table I  Chemically uncharacterized bioactivities in marine organisms belonging to genera represented in Atlantic Canadian waters. Numbers denoting target organisms for antifungal and antibacterial bioactivities refer to species listed in Table II.

**ALGAE**

**CLASS RHODOPHYCEAE**

**SUBCLASS BANGIOPHYCIDAe**

**ORDER PORPHYRIDALES**

- *Goniotrichum* sp.  toxic to mice (Hashimoto et al. 1972)
- *Porphyridium* sp.  antibacterial: 83 (two species) (Berland et al. 1972)

**ORDER BANGIALES**

- *Bangia atropurpurea*  *Ulva* morphogenetic factor (Provasoli & Pintner 1964) (as *B. fuscopurpurea*)
- *Porphyra atropurpurea*  folk medicine: poultices (Hoppe 1979)
- *P. coccinea*  folk medicine: goiter, throat diseases (Schwimmer & Schwimmer 1955)
- *P. columbina*  antibacterial: 5, 12, 27, 32, 37-40, 53, 62, 63, 66, 71 (Maurer 1965); laxative (Hoppe 1979)
- *P. crispata*  folk medicine: “cooling”, “soothing”, clearing the lungs, relieve tension and anxiety, pulmonary and lymphatic tuberculosis, goiter, toothache, high blood pressure, kidney and urinary problems (Anon. 1978)
- *P. dentata*  folk medicine: goiter, coughing, bronchitis, edema, measles (Anon. 1978)
- *P. haitanensis*  folk medicine: “cooling”, “soothing”, clearing the lungs, relieve tension and anxiety, pulmonary and lymphatic tuberculosis, goiter, toothache, high blood pressure, hypertension, kidney and urinary problems, scrofula, tonsillitis, bronchitis, asthma (Anon. 1978; Tseng & Zhang 1984)
- *P. leucosticta*  antibacterial: 71 (Fassina & Berti 1962)
- *P. suborbiculata*  folk medicine: “cooling”, “soothing”, clearing the lungs, relieve tension and anxiety, pulmonary and lymphatic tuberculosis, goiter, toothache, high blood pressure, kidney and urinary problems (Anon. 1978)
P. tenera
antifungal: 1, 2, 4-7, 10, 15, 18, 19, 21, 24, 28, 30, 36, 37, 45 (Sakagami et al. 1982); antibacterial: 5, 6a, 6b, 7, 7a, 12, 27, 31, 32aa, 32b, 48, 51, 53, 60a, 62, 68, 69a, 71 (Aubert et al. 1979; Sakagami et al. 1982); hypocholesterolemic (Tsuchiya 1969; cf. Nisizawa 1979); antioxidants (Fujimoto & Kaneda 1980); antiulcer (Sakagami et al. 1982)

P. umbilicalis
antimitotic: Helianthus assay (Chénieux et al. 1980); antibacterial: 27, 31, 71 (Biard et al. 1980)

Porphyra sp.
influences growth of Melosira moniliformis (Kucherova 1970); settling, attaching, and morphogenetic inducers for Haliotis rufescens (Morse & Morse 1984); folk medicine: goiter, scrofula (Tseng & Zhang 1984)

SUBCLASS FLORIDEOPHYCIDA

ORDER NEMALIALES

Audouinella sp.
Ulva morphogenetic factor (Provasoli & Pintner 1964) (as Rhodochorton sp.)

Bonnemia sonorae
antibacterial: 12, 27, 49, 71, 77 (Hornsey & Hide 1974)

B. hamifera
antibacterial: 12, 27, 49, 71, 77 (Hornsey & Hide 1974)

Gelidiolum amansii
antibacterial: 12, 39 (Kamimoto 1956; Ma & Tang 1984)

G. cartilagineum
antiviral: influenza B, mumps (Gerber et al. 1958)

G. cartilagineum var. robustum
toxic to mice (Habekost et al. 1955)

G. crinale
folk medicine: “cooling” or “soothing”, dysentery, blood platelet diseases (breaking up skin spots) (Anon. 1978)

G. divaricatum
folk medicine: “cooling” or “soothing”, dysentery, blood platelet diseases (breaking up skin spots), stomach ailments, hemorrhoids (Anon. 1978; Tseng & Zhang 1984)

G. filicinum
antibacterial: 5, 12, 27, 32, 37-40, 53, 62, 63, 66, 71 (Maurer 1965)

G. glandularefolium
anti-inflammatory (Baker 1984)

G. lingulatum
antibacterial: 5, 12, 27, 32, 37-39, 53, 62, 63, 66, 70, 71 (Maurer 1965)
**ORDER GIGARTINALES**

**Chondrus crispus**
- antifungal: 14, 47 (Biard et al. 1980); antibacterial: 12, 27, 49, 71, 77 (Hornsey & Hide 1974); folk medicine: "consumption", coughs, diarrhoea, dysentery, gastric ulcer, pulmonary disorders (Schwimmer & Schwimmer 1955; Hoppe 1979); inhibits feeding by Littorina littorea (Geiselman & McConnell 1981); inhibits growth of marine diatoms (Khafji & Boney 1979); weight gain and fertility enhancement in ewes (Brewer et al. 1979).

**Chondrus sp.**
- antibacterial: 27, 63, 71 (Maurer 1965).

**Cystoclonium purpureum**
- antifungal: 14, 47 (Biard et al. 1980); antibacterial: 12, 27, 31, 38, 61, 71 (Biard et al. 1980; Roos 1957 (as C. purpurascens)); antimitotic: Helianthus assay (Chénieux et al. 1980); agglutinin (Shiomi 1983).

**Furcellaria lumbricalis**
- antifungal: 14 (Biard et al. 1980); antibacterial: 31, 61, 71 (Biard et al. 1980), 11 (Chesters & Stott 1956 (as Furcellaria sp.)); antimitotic: Helianthus assay, crown gall assay (Chénieux et al. 1980); cytotoxic: KB (Chénieux et al. 1980); stimulates growth of Skeletonema costatum (Levring 1945) (as F. fastigiata); agglutinin (Shiomi 1983) (as F. fastigiata).

**Gigartina acicularis**
- antimitotic: Helianthus assay (Chénieux et al. 1980).

**G. alveata**

**G. cranwellae**

**G. stellata**
- antifungal: 14, 47 (Biard et al. 1980); antibacterial: 27, 31, 38, 71 (Biard et al. 1980).

**G. teedii**
- agglutinin (Shiomi 1983).

**Gigartina spp.**
- antibacterial: 63, 71 (Maurer 1965).

**Gracilaria bursa-pastoris**

**G. compressa**
- antifungal: 8 (Biard et al. 1980); antibacterial: 38 (Biard et al. 1980); antimitotic: Helianthus assay (Chénieux et al. 1980).

**G. confervoides**
- antibacterial: 63, 71 (Maurer 1965).

**G. constricta**
G. corticata  antibacterial: 8, 71 (Rao & Parekh 1981)

G. eucheumoides  folk medicine: goiter, scrofula, stomach ailments, hemorrhoids (Tseng & Zhang 1984)

G. foliifera  antifungal: 8 (Biard et al. 1980); antibacterial: 31, 38, 61 (Biard et al. 1980); antimitotic: Helianthus assay (Chénieux et al. 1980); produces mitotic anomalies in human synovial (McCoy) cell culture (Starr et al. 1966)

G. lichenoides  antibacterial: 76a, 77 (Reichelt & Borowitzka 1984); activity against Trichomonas foetus (Reichelt & Borowitzka 1984); inotropic (Baker 1984); folk medicine: intestinal and bladder problems (Schwimmer & Schwimmer 1955)

G. verrucosa  antifungal: 1, 2, 4-8, 10, 14, 15, 18, 19, 21, 24, 28, 30, 36, 37, 45, 47 (Sakagami et al. 1982); antibacterial: 5, 6a, 6b, 7, 7a, 12, 27, 31, 32aa, 32b, 48, 49, 51, 53, 60a, 62, 68, 69a, 71, 77 (Hornsey & Hide 1974; Sakagami et al. 1982); Helianthus assay (Chénieux et al. 1980); antilucre (Sakagami et al. 1982); folk medicine: “soothing”, “cooling”, dysentery, urinary problems, dropsy, enteric fever, assist stomach functions, “reinforcing body fluids”, “nourishing the blood”, goiter, scrofula (Anon. 1978; Tseng & Zhang 1984)

Gracilaria sp.  antifungal: 20, 45 (Reichelt & Borowitzka 1984); antibacterial: 71, 76a, 77 (Reichelt & Borowitzka 1984)

Gymnogongrus norvegicus  antimitotic: Helianthus assay (Chénieux et al. 1980)

Phyllophora crispa  antibacterial: 12, 27, 49, 71, 77 (Hornsey & Hide 1974); agglutinin (Shiomi 1983)

P. nervosa  anticoagulant (Hoppe 1979); antilipemic (Hoppe 1979)

P. pseudoceranoides  antibacterial: 12, 27, 49, 71, 77 (Roos 1957; Hornsey & Hide 1974) (as P. membranifolia); agglutinin (Shiomi 1983)

Polyides rotundus  antimitotic: Helianthus assay (Chénieux et al. 1980) (as P. caprinus); agglutinin (Shiomi 1983)

ORDER CRYPTONEMIALES

Corallina chilensis  antibacterial: 27, 63, 71 (Maurer 1965)

C. officinalis  antifungal: 8 (Biard et al. 1980); antibacterial: 8, 27, 31, 38, 71, 77 (Haas 1950; Biard et al. 1980; Rao & Parekh 1981); preferential settlement of Spiorbis larvae (Williams 1964)
C. pilulifera  antibacterial: 12 (Ohta 1979)
C. squamata  antibacterial: 27, 38 (Biard et al., 1980)
Corallina spp.  spasmogenic (Naqvi et al. 1980); folk medicine: burns, chronic gastritis, diarrhoea (Hoppe 1979); oxytocic (Naqvi et al. 1980); toxic to mice (Naqvi et al. 1980); vermicide (Hoppe 1979)
Dilsea carnosa  antifungal: 14 (Biard et al. 1980); antibacterial: 12, 27, 49, 71, 77 (Hornsey & Hide 1974); antimitotic: Helianthus assay (Chénieux et al. 1980)
Dumontia contorta  antimitotic: Helianthus assay (Chénieux et al. 1980); stimulates growth of Skeletonema costatum (Levringer 1945) (as D. incrassata)
Gloiosiphonia capillaris  antibacterial: 12, 27, 49, 71, 77 (Hornsey & Hide 1974)
Lithothamnion californicum  settling, attaching, and morphogenetic inducers for Haliotis rufescens (Morse & Morse 1984)
Jania rubens  hypoglycemic (Hoppe 1979); fibrinolytic (Hoppe 1979); lipolytic (Hoppe 1979) (as Corallina rubens)

ORDER PALMARIALES
Palmaria palmata  antibacterial: 8, 71 (Rao and Parekh 1981); antimitotic: Helianthus assay (Chénieux et al. 1980) (as Rhodymenia palmata); agglutinin (Shiomi 1983)

ORDER RHODYMENIALES
Halosaccion glandiforme²  antibacterial: 27, 53, 71 (Pratt et al. 1951)
Lomentaria articulata  antifungal: 14 (Biard et al. 1980); antibacterial: 27, 31, 71 (Biard et al. 1980); antimitotic: Helianthus assay (Chénieux et al. 1980)
Rhodymenia indica³  vermicide (Hoppe 1979)
R. ordisonei  antiviral: influenza A (Fassina & Berti 1962)
Rhodymenia spp.  antibacterial: 27, 63, 71 (Maurer 1965)
ORDER CERAMIALES

*Antithamnion cruciatum*  
Antibacterial: 12, 27, 49, 71, 77 (Fassina & Berti 1962; Hornsey & Hide 1974)

*A. glanduliferum*  
*Ulva* morphogenetic factor (Provasoli & Pintner 1964)

*A. plumula*  
Antibacterial: 12, 27, 49, 71, 77 (Hornsey & Hide 1974)

*A. sarniense*  
*Ulva* morphogenetic factor (Provasoli & Pintner 1964)

*Callithamnion arbuscula*  
Antibacterial: 12, 27, 49, 71, 77 (Hornsey & Hide 1974)

*C. corymbosum*  
Agglutinin (Shiomi 1983)

*C. tetragonum*  
Antibacterial: 12, 27, 49, 71, 77 (Hornsey & Hide 1974)

*C. tetricum*  
Antifungal: 14 (Biard et al. 1980); Antibacterial: 12, 27, 31, 38, 49, 71, 77 (Hornsey & Hide 1974; Biard et al. 1980); Antimitotic: *Helianthus* assay (Chénieux et al. 1980)

*Callithamnion* sp.  
Influences growth of *Melosira moniliformis* (Kucherova 1970)

*Ceramium acanthonotum*  
Antimitotic: *Helianthus* assay (Chénieux et al. 1980)

*C. boydenii*  
Antibacterial: 37 (Kamimoto 1956); Stimulates growth of bacteria: 36 (Kamimoto 1956)

*C. byssoides*  
Antibacterial: 27, 38, 71 (Burkholder et al. 1960)

*C. ciliatum*  
Antimitotic: *Helianthus* assay (Chénieux et al. 1980)

*C. diaphanum*  
Antibacterial: 12, 71 (Roos 1957)

*C. kondoi*  
Agglutinin (Shiomi 1983)

*C. loureirii*  
Folk medicine: "chest diseases" (Hoppe 1979)

*C. nitens*  
Stimulates growth of fungus: 5 (Welch 1962)

*C. rubrum*  
Antifungal: 8, 14, 47 (Biard et al. 1980); Antibacterial: 12, 27, 31, 38, 71 (Roos 1957; Biard et al. 1980; cf. Ikawa et al. 1973); Stimulates growth of *Skeletonema costatum* (Levrini 1945); Agglutinin (Shiomi 1983)

*Ceramium* sp.  
Hemolytic (Hashimoto et al. 1972); Toxic to mice (Hashimoto et al. 1972)
**Chondria armata**  
antibacterial: 8, 71 (Rao & Parekh 1981); hypotensive (Naqvi et al. 1980); toxic to mice, $LD_{50} = 17.8 \text{ mg kg}^{-1}$ (Naqvi et al. 1980)

**C. coerulescens**  
agglutinin (Shiomi 1983)

**C. dasyphylla**  
antibacterial: 12, 27, 49, 71, 77 (Hornsey & Hide 1974); antimitotic: Helianthus assay (Chénieux et al. 1980); inotropic (Baker 1984)

**C. littoralis**  
antifungal: 8 (Burkholder et al. 1960; Olesen et al. 1964; Hoppe 1979); antibacterial: 27, 38, 71, 83 (four species) (Burkholder et al. 1960; Olesen et al. 1964; Hoppe 1979); antitumor: KB (Martinez Nadal et al. 1965); vermifuge (Michanek 1979)

**C. sanguinea**  
folk medicine: indigestion (Hoppe 1979); anthelmintic (Hoppe 1979; Michanek 1979)

**C. vermicularis**  
folk medicine: indigestion (Hoppe 1979); anthelmintic (Hoppe 1979; Michanek 1979)

**Chondria sp.**  
hemolytic (Hashimoto et al. 1972)

**Dasya baillouviana**  
*Ulva* morphogenetic factor (Provasoli & Pintner 1964) (as *D. pedicellata*)

**Griffithsia flosculosa**  
agglutinin (Shiomi 1983)

**Griffithsia spp.**  
antibacterial: 63 (Maurer 1965); hemolytic (Hashimoto et al. 1972); toxic to mice (Hashimoto et al. 1972)

**Membranoptera alata**  
antifungal: 14 (Biard et al. 1980); antibacterial: 12, 49, 71, 77 (Hornsey & Hide 1974); agglutinin (Shiomi 1983)

**Odonthalia dentata**  
antibacterial: 12, 27, 49, 71, 77 (Hornsey & Hide 1974)

**Phycodrys rubens**  
antibacterial: 12, 71 (Roos 1957); agglutinin (Shiomi 1983)

**P. sinuosa**  
stimulates growth of *Skeletonema costatum* (Levring 1945)

**Plumaria elegans**  
agglutinin (Shiomi 1983)

**Polysiphonia elongata**  
antibacterial: 12, 27, 49, 71, 77 (Roos 1957; Hornsey & Hide 1974)

**P. ferrulacea**  
antibacterial: 71 (Burkholder et al. 1960)

**P. fruticulosa**  
antifungal: 14 (Biard et al. 1980); antibacterial: 31, 38, 61, 71 (Biard et al. 1980); antimitotic: Helianthus assay (Chénieux et al. 1980)
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<th>Species</th>
<th>Activity</th>
<th>References</th>
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<tr>
<td>P. harveyi</td>
<td>increases survival of vorticellids</td>
<td>Langlois 1975</td>
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<td>P. kappanae</td>
<td>antibacterial: 8, 71</td>
<td>Rao &amp; Parekh 1981</td>
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<td>P. lanosa</td>
<td>antibacterial: 12, 27, 49, 71, 77</td>
<td>Hornsey &amp; Hide 1974; Biard et al. 1980; antimitotic: Helianthus assay, crown gall assay (Chénieux et al. 1980); increases survival of vorticellids (Langlois 1975); agglutinin (Shiomi 1983)</td>
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<td>P. nigra</td>
<td>antibacterial: 12, 27, 49, 71, 77</td>
<td>Hornsey &amp; Hide 1974</td>
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<td>P. nigrescens</td>
<td>antibacterial: 12, 27, 49, 71, 77</td>
<td>Hornsey &amp; Hide 1974</td>
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<td>P. subulifera</td>
<td>increases serum lipolytic activity</td>
<td>Hoppe 1979</td>
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<td>P. thuyenoides</td>
<td>antifungal: 8, 14, 47</td>
<td>Biard et al. 1980</td>
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<td>P. urceolata</td>
<td>antibacterial: 12, 27, 49, 71, 77</td>
<td>Hornsey &amp; Hide 1974; Ma &amp; Tang 1984; Ulva morphogenetic factor (Provasoli &amp; Pintner 1964)</td>
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<td>P. violacea</td>
<td>antibacterial: 12, 71</td>
<td>Roos 1957; stimulates growth of Skeletonema costatum (Levring 1945)</td>
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<td>Polysiphonia spp.</td>
<td>antibacterial: 3 (two species), 11, 12, 27, 55, 57, 63, 70, 71, 76a, 77, 84 (two species)</td>
<td>Chesters &amp; Stott 1956; Maurer 1965; Reichelt &amp; Borowitzka 1984</td>
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<td>Ptilota plumosa</td>
<td>agglutinin</td>
<td>Blunden &amp; Rogers 1976; Shiomi 1983</td>
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<td>R. larix</td>
<td>antifungal: 8, 42, 46</td>
<td>Mautner et al. 1953</td>
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<td>R. subfusca</td>
<td>antibacterial: 10, 12 (two strains), 27, 33 (two strains), 37, 67, 70, 71 (twenty-three strains), 80</td>
<td>Roos 1957; stimulates growth of Skeletonema costatum (Levring 1945)</td>
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<td>Spyridia filamentosae</td>
<td>agglutinin</td>
<td>Shiomi 1983</td>
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<td>CLASS PHAEOPHYCEAE</td>
<td>ORDER ECTOCARPALES</td>
<td>抗菌: 12, 49, 71, 77 (Hornsey &amp; Hide 1974); 抗凝血: (Hoppe 1979); 血凝集素 (Shiomi 1983)</td>
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<td>Chordaria flagelliformis</td>
<td>antibacterial: 12, 49, 71, 77 (Hornsey &amp; Hide 1974); 抗凝血: (Hoppe 1979); 血凝集素 (Shiomi 1983)</td>
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<td>Colpomenia sinuosa</td>
<td>antibacterial: 5, 12, 27, 32, 37, 38, 40, 62, 63, 66, 71 (Maurer 1965)</td>
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<td>Dictyosiphon foeniculaceus</td>
<td>血凝集素 (Shiomi 1983)</td>
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<td>Ectocarpus siliculosus</td>
<td>抗菌: 12, 27, 71 (Roos 1957; Fassina &amp; Berti 1962)</td>
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<td>Pilayella littoralis</td>
<td>抗真菌: 47 (Biard et al. 1980); 抗菌: 27, 31, 38, 71 (Biard et al. 1980); 抗丝状核仁的: Helianthus assay (Chénieux et al. 1980); 刺激Skeletonema costatum 的生长 (Levring 1945)</td>
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<td>Ralfsia spongicarpa</td>
<td>抗藻类: Porphyridiscus simulans, Rhodyphysema elegans (Fletcher 1975)</td>
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<td>Scytosiphon lomentaria</td>
<td>抗真菌: 3, 4, 14, 31, 32 (Khalea et al. 1975; Biard et al. 1980); 抗菌: 31, 71 (Biard et al. 1980); 民间医学: 干咳嗽, 喉炎, 淋巴结结核 (Anon. 1978); 抗丝状核仁的: Helianthus assay (Chénieux et al. 1980); 刺激Skeletonema costatum 的生长 (Levring 1945); 减少涡虫的生存 (Langlois 1975)</td>
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<td>Sticteosiphon tortilis</td>
<td>血凝集素 (Shiomi 1983)</td>
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<th>ORDER DESMARESTIALES</th>
<th>Desmarestia aculeata</th>
<th>抗菌: 12, 27, 49, 71, 77 (Roos 1957; Hornsey &amp; Hide 1974); 血凝集素 (Shiomi 1983)</th>
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<td>D. ligulata</td>
<td>抗真菌: 14 (Biard et al. 1980); 抗菌: 12, 27, 49, 71, 77 (Hornsey &amp; Hide 1974); 血凝集素 (Shiomi 1983)</td>
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<td>D. viridis</td>
<td>血凝集素 (Shiomi 1983)</td>
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<th>ORDER LAMINARIALES</th>
<th>Alaria crassifolia</th>
<th>招致毒性 (Shirahama 1937); 混合毒性 (Shirahama 1937)</th>
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<td>A. esculenta</td>
<td>抗菌: 12, 27, 49, 71, 77 (Hornsey &amp; Hide 1974)</td>
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**Chorda filum**

antibacterial: 12, 71 (Roos 1957)

**Laminaria angustata**

antibacterial: 12, 27 (Niszawa 1979); antitumor: sarcoma-180, L-1210 leukemia, Meth-A, B-16 melanoma (Yamamoto et al. 1982)

**L. angustata var. longissima**

antitumor: L-1210 leukemia (Yamamoto et al. 1982)

**L. diabolica**

anticoagulant (Niszawa 1979)

**L. digitata**

antifungal: 14 (Biard et al. 1980), antibacterial: 11, 12, 27, 38, 49, 71, 77, 84 (two spp.) (Chesters & Stott 1956; Roos 1957; Hornsey & Hide 1974; Biard et al. 1980); antimitotic: *Helianthus* assay (Chénieux et al. 1980); stimulates growth of *Skeletonema costatum* (Levrin 1945)

**L. japonica**

antitumor: L-1210 leukemia (Yamamoto et al. 1982); anticoagulant (Niszawa 1979); hypocholesterolemic (Niszawa 1979); enhances activity of pancreatic lipase (Niszawa 1979); stimulates growth of rats (Brekhman 1970); produces resistance in rats to low barometric pressure (Brekhman 1970); folk medicine: normalizing blood pressure, hyperthyroidism, "glandular weakness", "cleaning the blood", producing a "cooling effect", urinary problems, scrofula, stomach ailments, hemorrhoids (Hoppe 1979; Tseng & Zhang 1984), dropsies (Read & How 1927), high blood pressure (Anon. 1978)

**L. japonica var. ochotensis**

antitumor: L-1210 leukemia (Yamamoto et al. 1982); convulsive toxin (Shirahama 1937) (as L. ochotensis)

**L. longipedalis**

anticoagulant (Niszawa 1979)

**L. religiosa**

anticoagulant (Niszawa 1979); folk medicine: menstrual disorders (Read & How 1927); increases action of uterus during labour (Read & How 1927)

**L. saccharina**

antifungal: 8 (Biard et al. 1980); antibacterial: 12, 27, 38, 49, 71, 77 (Roos 1957; Hornsey & Hide 1974; Biard et al. 1980); antimitotic: *Helianthus* assay, crown gall assay (Chénieux et al. 1980); cytotoxic: KB (Chénieux et al. 1980); agglutinin (Shiomi 1983); folk medicine: skin diseases, goiter, syphilis, constipation, arteriosclerosis (Schwimmer & Schwimmer 1955; Hoppe 1979)

**Laminaria spp.**

inhibits viral and bacterial neuraminidases (Kathan 1965); folk medicine: skin diseases (Read & How 1927), high blood pressure and menstrual difficulties (Hoppe 1979)

**Sacchoriza polyschides**

antifungal: 14, 47 (Biard et al. 1980); antibacterial: 27, 31, 38 (Biard et al. 1980); antimitotic: *Helianthus* assay (Chénieux et al. 1980)
ORDER SPHACELARIALES

*Halopteris pseudospicata*  antibacterial: 71, 76a, 77 (Reichelt & Borowitzka 1984)

*H. scoparia*  antifungal: 47 (Chénieux et al. 1980); antibacterial: 27, 31, 38, 71 (Chénieux et al. 1980); antimitotic: *Helianthus* assay (Chénieux et al. 1980)

*Halopteris* sp.  antibacterial: 76a (Reichelt & Borowitzka 1984)

*Sphacelaria* sp.  *Ulva* morphogenetic factor (Provasoli & Pintner 1964)

ORDER FUCALES

*Ascophyllum nodosum*  antibacterial: 5, 15, 27, 31, 33, 51, 53, 65, 71, 77 (Vacca & Walsh 1954; Biard et al. 1980); increases proliferation of soil bacteria (Nisizawa 1979); antimitotic: *Helianthus* assay (Chénieux et al. 1980); folk medicine: obesity, rheumatism, strains (Read & How 1927; Hoppe 1979) and glandular swellings (Read & How 1927); may reduce populations of red spider mites on apple (Booth 1969); various influences on seed germination (Senn & Skelton 1969); stimulates respiration in seeds, fruits and flowers (Senn & Skelton 1969); increases shelf life of peaches from treated trees (Skelton & Senn 1969); increases weight and heart diameter of lettuce, and curd diameter of cauliflower (Abetz & Young 1983); may increase hyoscine content of *Duboisia* hybrid (Luanratana & Griffin 1982); toxic to fish larvae (Sieburth & Jensen 1969; cf. Jensen & Ragan 1978); stimulates growth of *Skeletonema costatum* (Leving 1945); promotes settling of larvae of *Alcyonium polyomum* and *Flustrellidra hispida* (Crisp & Williams 1960); decreases survival of vorticellids (Langlois 1975); retards growth of rabbits (Hashimoto 1979); causes internal bleeding (Hashimoto 1979) and various other effects when fed to domestic animals (e.g. Bogen 1962; Jensen et al. 1968); agglutinin (Shiomi 1983)

*Fucus ceranoides*  agglutinin (Shiomi 1983)

*F. esculentus*  folk medicine: sclerosis, thyroid disturbances (Hoppe 1979)

*F. gardneri*  hypocholesterolemic (Tsuchiya 1969; Hoppe 1979)

*F. helminthocorton*  anthelmintic (Emerson & Taft 1945)
**F. serratus**

antibacterial: 10, 12 (two strains), 27, 33 (two strains), 37, 38, 53, 66, 67 (two spp.), 70, 71 (twenty-four strains), 76, 80, 85 (Roos 1957; Biard et al. 1980); promotes settling of larvae of *Alcyonium polyomum, Flustrellidra hispida* and *Spiroboris borealis* (Crisp & Williams 1960; Williams 1964); agglutinin (Shiomi 1983)

**F. spiralis**

antimitotic: *Helianthus* assay, crown gall assay (Chénieux et al. 1980); cytotoxic: KB (Chénieux et al. 1980); decreases survival of vorticellids (Langlois 1975); agglutinin (Shiomi 1983)

**F. vesiculosus**

antibacterial: 12, 31, 71 (Roos 1957; Biard et al. 1980); antimitotic: *Helianthus* assay (Chénieux et al. 1980); cytotoxic: KB (Chénieux et al. 1980); folk medicine: obesity, goiter, Basedo’s disease, scrofulosis (Hoppe 1979); stimulates growth of *Skeletonema costatum* (Levring 1945); promotes settling of larvae of *Alcyonium polyomum* and *Flustrellidra hispida* (Crisp & Williams 1960); antifeedant for *Littorina littorea* (Geiselman & McConnell 1981); agglutinin (Shiomi 1983)

**F. virgates**

antiviral: influenza A (Fassina & Berti 1962)

**CLASS DINOPHYCEAE**

**ORDER GYMNODINIALES**

**Amphidinium carterae**

antibacterial: 14, 24, 25, 29, 34 (three species), 71, 73, 76a, 77 (Duff et al. 1966; Reichelt & Borowitzka 1984); positively inotropic (Thurberg & Sasner 1973; cf. Hashimoto 1979); inhibits heart muscle activity (Thurberg & Sasner 1973; cf. Hashimoto 1979); toxic to mice and fish (Thurberg & Sasner 1979; Hashimoto 1979)

**Cochlodium sp.**

antibacterial: 86 (Burkholder 1968)

**Gymnodinium alaskensis**

toxic (Kremer 1981)

**G. breve**

neurotoxic (Spiegelstein et al. 1973; Der Marderosian 1979; Kremer 1981); irritant to eyes and throat (Hashimoto 1979); hemolytic (Spiegelstein et al. 1973); blood anticoagulant (Doig & Martin 1973); ichthyotoxic (Hashimoto 1979)

**G. mikimotoi**

toxic (Kremer 1981)

**G. sanguineum**

toxic (Kremer 1981)

**G. veneficum**

neurotoxic (Kremer 1981); ichthyotoxic (Hashimoto 1979)
ORDER NOCTILUCALES

*Noctiluca militaris*  ichthyotoxic (Hashimoto 1979)

ORDER PERIDINIALES

*Coolia monotis* inhibits growth of *Asterionella japonica* (Pincemin 1971)

*Gonyaulax acutinervis* toxic (Nisizawa & Chihara 1979)

*G. digitale* toxic (Kremer 1981)

*G. monilata* toxic (Kremer 1981); ichthyotoxic (Nisizawa & Chihara 1979)

*G. polyedra* toxic (Kremer 1981)

*G. tamarensis* antifungal: 8 (Burkholder et al. 1960); antibacterial: 71 (Burkholder et al. 1960)

*Heteraulacus* sp. antifungal: 8, 12, 33, 39, 45 (Sharma et al. 1968); antibacterial: 86 (Burkholder 1968); ichthyotoxic (Sharma, Michaels & Burkholder 1968) (as *Goniocystis* sp.)

*Protoperidinium polonium* ichthyotoxic (Der Marderosian 1979; Hashimoto 1979); inhibits growth and photosynthesis of algae (Hashimoto 1979) (as *Peridinium polonium*)

*Pyrodinium phoneus* toxic (Nisizawa & Chihara 1979)

*Scrippsiella trochoidea* inhibits growth of *Asterionella japonica* (Pincemin 1971) (as *Peridinium trochoideum*)

CLASS DESMOPHYCEAE

ORDER PROROCENTRALES

*Prorocentrum micans* inhibits growth of diatoms (Uchida 1981); stimulates antibiotic production by diatoms (Gauthier et al. 1978)

*P. minimum* stimulates growth of unidentified marine bacterium (Berland et al. 1972) (as *Exuviaella mariae-lebouriae*)

*Prorocentrum* sp. neurotoxic (Nisizawa & Chihara 1979); toxic to mice (Hashimoto 1979); ichthyotoxic (Hashimoto 1979) (as *Exuviaella* sp.)
CLASS HAPTOPHYCEAE

ORDER ISOCHRYSIDALES

*Emiliana huxleyi*  
antibacterial: 4, 14 (two species), 25 (two species), 29, 34 (three species), 48, 71 (two strains), 73 (Duff et al. 1966) (as *Coccolithus huxleyi*).

*Isochrysis galbana*  
antibacterial: 14 (two species), 25, 29, 34 (three species), 71 (two strains), 73, 75, 77 (Duff et al. 1966).

ORDER PAVLOVALES

*Pavlova lutheri*  
antibacterial: 14 (two species), 25 (two species), 29, 34 (three species), 71 (two strains), 73, 77 (Duff et al. 1966); vitamin $B_{12}$-binding factor (Droop 1968) (as *Monochrysis lutheri*).

ORDER PRYMNESIALES

*Prymnesium parvum*  
antibacterial: 12, 35, 43, 49, 66, 68, 71, 75 (Aubert et al. 1968; Aubert & Pesando 1969); cytotoxic: Ehrlich ascites, HeLa, FL amniotic, Chang liver (Shilo & Rosenberger 1960-1961); hemolytic (Shilo & Rosenberger 1960-1961); ichthyotoxic (Reich & Rotberg 1958; Shilo & Rosenberger 1960-1961; Reich & Parnas 1962); neurotoxic (Chapman 1979; Kremer 1981); toxic to molluscs and tadpoles (Shilo & Rosenberger 1960-1961).

CLASS CHRYSOPHYCEAE

ORDER OCHROMONADALES

*Ochromonas danica*  
ichthyotoxic (Reich & Spiegelstein 1964).

*O. malhamensis*  
antibacterial: 8, 12, 27, 71 (Hansen 1973); ichthyotoxic (Reich & Spiegelstein 1964).

*Olisthodiscus luteus*  
antialgal (Pratt 1966; cf. Tomas 1980); modifies larval development (Sieburth 1968).

ORDER PHAEOPLACALES

*Stichochrysis immobilis*  
antibacterial: 1, 3, 29, 82, 83 (two species) (Berland et al. 1972); enhances growth of bacteria: 59, 83 (Berland et al. 1972).
CLASS CRYPTOPHYCEAE
ORDER CRYPTOMONADALES
Cryptomonas sp. antibacterial: 14 (two species), 25 (two species), 29, 34 (three species) (Duff et al. 1966)

Hemiselmis virescens antibacterial: 14, 24, 25 (two species), 26, 29, 34 (two species), 71 (two strains), 73, 75 (Duff et al. 1966)

Rhodomonas baltica ichthyotoxic (Hashimoto 1979)

R. lens antibacterial: 14 (two species), 27, 29, 34 (two species), 73 (Duff et al. 1966)

CLASS PRASINOPHYCEAE
ORDER PRASINOCLADALES
Tetraselmis maculata antibacterial: 25, 71 (two strains), 73, 75 (Duff et al. 1966)

CLASS CHLOROMONADOPHYCEAE
Chattonella spp. ichthyotoxic (Nisizawa & Chihara 1979)

Heterosigma sp. inhibits growth of Skeletonema costatum (Honjo et al. 1978)

CLASS CHLOROPHYCEAE
ORDER VOLVOCALES
Dunaliella tertiolecta antibacterial: 24, 34, 73 (Duff et al. 1966); antihypertensive, bronchodilator, antiserotonin, antiwritiing, muscle relaxant, postsynaptic blocker, analgesic, antioedema (Baker 1984)

Dunaliella sp. antibacterial: 71 (Accorinti 1964); inhibits growth of Chlorella stigmatophora (Accorinti 1964)

ORDER CHLOROCOCCALES
Chlorella pyrenoidosa antibacterial: 83 (Steemann Nielsen 1955); immunogenic (Bernstein et al. 1969)

C. stigmatophora antibacterial: 71 (Accorinti 1964); enhances growth of Dunaliella sp. (Accorinti 1964)
**C. vulgaris**
- antibacterial: 64, 71 (Jørgensen & Steemann Nielsen 1961; Telitchenko et al. 1962); promotes growth of bacteria: 71 (Jørgensen & Steemann Nielsen 1961); immunogenic (Bernstein et al. 1969); reduces filtering rate of *Daphnia magna* (Ryther 1954)

**Protosiphon botryoides**
- antibacterial: 9, 13, 57, 71 (Harder & Oppermann 1953)

**Scenedesmus basilensis**
- immunogenic (Bernstein et al. 1969)

**S. obliquus**
- antibacterial: 64 (Telitchenko et al. 1962)

**S. quadricauda**
- reduces filtering rate of *Daphnia magna* (Ryther 1954)

**ORDER ULOTRICHALES**

**Monostroma nitidum**
- hypocholesterolemic (Tsuchiya 1969)

**Spongomonera arcta**
- antibacterial: 12, 71 (Roos 1957)

**Stichococcus bacillaris**
- antibacterial: 9, 13, 57, 71 (Harder & Oppermann 1953)

**ORDER ULVALES**

**Enteromorpha**

**chaetomorphoides**
- produces mitotic anomalies in human synovial (McCoy) cell culture (Starr et al. 1966)

**E. clathrata**
- folk medicine: relief from heat (Anon. 1978)

**E. compressa**
- antibacterial: 12, 27, 38, 71 (Roos 1957; Allen & Dawson 1960); hypocholesterolemic (Nisizawa 1979)

**E. flexuosa**
- produces mitotic anomalies in human synovial (McCoy) cell culture (Starr et al. 1966)

**E. hendayensis**
- antibacterial: 38, 71 (Biard et al. 1980); antimitotic: *Helianthus* assay (Chénieux et al. 1980)

**E. intestinalis**
- antifungal: 47 (Biard et al. 1980); antibacterial: 8, 27, 31, 38, 39, 63, 71 (Maurer 1965; Biard et al. 1980; Rao & Parekh 1981; Rao et al. 1982); antimitotic: *Helianthus* assay, crown gall assay (Chénieux et al. 1980); cytotoxic: KB (Chénieux et al. 1980); polysynaptic blocker (Baker 1984); agglutinin (Shiomi 1983); folk medicine: aphthae, back pain, paronychia, lymphatic swellings, goiter (Anon. 1978); stimulates growth of *Skeletonema costatum* (Levring 1945)
E. kylinii antibacterial: 12, 38, 71 (Allen & Dawson 1960)

E. lingulata produces mitotic anomalies in human synovial (McCoy) cell culture (Starr et al. 1966)

E. linza antiviral: influenza A (Fassina & Berti 1962)

E. prolifera antibacterial: 12, 38, 55, 71 (Allen & Dawson 1960; Starr et al. 1962); produces mitotic anomalies in human synovial (McCoy) cell culture (Starr et al. 1966); folk medicine: aphthae, back pain, paronychia, nosebleeds, “sore-hand”, lymphatic swellings, goiter, “cooling”, cough, bronchitis, tonsilitis, asthma (Anon. 1978; Tseng & Zhang 1984); hypocholesterolemic (Tsuchiya 1969)

E. ramulosa antifungal: 14 (Biard et al. 1980); antibacterial: 38, 71 (Biard et al. 1980); antimitotic: Helianthus assay (Chénieux et al. 1980)

Enteromorpha spp. antibacterial: 12, 27, 33, 37, 63, 71 (Katayama 1956-1957a; Roos 1957; Maurer 1965); influences muscle contraction in worms (Katayama 1956-1957c); diuretic (Naqvi et al. 1980); toxic to mice (Naqvi et al. 1980); influences growth of Melosira moniliformis (Kucherova 1970); folk medicine: goiter, scrofula, “cooling”, cough, bronchitis, tonsilitis, asthma, nosebleeds, “sore-hand” (Tseng & Zhang 1984)

Ulva arasakii agglutinin (Shiomi 1983)

U. conglobata agglutinin (Shiomi 1983); folk medicine: sore throat, laryngitis, lymphatic tuberculosis, headaches, halitosis, goiter, “soothing” or “cooling” (Anon. 1978; Tseng & Zhang 1984)

U. fasciata hemolytic (Hashimoto et al. 1972); toxic to mice (Naqvi et al. 1980); folk medicine: sore throat, laryngitis, lymphatic tuberculosis, headaches, halitosis, goiter, “soothing” or “cooling” (Anon. 1978; Tseng & Zhang 1984)

U. lactuca antifungal: 14 (Biard et al. 1980); stimulates growth (5) and sporulation (18) of fungi (Welch 1962); antibacterial: 5, 12, 27, 31, 32, 37-40, 49, 53, 61-63, 66, 70, 71, 77 (Roos 1957; Fassina & Berti 1962; Maurer 1965; Hornsey & Hide 1974; Biard et al. 1980); antimitotic: Helianthus assay, crown gall assay (Chénieux et al. 1980); cytotoxic: KB (Chénieux et al. 1980); vermifuge (Michanek 1979); agglutinin (Shiomi 1983); folk medicine: gout, scrofula, “irritations” (Hoppe 1979), furuncles, sore throat, laryngitis, lymphatic tuberculosis, headaches, halitosis, urinary problems, dropsy, goiter, “soothing” or “cooling” (Anon. 1978; Tseng & Zhang 1984); influences growth of U. lactuca (cited in Levring 1945 and Kucherova 1970)
**U. linza**  antibacterial: 27, 53, 71 (Pratt et al. 1951); folk medicine: heat stroke, goiter (Anon. 1978)

**U. penniformis**  folk medicine: “medicinal preparation” (Hoppe 1979)

**U. pertusa**  antibacterial: 12, 27, 36, 37, 80a (Kamimoto 1956; Nisizawa 1979; Ma & Tang 1984); influences muscle contraction in worms (Katayama 1956-1957c); hemolytic (Hashimoto et al. 1972); hypocholesterolemic (Tsuchiya 1969); anthelmintic (Katayama 1956-1957b); agglutinin (Shiomi 1983); folk medicine: fever (Hoppe 1979), heat stroke, edema, urinary problems, lymphatic swellings, goiter, high blood pressure, dropsy (Anon. 1978; Tseng & Zhang 1984)

**U. reticulata**  hemolytic (Hashimoto et al. 1972)

**U. rigida**  antibacterial: 76a, 77 (Reichelt & Borowitzka 1984)

**Ulva spp.**  vermifuge (Hoppe 1979); stimulates growth of diatoms (Levring 1945)

**ORDER CLADOPODORALES**

**Chaetomorpha antennina**  antifungal: 4, 9, 11, 26, 39 (Rao and Shelat 1982)

**C. brachygonata**  produces mitotic anomalies in human synovial (McCoy) cell culture (Starr et al. 1966)

**C. capillaris**  agglutinin (Shiomi 1983)

**C. linum**  antiviral: TMV (Caccamese et al. 1981); antibacterial: 5, 12, 27, 32, 37, 38, 40, 53, 62, 63, 66, 70, 71 (Maurer 1965)

**C. minima**  ichthyotoxic (Ohta 1979)

**Cladophora glomerata**  folk medicine: burns (Hoppe 1979)

**C. gracilis**  increases survival of vorticellids (Langlois 1975)

**C. monumentalisis**  antibacterial: 71 (Rao & Parekh 1981)

**C. pellucida**  antifungal: 3, 4, 31, 32 (Khaleefa et al. 1975); antibacterial: 12, 49, 71, 77 (Hornsey & Hide 1974)

**C. pinnulata**  toxic to mice, LD$_{50}$ = 8.25 mg·kg$^{-1}$ (Naqvi et al. 1980)

**C. prolifera**  antiviral: influenza A (Fassina & Berti 1962); antibacterial: 71 (Fassina & Berti 1962)
C. rupestris
antibacterial: 31, 38, 71 (Biard et al. 1980); antimitotic: Helianthus assay (Chénieux et al. 1980); cytotoxic: KB (Chénieux et al. 1980); agglutinin (Shiomi 1983)

Cladophora spp.
antiviral: murine meningopneumonitis virus (Starr et al. 1962); antibacterial: 38, 55, 63, 71 (Starr et al. 1962; Maurer 1965); cytotoxic: human synovial (Starr et al. 1962)

Rhizoclonium riparium
antibacterial: 76a (Reichelt & Borowitzka 1984); beta-blocker, 5-hydroxytryptamine blocker (Baker 1984); folk medicine: wounds (Hoppe 1979)

R. rivulare
vermifuge (Hoppe 1979); folk medicine: wounds (Hoppe 1979)

Rhizoclonium sp.
antibacterial: 27, 63, 71 (Maurer 1965)

ORDER CODIALES

Bryopsis hypnoides
agglutinin (Shiomi 1983)

B. pennata
produces mitotic anomalies in human synovial (McCoy) cell culture (Starr et al. 1966)

B. plumosa
antiviral: influenza A (Fassina & Berti 1962); antibacterial: 12, 49, 71, 77 (Fassina & Berti 1962; Hornsey & Hide 1974)

Codium adhaerens
antibacterial: 71, 76a, 77 (Biard et al. 1980; Reichelt & Borowitzka 1984); antimitotic: Helianthus assay (Chénieux et al. 1980); inotropic (Baker 1984); toxic to mice (Hashimoto et al. 1972)

C. coralloides
antiviral: TMV (Caccamese et al. 1981); antifungal: 18a (Caccamese et al. 1981)

C. dimorphum
antibacterial: 5, 27, 32, 37-40, 63, 66, 70, 71 (Maurer 1965)

C. effusum
antiviral: TMV (Caccamese et al. 1981); antifungal: 18a (Caccamese et al. 1981)

C. fragile
antibacterial: 12, 27, 37, 49, 71, 77 (Kamimoto 1956; Hornsey & Hide 1974); stimulates growth of bacteria: 36 (Kamimoto 1956); antimitotic: Helianthus assay (Chénieux et al. 1980); cytotoxic: KB (Chénieux et al. 1980); vermifuge (Tseng & Zhang 1984); folk medicine: urinary problems, dropsy (Tseng & Zhang 1984)

C. fragile subsp. allanticum
agglutinin (Shiomi 1983)

C. fragile subsp. tomentoides
agglutinin (Shiomi 1983)
C. intertextum  antibacterial: 7, 12 (Nuñez & Serpa Sanabria 1975)
C. intricatum  toxic to mice (Hashimoto et al. 1972)
C. isthmocladum  stimulates sporulation of fungi: 3, 18 (Welch 1962); produces mitotic anomalies in human synovial (McCoy) cell culture (Starr et al. 1966); agglutinin (Shiomi 1983)
C. latum  antibacterial: 12 (Ohta 1979); repels snail Monodontia neritoides (Ohta et al. 1978)
C. muelleri  antibacterial: 71, 76a, 77 (Reichelt & Borowitzka 1984); antifungal: 9a (Reichelt & Borowitzka 1984)
C. pugniformis  antitumor: Ehrlich ascites, Ehrlich solid, Sarcoma-180 solid (Nisizawa 1979)
C. spongiosum  antibacterial: 27, 71, 76a, 77 (Reichelt & Borowitzka 1984)
C. tomentosum  antibacterial: 12, 27, 49, 71, 77 (Hornsey & Hide 1974)
C. vermicaria  antimitotic: Helianthus assay (Chénieux et al. 1980)
Codium spp.  vermifuge, especially vs. Ascaris lumbricoides (Hoppe 1979); influences muscle contraction in worms (Katayama 1956-1957c)

CLASS BACILLARIOPHYCEAE
SUBCLASS PENNATOPHYCEIDAE
ORDER DIATOMALES
Asterionella japonica  antifungal: 14 (Pesando et al. 1979b); antibacterial: 12, 17-23, 43, 47, 66, 71, 72, 75, 81, 87 (eight species) (Aubert et al. 1968, 1979; Aubert & Pesando 1969; Gauthier et al. 1978)
A. notata  antifungal: 2, 8, 14, 21, 33 (three species), 39, 43, 45, 49 (three species), 50 (six species) (Gauthier 1969; Pesando et al. 1979a,b); antibacterial: 6, 16, 27 (three strains), 30, 31, 41-45, 49-53, 60, 64, 66, 68, 69, 71 (three strains), 72, 75, 83 (seven species, Gram-negative) (Aubert & Pesando 1969; Gauthier 1969); inhibitory to phytoplankton: Asterionella japonica, A. notata, Coccolithus elebens, Nitzschia sciscularis, Phaeodactylum tricornutum, Tetraselmis maculata, T. striata, T. tetraphle (Gauthier 1969)
Fragilaria pinnata  antifungal: 8, 14, 21, 43, 45 (Pesando et al. 1979b)
F. striatula possible cause of contact dermatitis (Fraser & Lyell 1963; cf. Carlé & Christophersen 1980)
Licmophora abbreviata antibacterial: 43, 66, 71 (Aubert et al. 1968)
Thalassionema nitzschioides influences growth of T. nitzschioides (Kustenko 1975)
Thalassiothrix frauenfeldi antibacterial: 43, 66, 71 (Aubert et al. 1968)
T. nordenskioldii antibacterial: 66 (Sieburth 1965)

ORDER NAVICULALES

Bacillaria paradoxa antibacterial: 43 (Aubert et al. 1968)
Gyrosigma fasciola antifungal: 14 (Pesando et al. 1979b)
G. spenceri antibacterial: 43, 66, 71 (Aubert et al. 1968)
Navicula incerta antibacterial: 88 (Aubert et al. 1979)
N. gregilli inhibition or enhancement of growth of algal germlings and sporelings (Huang and Boney 1983); production of morphological abnormalities in sporelings of Ulva lactuca and Gigartina stellata (Huang & Boney 1983)
N. pelliculosa reduces filtering rate of Daphnia magna (Ryther 1954)
Navicula sp. antibacterial: 71, 76a, 77 (Reichelt & Borowitzka 1984)
Nitzschia ascicularis antibacterial: 43, 66, 71 (Aubert et al. 1968)
N. longissima var. closterium antibacterial: 43, 66, 71 (Aubert et al. 1968)
N. palea antimitotic, autotoxic (Harder & Oppermann 1953)
N. seriata antibacterial: 43, 66, 71 (Aubert et al. 1968)
Nitzschia sp. growth inhibitor, autotoxic (Badour & Gergis 1965)
Phaeodactylum tricornutum antibacterial: 14 (two species), 25 (two species), 26, 29, 34 (three species), 75 (Duff et al. 1966); enhances growth of bacteria: 2, 28, 74, 82, 83 (two species) (Berland et al. 1972); antialgal: Thalassiosira pseudonana (Sharp et al. 1979)
Mixed culture of diatoms, including *Achnanthes longipes*, *Cocconeis scutellum*, *Grammatophora marina*, *Licmophora abbreviata*, *Navicula sp.*, *Nitzschia sp.*, and *Rhabdonema adriaticum*

**SUBCLASS CENTROPHYCIDEAE**

**ORDER BIDDULPHIALES**

*Chaetoceros affinis*  
antibacterial: 3, 29 (Berland et al. 1972); enhances growth of bacteria: 1, 2, 28, 56, 58, 78, 82, 83 (Berland et al. 1972)

*C. lauderi*  
antifungal: 2, 14, 21, 43, 45 (Pesando et al. 1979b); antibacterial: 71, 72 (Gauthier et al. 1978; Pesando et al. 1979a)

*C. peruvianus*  
antibacterial: 43, 66, 71 (Aubert et al. 1968)

*C. pseudocurvisetus*  
antifungal: 14, 21, 45 (Pesando et al. 1979b)

*C. socialis*  
antifungal: 14, 21, 45 (Pesando et al. 1979b); antibacterial: 71 (Aubert et al. 1968)

*C. teres*  
antibacterial: 12, 43, 49-51, 66, 69, 71 (Aubert et al. 1968; Aubert & Pesando 1969)

**ORDER COSCINODISCACEAE**

*Cyclotella nana*  
antibacterial: 5, 14, 25, 27, 34, 48, 64, 71 (two strains), 73 (Duff et al. 1966)

*Skeletonema costatum*  
antifungal: 14 (Pesando et al. 1979b); antibacterial: 3, 14 (two species), 25 (two species), 27, 29 (two species), 34 (three spp.), 37, 66, 71 (three species), 73, 75, 77, 80a, 83 (three species) (Sieburth & Pratt 1961-1962; Sieburth 1965, 1968a; Duff et al. 1966; Aubert et al. 1968; Bell et al. 1974); influences growth of *S. costatum* (Kustenko 1975)

*Thalassiosira decipiens*  
antibacterial: 71 (Aubert et al. 1968)

*Thalassiosira sp.*  
antifungal: 14 (Pesando et al. 1979b)
ORDER RHIZOSOLENIALES

*Bacteriastrem elegans*  antibacterial: 66, 71 (Aubert et al. 1968)

*Dentonula confervacea*  antibacterial: 46, 66 (Sieburth 1965)

*Lithodesmium undulatum*  antibacterial: 66, 71 (Aubert et al. 1968)

*Rhizosolenia alata*  antibacterial: 43 (Aubert et al. 1968)

INVERTEBRATES

PHYLUM PORIFERA

CLASS CALCAREA

*Scypha sp.*  ichthyotoxic (Green 1977)

CLASS DESMOSPONGIAE

ORDER HAPLOSCLERIDA

*Haliclona coerulescens*  cardiotoxic (Kaul et al. 1977); depresses blood pressure (Kaul et al. 1977)

*H. doria*  ichthyotoxic (Green 1977)

*H. erina*  cytotoxic: KB (Stempien et al. 1970); positively inotropie (Kaul et al. 1977); ichthyotoxic (Stempien et al. 1970); causes clumping of sea urchin eggs (Stempien et al. 1970)

*H. hogarthi*  cardioactive (Kaul et al. 1977)

*H. longleyi*  positively inotropic (Kaul et al. 1977); depresses blood pressure (Kaul et al. 1977)

*H. magnicanulosa*  hypotensive (Baslow & Read 1968)

*H. permallis*  positively inotropic (Kaul et al. 1977)

*H. rosea*  antibacterial: 27 (Nigrelli et al. 1967)

*H. rubens*  cytotoxic: KB (Stempien et al. 1970); cardiotoxic (Kaul et al. 1977); depresses blood pressure (Kaul et al. 1977); depolarizes muscle (Wang et al. 1973); ichthyotoxic (Stempien et al. 1970; Green 1977); causes clumping and parthenogenic development of sea urchin eggs (Stempien et al. 1970)
**H. subtriangularis**
antitumor: PS (Sigel et al. 1970)

**H. variabilis**
cellular aggregation factor (Der Marderosian 1968)

**H. viridis**
antifungal: 8 (Nigrelli et al. 1967); antibacterial: 5, 27, 40, 59, 71 (Nigrelli et al. 1967; Baslow & Read 1968); antitumor: Ehrlich ascites (Li et al. 1974); toxic to Paramecium, sea urchin larvae, amphibia, fish, mice and other vertebrates (Jakowsk & Nigrelli 1960-1961; Baslow & Read 1968; Green 1977); hypotensive (Baslow & Read 1968); causes developmental abnormalities in sea urchin eggs (Stempien et al. 1970)

**H. viscosa**
antibacterial: 27 (Nigrelli et al. 1967)

**Haliclona spp.**
antibacterial: 12, 27 (Nigrelli et al. 1967; Nemanich et al. 1978); antitumor: Walker 256 (Burkholder & Sharma 1969); cytotoxic: KB (Nemanich et al. 1978); ichthyotoxic (Stempien et al. 1970; Green 1977; Bakus 1981)

**ORDER POECilosclERIDA**

**Microciona parthena**
ichthyotoxic (Green 1977)

**M. prolifera**

**Mycale angulosa**
positively inotopic (Kaul et al. 1977); depresses blood pressure (Kaul et al. 1977)

**M. laevis**
causes developmental abnormalities in sea urchin eggs (Stempien et al. 1970)

**M. lingua**
ichthyotoxic (Green 1977)

**M. microstigmatosa**
antitumor: Walker M (Burkholder & Sharma 1969)

**Mycale sp.**
ichthyotoxic (Green 1977)

**ORDER HALICHONDRIIDA**

**Halichondria melanaduca**
antibacterial: 27 (Stempien et al. 1970); positively inotopic and positively chronotropic (Kaul et al. 1977)
**H. panicea**  
antibacterial: 27, 89 (Jakowska & Nigrelli 1960-1961); ichthyotoxic (Green 1977)

**Halichondria sp.**  
cytotoxic: KB (Nemanich et al. 1978); ichthyotoxic (Green 1977)

**Pellina carbonaria**  
antifungal: 8 (Sharma, Vig & Burkholder 1968); cytotoxic: KB (Stempien et al. 1970); causes cytoplasmic abnormalities in KB tumor cells (Stempien et al. 1970)

**P. coela**  
cardiotoxic (Kaul et al. 1977)

**ORDER AXINELLIDA**

**Phakellia flabellata**  
antibacterial (Sharma, Vig & Burkholder, 1968)

**P. ventilabrum**  
antibacterial: 32a, 72 (Amade et al. 1982)

**ORDER HADROMEDA**

**Cliona caribboea**  
positively inotropic (Kaul et al. 1977); modifies coronary flow and blood pressure (Kaul et al. 1977)

**C. celata**  
antifungal: 8, 45 (Jakowska & Nigrelli 1960-1961; Amade et al. 1982); antibacterial: 27, 89 (Burkholder 1968); causes developmental anomalies in sea urchin eggs (Ruggieri et al. 1961)

**Suberites anastomosus**  
positively inotropic (Kaul et al. 1977)

**S. domunculus**  
toxic to dogs and rabbits (Hashimoto 1979); respiratory system, cardiovascular system and local activities (Der Marderosian 1969a)

**S. inconstans**  
causes itching and swelling in humans (Hashimoto 1979)

**PHYLUM CNIDARIA (COELENTERATA)**

**CLASS HYDROZOA**

**ORDER THECATA**

**Halecium beani**  
cardioactive (Kaul et al. 1977)
ORDER SIPHONOPHORA

*Physalia physalis*  
venom: dermonecrotic, cardiotoxic, neurotoxic, musculotoxic to clam, fish, frog, mouse, rat, dog and man (Burnett & Calton 1977); depolarizes cell membranes (Hashimoto 1979); impedes binding of Ca$^{2+}$ to muscle (Calton et al. 1973; Hashimoto 1979); folk medicine: ailments of blood vessels, nerves and muscles (Anon. 1978)

CLASS SCYPHOZOA

*Aurelia aurita*  
folk medicine: ailments of central nervous system (Anon. 1978)

*A. labiata*  
antitumor: Ehrlich ascites, PS (Sigel et al. 1970; Tabrah et al. 1972)

*Cyanea capillata*  
histamine-releasing factor (Uvnäs 1960-1961); dermonecrotic, cardiotoxic, vasoconstrictive, spasmogenic to mouse, rat, guinea pig, rabbit, man (Walker 1977)

CLASS ANTHOZOA

ORDER ZOANTHIDEA

*Epizoanthus* sp.  
cytotoxic: KB (Nemanich et al. 1978)

ORDER ACTINIARIA

*Metridium senile*  
positively inotropic, positively chronotropic (Shibata et al. 1974); toxic to crayfish and barnacles (Hashimoto 1979)

*Tealia coriacea*  
positively inotropic (Shibata et al. 1974)

*T. felina*  
cytolytic toxin (Alsen 1983)

*T. lofotensis*  
positively inotropic (Shibata et al. 1974); cytolytic toxin (Alsen 1983)

PHYLUM ECTOPROCTA (BRYOZOA)

ORDER CHEILOSTOMA

*Bugula nerita*  
antitumor: PS lymphocytic leukemia (Pettit et al. 1970)
PHYLUM CTENOPHORA
Bolinopsis infundibulum inhibits murine erythrocyte proliferation in vivo (Premuzic et al. 1976)

PHYLUM MOLLUSCA
CLASS GASTROPODA
ORDER MESOGASTROPODA
Littorina ziczac positively inotropic (Kaul et al. 1977); decreases coronary flow (Kaul et al. 1977)

ORDER NEOGASTROPODA (STENOGLOSSA)
Buccinum undatum cardiotonic (Emerson & Taft 1945); toxic to man (Hashimoto 1979); anemone attachment factor (McCauley 1969)

ORDER NUDIBRANCHIA
Aeolidia papillosa predation signal (McCauley 1969)

CLASS BIVALVIA (PELECYPODA)
ORDER PTEROCONCHIDA
Crassostrea angulata antiviral: TMV (Limasset 1961)
Crassostrea spp. and/or Ostrea spp. antiviral: poliovirus (types I, II, III), influenza B (Li et al. 1961-1962); antibacterial: 71, 77 (Li 1960; Li et al. 1961-1962); can be toxic to humans (venerupin toxin) (Hashimoto 1979)
Mytilus edulis var. galloprovincialis antiviral: TMV (Limasset 1961)
M. viridis folk medicine: intestinal or uterine bleeding, dizziness, blurred vision, impotence, premature ejaculation, hypertension, high blood pressure (Anon. 1978)
Ostrea denselamellosa folk medicine: tranquilizing, neuroses, high blood pressure, promote salivation, stop coughing, lymphatic tuberculosis, stomach ache, stomach acidity and inflammation, night sweat, anal prolapse, diarrhoea, seminal emission, kidney problems, scarlet fever, inflammations, tuberculosis, osteomalacia, erysipelas (Anon. 1978)
O. gigas
O. rivularis
**O. spreta**
antitumor: PS (Sigel et al. 1970)

**O. virginica**
antibacterial: 71 (Li 1960); antitumor: Sarcoma-180 (Schmeer & Huala 1965); spawning promoter, filtering promoter (Emerson & Taft 1945)

**ORDER HETERODONTIDA**

**Mercenaria campechiensis**
antitumor: Krebs-2 (Schmeer & Beery 1965)

**M. mercenaria**
antiviral: Rous sarcoma, Moloney, Friend (Li et al. 1974); antibacterial: 71 (Li 1960); antitumor: Sarcoma-180, Krebs-2, Rous sarcoma, L1210 (Schmeer et al. 1966; Li et al. 1974); inhibits murine erythrocyte proliferation in vivo (Premuzic et al. 1976); chemical defensive cue vis-à-vis starfish (Doering 1982); inhibits growth of larvae of Crassostrea virginica, *M. mercenaria*, Spisula solidissima (Premuzic et al. 1976)

**Mercenaria sp.**
antiviral: herpes simplex, adenovirus-12 (Li et al. 1965)

**Spisula solidissima**
inhibits murine erythrocyte proliferation in vivo (Premuzic et al. 1976)

**CLASS CEPHALOPODA**

**ORDER TEUTHIDIDA (TEUTOIDEA)**

**Loligo sp.**
antitumor: Sarcoma-180 (Schmeer & Huala 1965)

**ORDER OCTOPODIDA (OCTOPODA)**

**Octopus dofleini**
toxic to crayfish (Hashimoto 1979)

**O. macropus**
toxic to crustaceans (Hashimoto 1979)

**0. maurus**
toxic to man (Der Marderosian 1969b)

**O. ochellatus**
folk medicine: stimulate maternal milk production, treat malaria (Anon. 1978)

**O. vulgaris**
cardiotoxic (Emerson & Taft 1945); toxic to crustaceans (Hashimoto 1979); folk medicine: stimulate maternal milk production, treat malaria (Anon. 1978)
PHYLUM ENTPROCTA

*Pedicellina* sp.

antibacterial: 12, 27 (Nemanich et al. 1978); cytotoxic: KB (Nemanich et al. 1978)

PHYLUM ANNELEIDA

ORDER TEREPELLIDA

*Pectinaria australis*

chemoattractant (McCaughey 1969)

PHYLUM ARTHROPODA

CLASS CRUSTACEA

SUBCLASS CIRRIPIEDIA

*Balanus balanoides*

hatching promoter (Crisp 1956)

*B. eburneus*

antitumor: PS (Sigel et al. 1970)

SUBCLASS MALACOSTRACA

*Cancer borealis*

cardioacceleration (Belamarich 1963); neurotransmission blockers (Kravitz et al. 1963)

*C. irroratus*

cardioacceleration (Belamarich 1963)

*Carcinus maenas*

antiviral: TMV (Limasset 1961); cardioacceleration (Kerkut & Price 1964)

*Homarus americanus*

neurotransmission blockers (Kravitz et al. 1963); inhibits murine erythrocyte proliferation in vivo (Premuzic et al. 1976)

PHYLUM ECHINODERMATA

CLASS HOLOTHUROIDEA

ORDER DENDROCHIROTIDA

*Cucumaria echinata*

ichthyotoxic (Yamanouchi 1955)

*C. japonica*

ichthyotoxic (Yamanouchi 1955)
C. miniata  
antifungal: 8 (Constantine et al. 1975); antibacterial: 71 (Constantine et al. 1975)

Cucumaria spp.  
antifungal: 27, 39 (Nemanich et al. 1978); cytotoxic: KB (Nemanich et al. 1978); ichthyotoxic (Yamanouchi 1955)

Pentacta australis  
ichthyotoxic (Yamanouchi 1955)

ORDER APODIDA

Leptosynapta ooplax  
ichthyotoxic (Yamanouchi 1955)

ORDER MOLPADIIIDA

Caudina chilensis  
ichthyotoxic (Yamanouchi 1955)

CLASS ECHINOIDEA

ORDER ECHINOIDA

Strongylocentrotus dröbachiensis  
toxins (cited in Frey 1951)

Strongylocentrotus sp.  
cardioactive (Kaul et al. 1977)

CLASS STELLEROIDEA

ORDER PAXILLOSIDA

Leptychaster sp.  
cytotoxic: KB (Kaul et al. 1977)

ORDER VALVATIDA

Hippasteria spinosa  
antifungal: 45 (Constantine et al. 1975); antibacterial: 71 (Constantine et al. 1975); predation signal (McCauley 1969)

H. phrygiana  
predation signal (McCauley 1969)

Mediaster aequalis  
antifungal: 8 (Constantine et al. 1975); antibacterial: 27, 71 (Constantine et al. 1975); cytotoxic: KB (Nemanich et al. 1978)
ORDER SPINULOSIDA

*Henricia leviuscula*  cytotoxic: KB (Nemanich et al. 1978)
*H. sanguinolenta*  muscle contractant (McCauley 1969)
*Solaster papossus*  predation signal (McCaucey 1969)

ORDER FORCIPULATIDA

*Asterias amurensis*  toxic to fish, insects, earthworms (Yasumoto et al. 1964; Yasumoto & Hashimoto 1965; Hashimoto 1979); hemolytic (Hashimoto 1979); vomitory in cats (Yasumoto et al. 1964; Hashimoto 1979)
*A. forbesi*  antiviral: influenza (Shimizu 1971); toxic to marine echinoderms and annelid (Chaet 1962); inhibits murine erythrocyte proliferation *in vivo* (Premuzic et al. 1976); delayed hypersensitivity (Li et al. 1974); macrophage inhibition (Li et al. 1974); induces autonomy in starfish (Chaet 1962); chemical signal to clams (Doering 1982)
*A. pectinifera*  antiviral: influenza (Shimizu 1971); hemolytic (Yasumoto et al. 1966)
*A. rollestoni*  cardiotoxic (Emerson & Taft 1945)
*A. rubens*  muscle contractant (McCaucey 1969); chemical signal (McCaucey 1969)
*A. vulgaris*  cytolytic (Owelen et al. 1973)

VERTEBRATES (tunicates only)

PHYLUM CHORDATA

ORDER PLEUROGONA

*Molgula manhattensis*  inhibits murine erythrocyte proliferation *in vivo* (Premuzic et al. 1976)
*M. occidentalis*  antitumor: PS lymphocytic leukemia (Pettit et al. 1970)

ORDER ENTEROGONA

*Ascidia mantula*  antitumor: L1210, YC 8 MF 2S (Guyot & Morel 1978)
*Ciona intestinalis*  oxytocic, pressor and melanophore-dilating activities (Emerson & Taft 1945)
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<tr>
<td>Prorocentrum</td>
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</tr>
<tr>
<td>Protopereidinum</td>
<td>97</td>
<td>Ulva</td>
<td>101</td>
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</table>

**Notes:**

1. Despite one report, the occurrence of *Gelidium* in Atlantic Canada is doubtful.
2. *Halosaccion ramentaceum*, occurring in Atlantic Canada, has now been referred to *Devaleraea*, while *H. glandiforme* remains in *Halosaccion*.
3. *Rhodymenia palmata*, occurring in Atlantic Canada, has now been referred to *Palmaria*; *Rhodymenia*, in the current sense, may occur no closer than Massachusetts.
4. *P. sinusosa* may be identical with *P. rubens*.
5. *P. thuyoides* may be referable to the genus *Pterosiphonia*, which is not known from Atlantic Canada.
6. Chlorococcales are typically fresh-water, but many strains are halotolerant.
7. Fresh-water species.
8. *Codium* spp., although not reported from Atlantic Canadian waters, have now been reported in the Gulf of Maine.
10. *Ostrea* has recently been introduced for aquaculture.
### Table II  Target organisms for antifungal and antibacterial bioactivities (numbers refer to Table I)

<table>
<thead>
<tr>
<th>Fungi:</th>
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<tbody>
<tr>
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<tr>
<td>3</td>
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<tr>
<td>4</td>
<td>Aspergillus niger</td>
</tr>
<tr>
<td>5</td>
<td>Aspergillus oryzae</td>
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<tr>
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<tr>
<td>7</td>
<td>Aspergillus sydowii</td>
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<tr>
<td>8</td>
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<tr>
<td>9</td>
<td>Candida tropicalis</td>
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<td>10</td>
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<tr>
<td>11</td>
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</tr>
<tr>
<td>12</td>
<td>Bacillus subtilis</td>
</tr>
<tr>
<td>13</td>
<td>Bacterium coli (= Escherichia coli)</td>
</tr>
<tr>
<td>14</td>
<td>Brevibacterium sp.</td>
</tr>
<tr>
<td>15</td>
<td>Brucella melitensis</td>
</tr>
<tr>
<td>16</td>
<td>Citrobacter sp.</td>
</tr>
<tr>
<td>17</td>
<td>Clostridium botulinum</td>
</tr>
<tr>
<td>18</td>
<td>Clostridium chauvoei</td>
</tr>
<tr>
<td>19</td>
<td>Clostridium histolyticum</td>
</tr>
<tr>
<td>20</td>
<td>Clostridium oedematiens</td>
</tr>
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<td>21</td>
<td>Clostridium septicum</td>
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<td>Clostridium sordellii</td>
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<tr>
<td>23</td>
<td>Clostridium tetani</td>
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<tr>
<td>24</td>
<td>Corynebacterium diphtheriae</td>
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<tr>
<td>25</td>
<td>Corynebacterium sp.</td>
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<tr>
<td>26</td>
<td>Diplococcus pneumoniae</td>
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<td>Penicillium sp.</td>
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<tr>
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<td>Phoma tracheiphila</td>
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<td>Piricularia oryzae</td>
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<td>38</td>
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<td>44</td>
<td>Trichoderma sp.</td>
</tr>
<tr>
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<td>46</td>
<td>Trichophyton rubrum</td>
</tr>
<tr>
<td>47</td>
<td>Trichophyton tonsurans</td>
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<tr>
<td>48</td>
<td>Trichophyton sp.</td>
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<tr>
<td>49</td>
<td>unidentified fungi</td>
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<tr>
<td>50</td>
<td>unidentified yeasts</td>
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### Bacteria: |  |
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<tr>
<td>4</td>
<td>Achromobacterium sp.</td>
</tr>
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<tr>
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<td>Bacillus agri</td>
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<tr>
<td>6b</td>
<td>Bacillus anthracis</td>
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<td>Bacillus pseudodiphtheriae</td>
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<td>Bacillus pumilis</td>
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<td>Bacterium coli (=Escherichia coli)</td>
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<td>Mycobacterium phlei</td>
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<td>Mycobacterium smegmatis</td>
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The data presented above (Table I) illustrate some of the potential inherent in the marine biological resources of Atlantic Canada. Organisms from many genera contain antibacterial, antiviral, antitumor, cytotoxic or cardioactive metabolites whose chemical structures are currently unknown. Much less survey work has centered on neuroactive, immunopotentiating, anti-inflammatory, antifertility, mutagenic, anthelmintic and insecticidal principles, and other important bioactivities (e.g. antimalarial, antileprotic, antiarthritic, molluscicidal, memory-enhancing, tissue-regenerative, and most crop yield-related activities) have been totally ignored.

Chemical reinvestigation of the activities listed (Table I) would in all probability yield not only a lengthy list of novel bioactive natural products, but also data fundamental to answering broader questions central to the three areas of research described earlier. For example:

Are marine organisms employing certain adaptive strategies disproportionately rich or poor in specific types of bioactive compounds? The observations of Green (1977) and Bakus (1981) suggest that sessile, exposed, soft-bodied invertebrates in tropical ecosystems, where there is intense grazing pressure by fish, tend to be more ichthyotoxic than cryptic or hard-bodied invertebrates in the same ecosystems. Such toxicities may play an important role in maintaining species diversity in such ecosystems (Jackson & Buss 1975). It remains to be demonstrated whether these observations can be generalized to other ecosystems, adaptive strategies and bioactivities.
Are certain taxa of marine organisms disproportionately rich or poor in specific bioactive compounds? Weinheimer et al. (1978) screened 2252 species of marine organisms and found that 10.9% exhibited activity in the U.S. National Cancer Institute’s P-388 murine leukemia bioassay; sponges, tunicates and fish yielded above-average “hit rates” (proportions of positive results), whereas the algae investigated were significantly below average (2.5%). Similarly, antiviral activities were more frequent among sponges, cnidarians, echinoderms, chordates, cyanobacteria, brown algae and red algae than among the other marine organisms examined by Rinehart et al. (1981). Multiple regression analysis (examining ecological, geographical and hydrographic as well as taxonomic variables) of such data might indicate whether the apparent correlations are in fact taxonomically based, and might provide a test for the relationship between phyletic and chemical diversities in “lower” organisms, as proposed in the Introduction.

Is there an independent geographical component in the distributional pattern of marine bioactivities? The fact that most investigations of marine bioactive substances have centered on tropical and subtropical species has reinforced the notion that the greatest potential for such compounds resides among the stereotypical flora and fauna of these regions: brightly coloured fishes and corals, toxic seaweeds, poisonous jellyfish, exotic sponges, venomous animals, and red tide plankton. By contrast, the colder-water flora and fauna are often assumed to be chemically uninteresting. This generalization has been supported for ichthyotoxicity of Pacific Ocean sponges (Green 1977), for antimicrobial activities of certain gorgonians (Burkholder and Burkholder 1958), and seems to be valid for many marine animal toxicities in general (Halstead 1965-1970). Large and taxonomically less restricted investigations (Weinheimer et al. 1978; J.T. Baker, pers. commun. 1981) have, however, revealed a more complex geographical distribution of activities “for which no ready rationalizations are apparent” (Weinheimer et al. 1978). Cold-water ecosystems typically exhibit less biological diversity than do tropical ecosystems (and thereby may be more amenable to biochemical analysis); nonetheless, individual colder-water organisms face the same types of biological challenges as do tropical ones (predation, fouling, etc.) and moreover do so in a physically changeable environment. Therefore, to the extent that bioactive natural products are of adaptive significance, there is no compelling reason to suspect a priori that individual colder-water organisms are unlikely to produce interesting bioactive compounds.

There have been disappointingly few examinations of bioactive compounds among colder-water organisms. Modest surveys, generally of only one activity, have been reported (e.g. Chesters & Stott 1956; Roos 1957; Hornsey & Hide 1974; Biard et al. 1980; Chénieux et al. 1980; Blunden et al. 1981), but most information has come from small, nonsystematic investigations which rarely have lead to chemical characterization of the active metabolite.

Can an ecological approach help predict the occurrence of pharmaceutically or biomedically relevant bioactive compounds? Sieburth (1968b) conjectured the existence of such a predictive (positive) correlation. However, the few demonstrated relationships between ecotype and presence of bioactive metabolites (above) are restricted to toxins, and toxicity often limits the clinical utilization of otherwise efficacious compounds. Confirmation of a correlation, whether positive or negative, could greatly rationalize pharmaceutically oriented screening programs.
Do marine organisms constitute a promising source of novel pharmaceuticals, agrichemicals and other important bioactive compounds? All the conditions required for an optimistic response to this question appear to be in place. There is a well-recognized need for novel antibiotics, pharmaceuticals and agrichemicals (Meinhof 1979; Zak 1980; Anon. 1981a; Mitchell 1981; Shaw 1981; Weatherall 1982). Natural products are central to modern chemotherapy not only directly (Gosselin 1962; Farnsworth & Bingel 1977), but perhaps more importantly in the long term, by broadening our understanding of chemistry and biology. Not only do marine organisms synthesize a wide variety of novel natural products, but “hit rates” are often significantly higher with marine organisms than with terrestrial plants or microbiological fermentation broths (Weinheimer et al. 1978; Suffness & Douros 1982). Modern surveys can build on both traditional medicinal utilization and preliminary assay data (e.g. Table I). Despite the lengthy and difficult path from laboratory to market (Baker 1984), marine-derived anthelmintic, antitumor, analgesic and insecticidal agents are already in use (Der Marderosian 1979); other pharmaceuticals may be marketed commercially by the mid-1980s (Anon. 1981b), and still others are in advanced developmental stages (Suffness & Douros 1981, 1982; Suffness, pers. commun. 1984). Clearly, the potential of marine organisms as a source of novel pharmaceuticals, agrichemicals and other bioactive compounds, has yet to be fully realized.

Acknowledgments

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References


Kaul, P.N. and Sindermann, C.J., eds. 1978. *Drugs and Food from the Sea. Myth or Reality?* Univ. of Oklahoma, Norman, OK.


