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BIOACTIVITIES IN MARINE GENERA OF ATLANTIC CANADA: THE UNEXPLORED POTENTIAL[1]

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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, chemorecognition, chemoattractant, and ichthyotoxic principles.

Cent soixante genres d'algues marines, d'invertébrés et de tuniciers, représentés dans les eaux de l'Atlantique canadien, contiennent des métabolites bioactifs non caractérisés chimiquement. Ces métabolites ont un intérêt potentiel en chémothérapie on en ecologie marine. On y retrouve des principes antiviraux, antimycophytes, antibactériels, antitumoraux, cytotoxiques, cardiovasculaires et hormonaux, des répresseurs alimentaires, des substances de reconnaissance et d'attraction chimiques ainsi que des toxines ichthyospecifiques.

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; Fuhrmann & 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-Piferrer 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 *Zooanthus* (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 PORPHYRIDIALES	
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, tonsilitis, 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 FLORIDEOPHYCIDAE

ORDER NEMALIALES

Audouinella sp.	*Ulva* morphogenetic factor (Provasoli & Pintner 1964) (as *Rhodochorton* sp.)
Bonnemaisonia asparagoides	antibacterial: 12, 27, 49, 71, 77 (Hornsey & Hide 1974)
B. hamifera	antibacterial: 12, 27, 49, 71, 77 (Hornsey & Hide 1974)
Gelidium amansii[1]	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. glandulaefolium	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 (Khfaji & 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	antibacterial: 71, 76a (Reichelt & Borowitzka 1984)
G. cranwellae	antibacterial: 76a, 77 (Reichelt & Borowitzka 1984)
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	folk medicine: cooling effect, "soothing", goiter, cough, congestion (Anon. 1978)
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	folk medicine: cooling effect, "soothing", goiter, cough, congestion (Anon. 1978)

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 (McCoý) 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); antiulcer (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 *Spirorbis* 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); vermifuge (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* (Levring 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 glandiforme[2]	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 indica[3]	vermifuge (Hoppe 1979)
R. ordissonei	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. byssoideum	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* (Levring 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 $mg \cdot kg^{-1}$ (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[4]	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)

P. harveyi	increases survival of vorticellids (Langlois 1975)
P. kappannae	antibacterial: 8, 71 (Rao & Parekh 1981)
P. lanosa	antibacterial: 12, 27, 49, 71, 77 (Hornsey & 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)
P. nigra	antibacterial: 12, 27, 49, 71, 77 (Hornsey & Hide 1974)
P. nigrescens	antibacterial: 12, 27, 49, 71, 77 (Hornsey & Hide 1974)
P. subulifera	increases serum lipolytic activity (Hoppe 1979)
P. thuyoïdes[5]	antifungal: 8, 14, 47 (Biard et al. 1980); antibacterial: 31, 38, 61, 71 (Biard et al. 1980)
P. urceolata	antibacterial: 12, 27, 49, 71, 77 (Hornsey & Hide 1974; Ma & Tang 1984); *Ulva* morphogenetic factor (Provasoli & Pintner 1964)
P. violacea	antibacterial: 12, 71 (Roos 1957); stimulates growth of *Skeletonema costatum* (Levring 1945)
Polysiphonia spp.	antibacterial: 3 (two species), 11, 12, 27, 55, 57, 63, 70, 71, 76a, 77, 84 (two species) (Chesters & Stott 1956; Maurer 1965; Reichelt & Borowitzka 1984)
Ptilota plumosa	agglutinin (Blunden & Rogers 1976; Shiomi 1983)
Rhodomela confervoides	antifungal: 14 (Biard et al. 1980); antibacterial: 12, 31, 49, 71, 77, 80a (Hornsey & Hide 1974; Biard et al. 1980; Ma & Tang 1984); antimitotic: *Helianthus* assay (Chénieux et al. 1980)
R. larix	antifungal: 8, 42, 46 (Mautner et al. 1953); antibacterial: 5, 8, 27, 31, 36, 37, 39, 53, 61, 71 (Mautner et al. 1953)
R. subfusca	antibacterial: 10, 12 (two strains), 27, 33 (two strains), 37, 67, 70, 71 (twenty-three strains), 80 (Roos 1957); stimulates growth of *Skeletonema costatum* (Levring 1945)
Spyridia filamentosa	agglutinin (Shiomi 1983)

CLASS PHAEOPHYCEAE

ORDER ECTOCARPALES

Chordaria flagelliformis	antibacterial: 12, 49, 71, 77 (Hornsey & Hide 1974); anticoagulant (Hoppe 1979); agglutinin (Shiomi 1983)
Colpomenia sinuosa	antibacterial: 5, 12, 27, 32, 37, 38, 40, 62, 63, 66, 71 (Maurer 1965)
Dictyosiphon foeniculaceus	agglutinin (Shiomi 1983)
Ectocarpus siliculosus	antibacterial: 12, 27, 71 (Roos 1957; Fassina & Berti 1962)
Pilayella littoralis	antifungal: 47 (Biard et al. 1980); antibacterial: 27, 31, 38, 71 (Biard et al. 1980); antimitotic: *Helianthus* assay (Chénieux et al. 1980); stimulates growth of *Skeletonema costatum* (Levring 1945)
Ralfsia spongiocarpa	antialgal: *Porphyrodiscus simulans, Rhodophysema elegans* (Fletcher 1975)
Scytosiphon lomentaria	antifungal: 3, 4, 14, 31, 32 (Khaleafa et al. 1975; Biard et al. 1980); antibacterial: 31, 71 (Biard et al. 1980); folk medicine: dry coughs, laryngitis, lymphatic tuberculosis (Anon. 1978); antimitotic: *Helianthus* assay (Chénieux et al. 1980); stimulates growth of *Skeletonema costatum* (Levring 1945); decreases survival of vorticellids (Langlois 1975)
Stictyosiphon tortilis	agglutinin (Shiomi 1983)

ORDER DESMARESTIALES

Desmarestia aculeata	antibacterial: 12, 27, 49, 71, 77 (Roos 1957; Hornsey & Hide 1974); agglutinin (Shiomi 1983)
D. ligulata	antifungal: 14 (Biard et al. 1980); antibacterial: 12, 27, 49, 71, 77 (Hornsey & Hide 1974); agglutinin (Shiomi 1983)
D. viridis	agglutinin (Shiomi 1983)

ORDER LAMINARIALES

Alaria crassifolia	convulsive toxin (Shirahama 1937); paralytic toxin (Shirahama 1937)
A. esculenta	antibacterial: 12, 27, 49, 71, 77 (Hornsey & Hide 1974)

Chorda filum	antibacterial: 12, 71 (Roos 1957)
Laminaria angustata	antibacterial: 12, 27 (Nisizawa 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 (Nisizawa 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* (Levring 1945)
L. japonica	antitumor: L-1210 leukemia (Yamamoto et al. 1982); anticoagulant (Nisizawa 1979); hypocholesterolemic (Nisizawa 1979); enhances activity of pancreatic lipase (Nisizawa 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 (Nisizawa 1979)
L. religiosa	anticoagulant (Nisizawa 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)
Saccorhiza 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* (Levring 1945); promotes settling of larvae of *Alcyonidium polyoum* 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 *Alcyonidium polyoum, Flustrellidra hispida* and *Spirorbis 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 *Alcyonidium polyoum* and *Flustrellidra hispida* (Crisp & Williams 1960); antifeedant for *Littorina littorea* (Geiselman & McConnell 1981); agglutinin (Shiomi 1983)
F. virsoides	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)
Cochlodinium 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 acatenella	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 *Goniodoma* 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 trochoïdeum*)

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, antiwrithing, muscle relaxant, postsynaptic blocker, analgesic, antioedema (Baker 1984)
Dunaliella sp.	antibacterial: 71 (Accorinti 1964); inhibits growth of *Chlorella stigmatophora* (Accorinti 1964)

ORDER CHLOROCOCCALES[6]

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 (Jørgenson & 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)
Spongomorpha 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 CLADOPHORALES	
Chaetomorpha antennina	antifungal: 4, 9, 11, 26, 39 (Rao and Shelat 1982)
C. brachygona	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. monumentalis	antibacterial: 71 (Rao & Parekh 1981)
C. pellucida	antifungal: 3, 4, 31, 32 (Khaleafa 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[7]	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 *Monodonta 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. vermilaria	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 PENNATOPHYCIDEAE

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, Coccochloris elebens, Nitzschia ascicularis, Phaeodactylum tricornutum, Tetraselmis maculata, T. striata, T. tetrathele* (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. grevillei	inhibition or enhancement of growth of algal germlings and sporelings (Huang and Boney 1983); production of morphological abnormalities in sporelings of *Ulva lactuca* and *Cigartina 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)
Nitzchia 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*	stimulates growth of phytoplankton: *Nitzschia parvula, Prorocentrum micans, Synedra tabulata* (Kabanova 1959)
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 COSCINODISCALES	
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

Bacteriastrum 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 inotropic (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 (Jakowska & 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	antifungal: 8 (Nigrelli et al. 1959; Jakowska & Nigrelli 1960-1961); antibacterial: 27, 40, 54, 57, 71, 89 (two species) (Nigrelli et al. 1959; Jakowska & Nigrelli 1960-1961); causes developmental anomalies in sea urchin eggs (Ruggieri et al. 1961)
Mycale angulosa	positively inotropic (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 HALICHONDRIDA	
Halichondria melanadocia	antibacterial: 27 (Stempien et al. 1970); positively inotropic 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[9]	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. inconstants	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: dermatonecrotic, 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); dermatonecrotic, 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 infudibulum	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[10] *O. gigas* *O. rivularis*	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, erysipalis (Anon. 1978)

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 (TEUTHOIDEA)	
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. maculosus	toxic to man (Der Marderosian 1969b)
O. ochellatus	folk medicine: stimulate maternal milk production, treat malaria (Anon. 1978)
O. vulgaris	cardiotonic (Emerson & Taft 1945); toxic to crustaceans (Hashimoto 1979); folk medicine: stimulate maternal milk production, treat malaria (Anon. 1978)

PHYLUM ENTOPROCTA

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

PHYLUM ANNELIDA

ORDER TEREBELLIDA

Pectinaria australis	chemoattractant (McCauley 1969)

PHYLUM ARTHROPODA

CLASS CRUSTACEA

SUBCLASS CIRRIPEDIA

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); cardioaccelaration (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 MOLPADIIDA	
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 (McCauley 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 (McCauley 1969); chemical signal (McCauley 1969)
A. vulgaris	cytolytic (Owellen 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)

Metridium	110	Protosiphon	100
Microciona	108	Prymnesium	98
Molgula	115	Ptilota	92
Monostroma	100	Pyrodinium	97
Mycale	108	Ralfsia	93
Mytilus	111	Rhabdonema	106
Navicula	105	Rhizoclonium	103
Nitzschia	105	Rhizosolenia	107
Noctiluca	97	Rhodomela	92
Ochromonas	98	Rhodomonas	99
Octopus	112	Rhodymenia	89
Odonthalia	91	Saccorhiza	94
Olisthodiscus	98	Scenedesmus	100
Ostrea	111	Scrippsiella	97
Palmaria	89	Scypha	107
Pavlova	98	Scytosiphon	93
Pectinaria	113	Skeletonema	106
Pedicellina	113	Solaster	115
Pellina	109	Sphacelaria	95
Pentacta	114	Spisula	112
Phaeodactylum	105	Spongomorpha	100
Phakellia	109	Spyridia	92
Phycodrys	91	Stichochrysis	98
Phyllophora	88	Stichococcus	100
Physalia	110	Stictyosiphon	93
Pilayella	93	Strongylocentrotus	114
Plumaria	91	Suberites	109
Polyides	88	Tealia	110
Polysiphonia	91	Tetraselmis	99
Porphyra	85	Thalassionema	105
Porphyridium	85	Thalassiosira	106
Prorocentrum	97	Thalassiothrix	105
Protoperidinium	97	Ulva	101

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. sinuosa* may be identical with *P. rubens*.
5. *P. thuyoides* may be referrable 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.
9. *Phakellia* now referred to *Cladocroce* (Gosner 1971).
10. *Ostrea* has recently been introduced for aquaculture.

Table II Target organisms for antifungal and antibacterial bioactivities (numbers refer to Table I)

Fungi:

1 *Alternaria kikuchiana*
2 *Aspergillus fumigatus*
3 *Aspergillus glaucus*
4 *Aspergillus niger*
5 *Aspergillus oryzae*
6 *Aspergillus parasiticus*
7 *Aspergillus sydowii*
8 *Candida albicans*
9 *Candida tropicalis*
10 *Colletotrichum gloeosporioides*
11 *Colletotrichum* sp.
12 *Bacillus subtilis*
13 *Bacterium coli (= Escherichia coli)*
14 *Brevibacterium* sp.
15 *Brucella melitensis*
16 *Citrobacter* sp.
17 *Clostridium botulinum*
18 *Clostridium chauvoei*
19 *Clostridium histolyticum*
20 *Clostridium oedematiens*
21 *Clostridium septicum*
22 *Clostridium sordellii*
23 *Clostridium tetani*
24 *Corynebacterium diphtheriae*
25 *Corynebacterium* sp.
26 *Diplococcus pneumoniae*
27 *Escherichia coli*
28 *Penicillium chrysogenum*
29 *Penicillium citrinum*
30 *Penicillium digitatum*
31 *Penicillium glaucum*
32 *Penicillium olivaceum*
33 *Penicillium* sp.
34 *Phoma tracheiphila*
35 *Pichia membranaefaciens*
36 *Piricularia oryzae*
37 *Rhizopus japonicus*
38 *Rhizopus oryzae*
39 *Saccharomyces cerevisiae*
40 *Saccharomyces pastorianus*
41 *Saccharomyces uvarum*
42 *Schizosaccharomyces pombe*
43 *Sporothrix schenckii*
44 *Trichoderma* sp.
45 *Trichophyton mentagrophytes*
46 *Trichophyton rubrum*
47 *Trichophyton tonsurans*
48 *Trichophyton* sp.
49 unidentified fungi
50 unidentified yeasts

Bacteria:

1 *Achromobacter parvulus*
2 *Achromobacter stationis*
3 *Achromobacter* sp.
4 *Achromobacterium* sp.
5 *Aerobacter aerogenes*
6 *Aerobacter cloacae*
6a *Bacillus agri*
6b *Bacillus anthracis*
7 *Bacillus cereus*
7a *Bacillus licheniformis*
8 *Bacillus megatherium*
9 *Bacillus mycoides*
10 *Bacillus pseudodiphtheriae*
11 *Bacillus pumilis*
12 *Bacillus subtilis*
13 *Bacterium coli (= Escherichia coli)*
14 *Brevibacterium* sp.
15 *Brucella melitensis*
16 *Citrobacter* sp.
17 *Clostridium botulinum*
18 *Clostridium chauvoei*
19 *Clostridium histolyticum*
20 *Clostridium oedematiens*
21 *Clostridium septicum*
22 *Clostridium sordellii*
23 *Clostridium tetani*
24 *Corynebacterium diphtheriae*
25 *Corynebacterium* sp.
26 *Diplococcus pneumoniae*
27 *Escherichia coli*
28 *Flavobacterium aquatile*
29 *Flavobacterium* sp.
30 *Hafina* sp.
31 *Klebsiella pneumoniae*
32 *Klebsiella* sp.
32aa *Micrococcus flavus*
32a *Micrococcus luteus*
32b *Micrococcus lysodeikticus*
33 *Micrococcus pyogenes*
34 *Micrococcus* sp.
35 *Moraxella bovis*
36 *Mycobacterium avium*
37 *Mycobacterium phlei*
38 *Mycobacterium smegmatis*

39 *Mycobacterium tuberculosis*
40 *Mycobacterium* sp.
41 *Neisseria catarrhalis*
42 *Neisseria caviae*
43 *Neisseria flava*
44 *Neisseria flavescens*
45 *Neisseria perflava*
46 *Pasteurella multocida*
47 *Plectridium tetani*
48 *Proteus mirabilis*
49 *Proteus morganii*
50 *Proteus rettgeri*
51 *Proteus vulgaris*
52 *Providencia* sp.
53 *Pseudomonas aeruginosa*
54 *Pseudomonas aeruginospae*
55 *Pseudomonas fluorescens*
56 *Pseudomonas putida*
57 *Pseudomonas pyocyanea*
58 *Pseudomonas stereotropis*
59 *Pseudomonas* sp.
60 *Salmonella cholerae suis*
60a *Salmonella entiritidis*
61 *Salmonella gallinarum*
62 *Salmonella pullorum*
63 *Salmonella typhi*
64 *Salmonella typhimurium*
65 *Salmonella typhosa*
66 *Sarcina lutea (= Micrococcus luteus)*
67 *Sarcina* sp.
68 *Serratia marcescens*
69 *Shigella dysenteriae*
69a *Shigella flexneri*
70 *Staphylococcus albus*
71 *Staphylococcus aureus*
72 *Staphylococcus epidermidis*
73 *Staphylococcus peoria*
74 *Staphylococcus* sp.
75 *Streptococcus faecalis*
76 *Streptococcus lactis*
76a *Streptococcus pneumoniae*
77 *Streptococcus pyogenes*
78 *Vibrio algosus*
79 *Vibrio anguillarum*
80 *Vibrio finckler*
80a *Vibrio* sp.
81 *Welchia perfringens*
82 *Xanthomonas* sp.
83 unidentified marine bacteria
84 unidentified coryneform bacteria
85 unidentified enterococci
86 unidentified Gram-positive bacteria
87 unidentified pathogenic staphylococci
88 unidentified soil bacteria
89 unidentified "tubercule bacilli"

Envoi

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 chemotherapeutics not ony 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.

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