Oligotrophic Habitats (an Extreme Environment?)

What types of organisms and how do they adapt?
Oligotrophic organisms are those that are adapted to uninterrupted nutrient limitation. Such microorganisms have physiological and morphological characteristics that maximize their ability to import inorganic nutrients or organic substrates across steep gradients (i.e. from very low external concentrations) and utilize these resources conservatively (i.e., usually grow slowly).

Copiotrophic organisms are those that live in high nutrient or substrate concentrations (at least periodically), consuming them rapidly, but are inefficient in the uptake of these compounds at low concentrations.
Generalized comparison between oligotrophs & copiotrophs

Growth rate

A. Resource Growth Curves

B. Dynamics

Nutrient concentration

Time (hrs or min)

High nutrient

Nutrient concentration

oligotroph

copiotroph

oligotroph

copiotroph
Waldo Lake with Diamond Peak in background; this is one of the few ultra-oligotrophic lakes in the world that have been studied.

*total solutes less than U of Oregon distilled H₂O
Organic “shelves” along shore: stromatolites? (Waldo Lake, OR)

Essentially all primary productivity is benthic; no snails..no calcium
Waldo Lake: “stromatolites”
Section of Waldo Lake “stromatolite” with cyanobacterial surface layer

The underpart is relatively soft and mainly organic
Bryophytes (mosses) in shallow bay, Waldo Lake
Cover of scytonemin-rich cyanobacteria (Waldo Lake shallows)

dark cover of cyanos.

*Stigonema* + *Scytonema*
Close-up of scytonemin-rich cyanobacteria (mainly *Stigonema*)

In shallow water
Stigonema from Waldo Lake taken from benthic cover
Stigonema with scytonemin in sheath
Bryophytes (mosses) in shallow bay, Waldo Lake

Scytonema with scytonemin in sheaths
*Stigonema* (phase contr.) (scytonemin in sheath)

Fluorescence with green light excitation

Fluorescence with UV excitation, 365 nm

No response
In vivo, the scytonemin maximum absorption at 372 nm.

Absorption spectra of:

\[ S = \text{scytonemin (in tetrahydrofuran)} \]

\[ M = \text{mycosporine-like amino acids (in vivo)} \]
Crater Lake, Oregon: 2nd deepest in W. Hemisphere (589 m); ultra-oligotrophic
Two well-known oligotrophic, chemoheterotrophic bacteria

*Caulobacter crescentus*, a well studied freshwater bacterium that occurs in oligotrophic lakes and ponds (and bottled water; e.g. Earth$_2$O)

*Sphingopyxis alaskensis*, a very minute marine bacterium: cell volume $<< 0.1 \mu m^3$, i.e. $< 0.3 \mu m$ diameter
Caulobacter crescentus
dividing cell

Complete Genomic seq.
known: 3,767 genes

~0.7µm in diameter;
length varies
Caulobacter mutants

NA1000 (wild-type)  
*****

YB720 (phoBΩ12)  
No elongation

YB767 (pstS1100)  
Always elongates
Caulobacter cycle

Flagellum ejection
Pili retraction
Flagellum biogenesis
Chemotaxis machinery
Pili biogenesis
Holdfast synthesis
Stalk synthesis and elongation
DNA methylation
Replication initiation
Chromosome replication
Chromosome segregation
Cell separation
Smaller cells have greater surface area to volume ratio; usually this allows a greater uptake ability. This is because transport rates are to some degree a function of the membrane surface area available, and relative to cell volume, small cells have more surface area available than do large cells.

E.g., picocyanobacteria, picobacteria, and picoarchaea in seawater and oligotrophic lakes.
Also, prosthecate bacteria

Size not to scale of cells on the right
Other oligotrophic habitats:

• Some soils
• Sargasso Sea (and most other oceanic regions), including
  • Many tropical and subtropical coral reefs
• etc.
The Sargasso Sea

20° to 35° N. Lat.
30° to 70° W. Long.
Sargassum in the blue Sargasso Sea near Bermuda
Floating *Sargassum* with flotation bladders and epiphytic hydroids
Washed-up Sargassum, Bermuda beach
Sargassum with Angler Fish
Sargassum crab
Flying Fish eggs laid on *Sargassum*
Sargassum Flying Fish
Cyanobacterial endosymbionts with PE

Ornithocercus spp. (dinoflagellate)
Cryptomonad chloroplasts (with PE)

*Dinophysis* spp. (dinoflagellate)
*Rhizosolenia* (diatom) with chloroplasts and *Richelia* (cyanobacterium) endosymbiont
Rhizosolenia with Richelia (preserved sample)
Hemialulus (planktonic diatom) w/ Richelia

Richelia
(arrows on heterocyst),
PE autofluorescence

chloroplasts
Chlorophyll fluorescence
Radiolarians with silica "skeleton"

(amoeboid unicells)
tintinnid ciliate with cryptomonad endosymbiont
*Mesodinium rubrum* (ciliate protist with Cryptophyte Endosymbiont)
Radiolarians drawn by E. Haeckel (1908) (showing some symbionts)
Shark Bay, Western Australia  "stromatolites"
Living “stromatolites”
Hamelin Pool, Shark Bay, W. Australia
Hamelin Pool, Shark Bay, NW Australia
Cuatro Cienegas
Caldera Lakes of Niuafo'ou, Tonga
Bathymetric Map of Vai Lahi and Vai Sili

Survey: Niuafo'ou Expedition June 1996
S. Kemp, A. Innes, J. Kasamegger

Fig. 1 Location of Niuafo'ou Island in Tonga Archipelago (arrow head). a Aerial view of caldera lakes of Niuafo'ou Island (photographed from northeast). Sites of stromatolite and water sampling are indicated on bathymetric map of the two largest lakes, Vai Lahi and Vai Sili. b View of Vai Lahi stromatolite field. c An example of large Vai Lahi stromatolite (length of hammer, 28 cm).
Cuatro Cienegas, relict Pleistocene pools with endemic fish, etc.
Posa Azul, Cuatro Cienegas, Mexico
“stromatolite” Poza Azul, CC
1967  Surtsey, last eruption
Surtsey, 1970-stream vents with bacteria
Coral reefs occupy tropical & subtropical areas (30 N- 30 S Lat.) and are usually in ultra-oligotrophic waters.

However, pollution and eutrophication are occurring in many areas and corals are disappearing, in many cases because of higher water temperatures and ejection of their essential photosynthetic endosymbionts. However, some of these symbionts are adapting.
Brain coral with endosymbiotic “zooxanthellae” (dinoflagellate)
Tropical coral reef organisms with endosymbiotic dinoflagellates

- sponge
- coral polyps
- Coral reef
- Soft coral