Hydrothermal Vent Ecosystems: Discovery, species variability on temporal and spatial scales, importance and uses, conservation issues and vent protected areas.

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The Deep Sea: An extreme environment?

Low Temperature

Low Biomass (food)

Very Little Light

High Pressure

The Deep Sea:
An extreme environment?
Not really.

Low Temperature

Low Biomass (food)

Very Little Light

High Pressure

Adapting to high pressure is simple, evolutionarily.

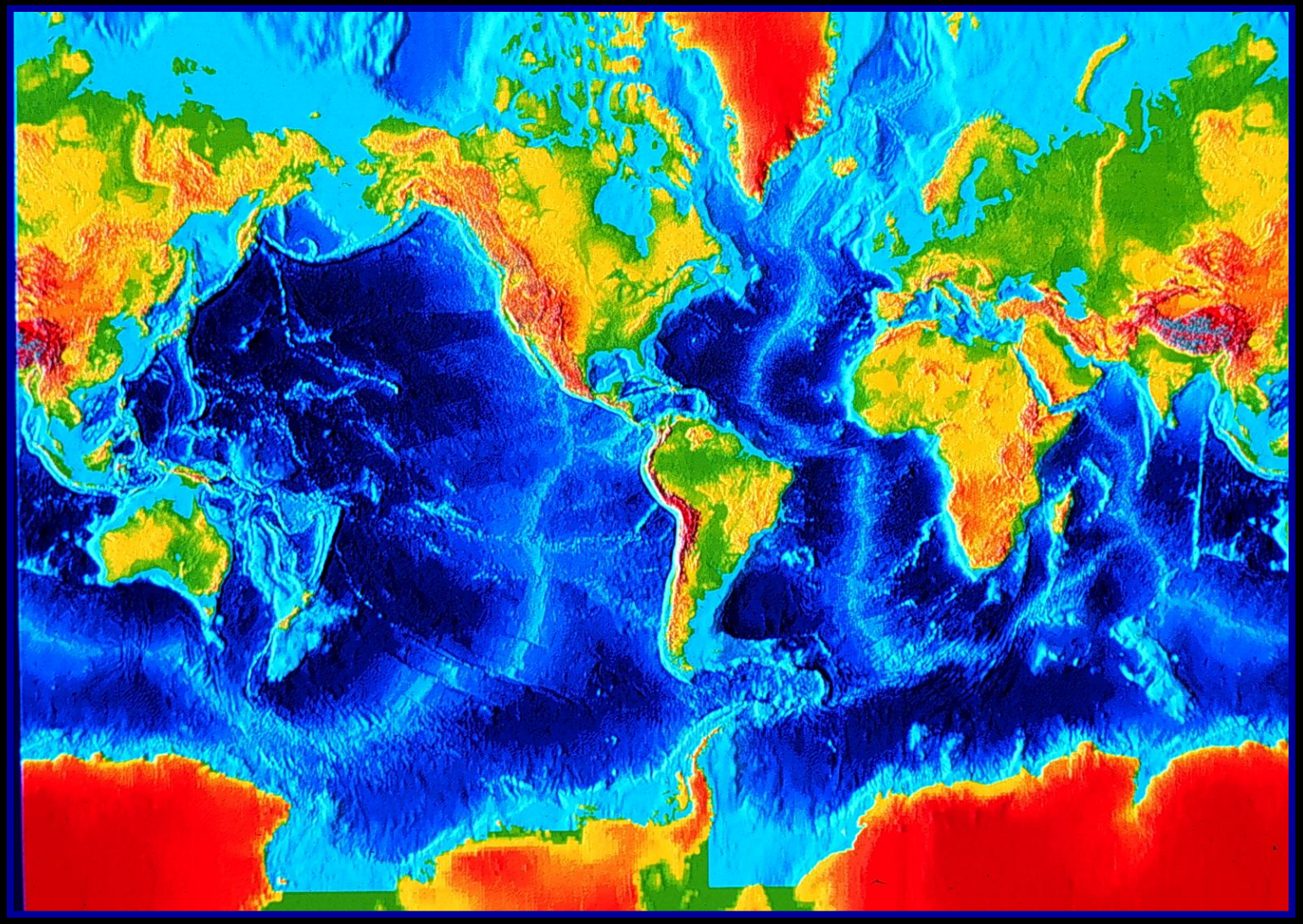
A few small changes in proteins and membranes is all it takes

The deep sea is a stable environment with relatively constant darkness, pressure, temperature, chemistry and humidity.

(Certainly less extreme that Pennsylvania or even Fiji…)

- Hundreds, if not thousands of different animal groups have independently evolved to inhabit the deep sea.
- Biodiversity in the deep sea is high: about 200,000 described animal species, representing most major groups of animals.
- There are likely hundreds of thousands more species yet to be described in the deep sea.

But, all of the deep sea is not so mellow



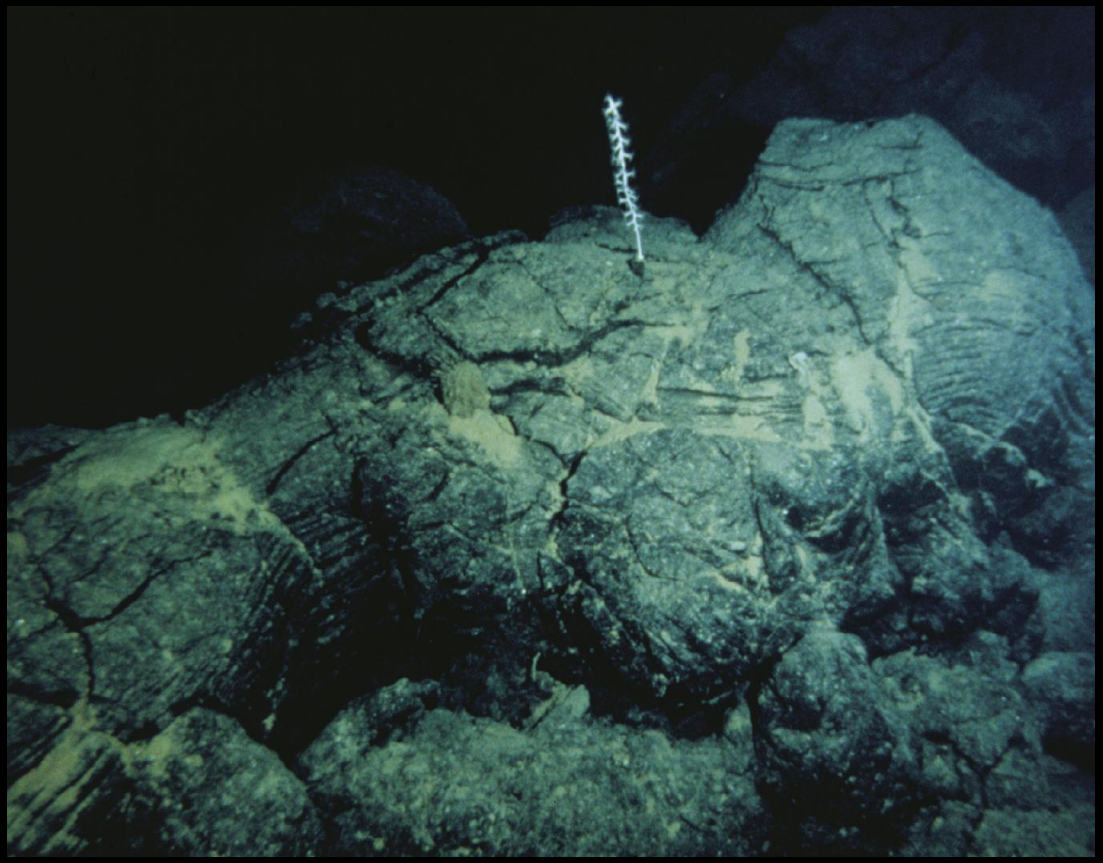
When deep sea hydrothermal vents were discovered we expected…….

No sunlight

New seafloor

No sediment

Low biomass
(not much food or life)



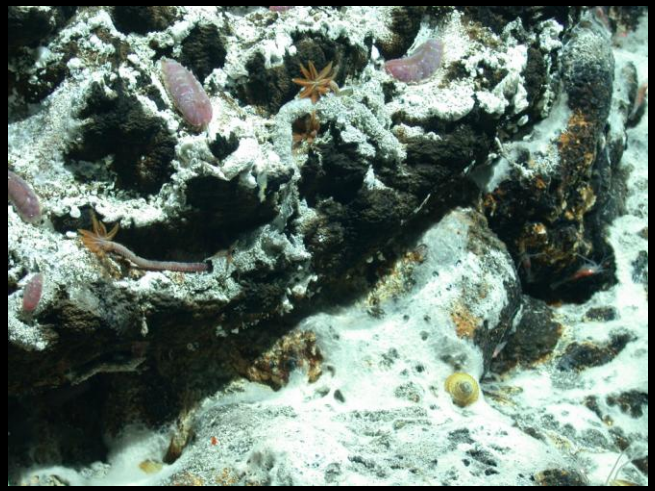
But… Rose Garden……

Deep sea hydrothermal vents are extreme environments

- High and variable temperatures
- Low/no oxygen
- Toxic chemistry, particularly sulfide (also heavy metals, radiation)

Temperature and Vent Animals: **Gradients** can be extreme

- 2° C - 350° C over < 1cm
- 10° C - 60° C+ along an alvinellid
- 2° C - 30° C+ along a tubeworm
- Variable over sec/min/hr....



Toxicity in the vent environment

Hydrogen sulfide is toxic to most animals

- Sulfide poisons most hemoglobins (blood)
- Sulfide can knock out respiration

There are also a variety of other potential toxins that must be overcome or avoided. ie:

- Heavy metals, pH, radioactivity

So, why bother?

Because hydrothermal vents are an energy (and food) rich oasis habitat in the food limited deep sea.

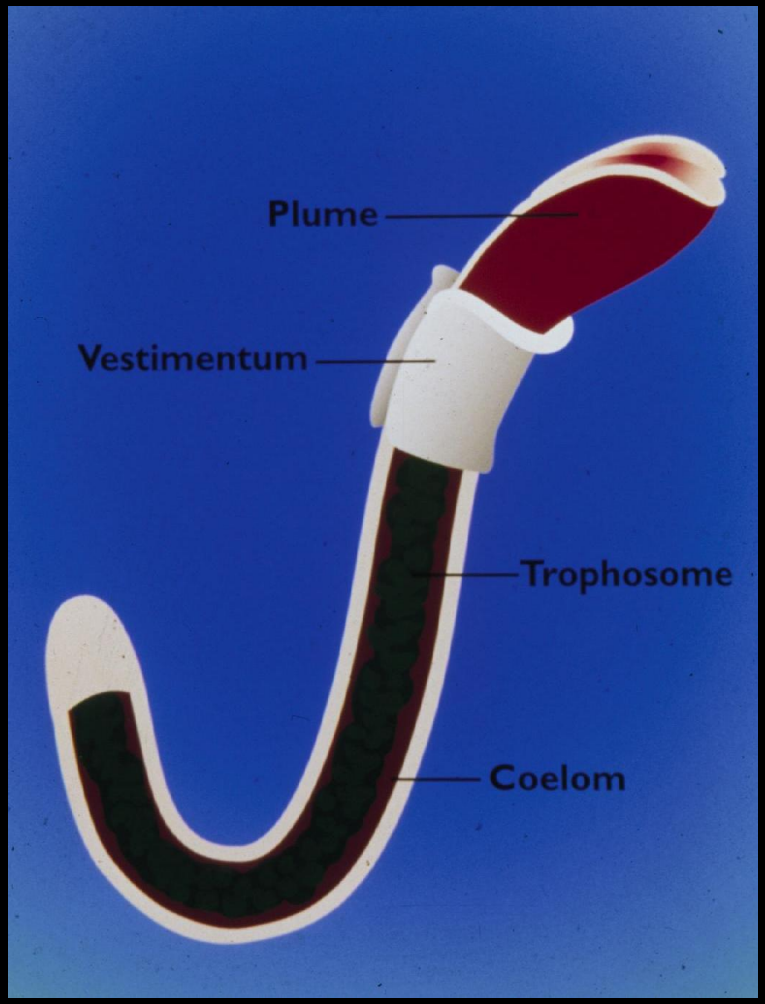
Where does the food come from?

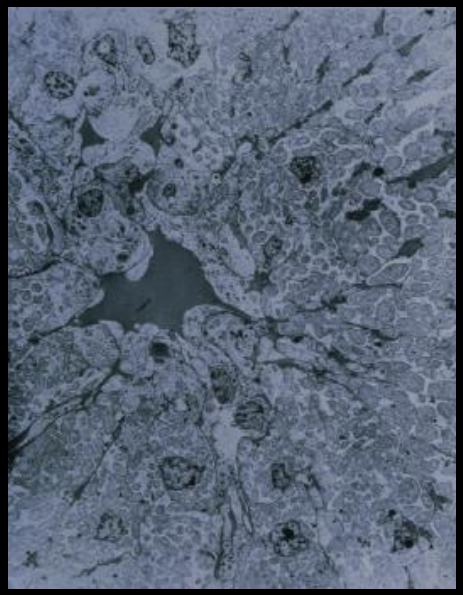
On land and in shallow water, the energy comes from sunlight. Plants, algae (and corals with symbiotic algae), use the energy to make food by the process of photosynthesis

At deep sea hydrothermal vents the energy comes from chemicals (mostly sulfide) in the hot water. Bacteria (and some animals with symbiotic bacteria) use the energy to make food by the process of chemoautotrophy

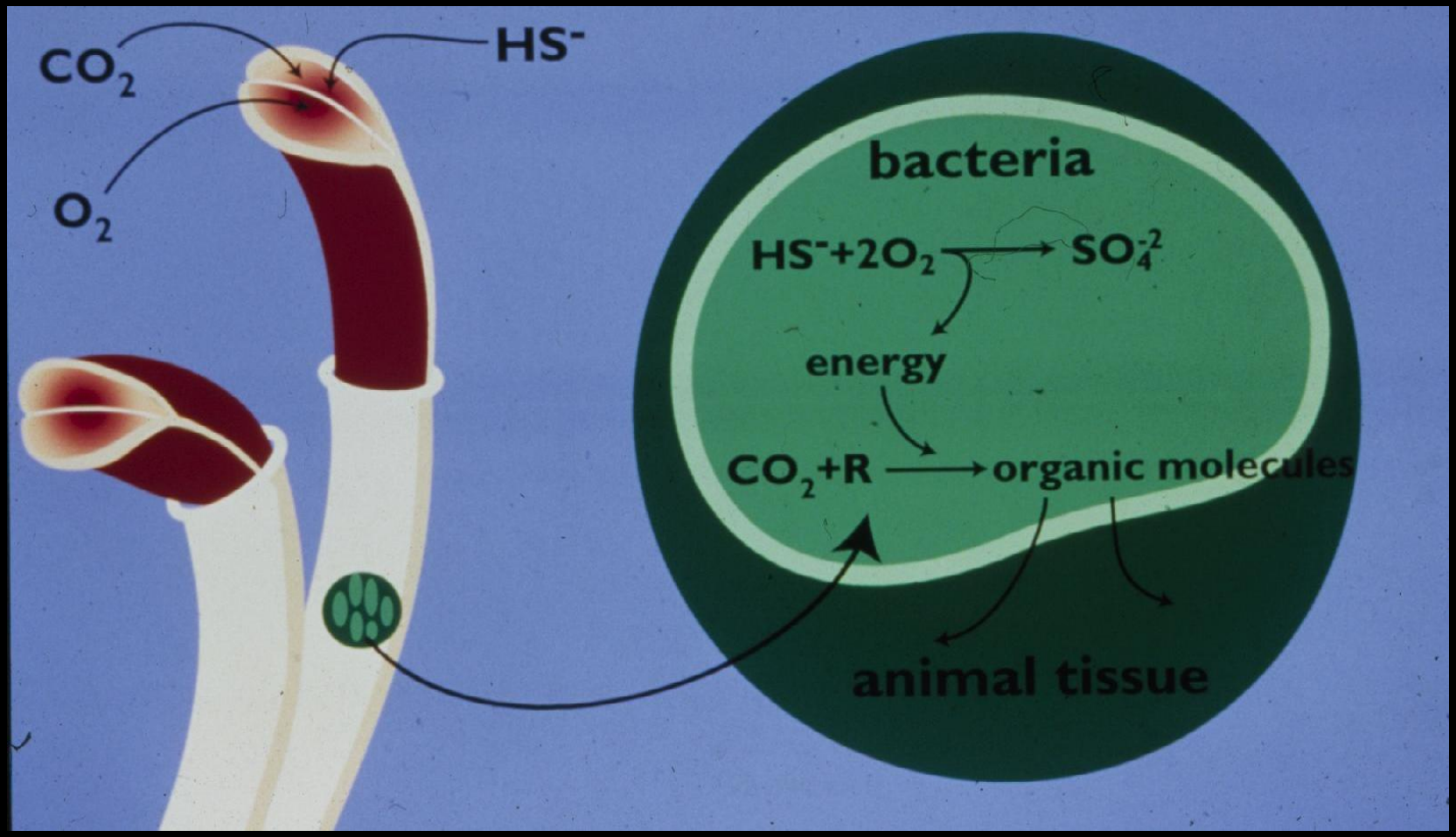
Chemoautotrophic symbiosis: Vent animals that make their own food.

Giant tubeworms

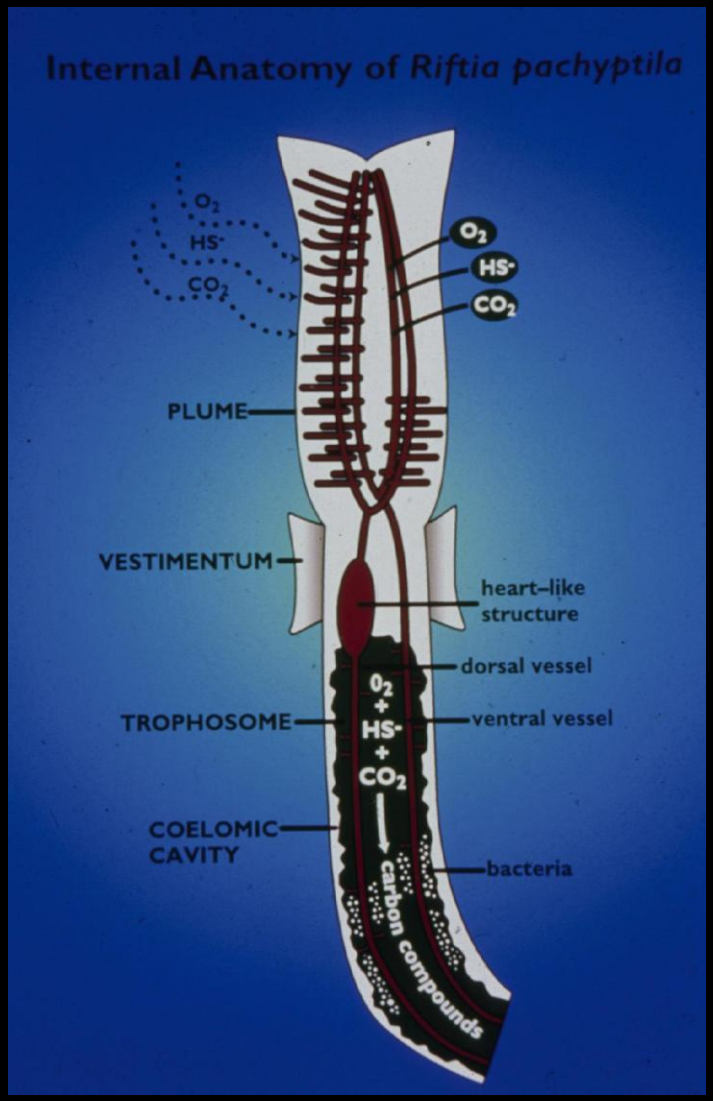




Giant tubeworms



Giant tubeworms



Special Blood!

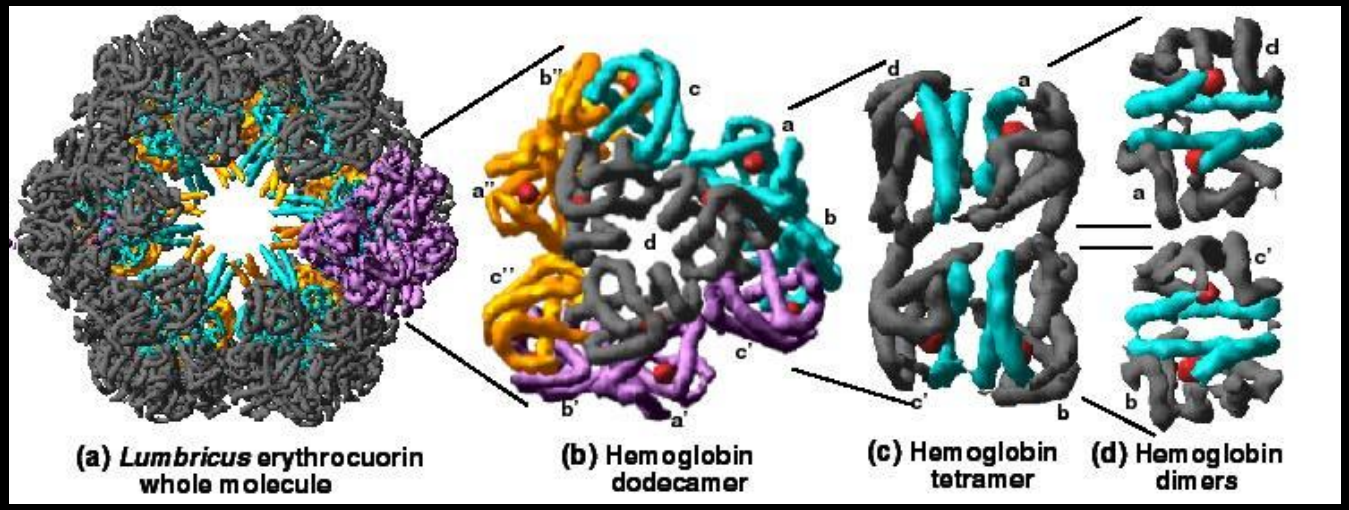
Hemoglobins bind oxygen and sulfide:

- With high affinity
- With high capacity
- Non competitively
- Reversibly

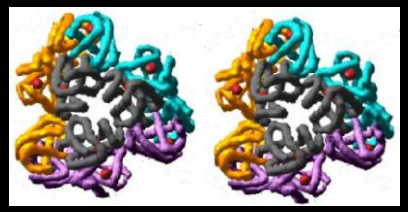
Tubeworm hemoglobins:

Giant extracellular proteins

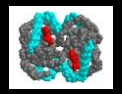
3500kDa Hb



400kDa Hb

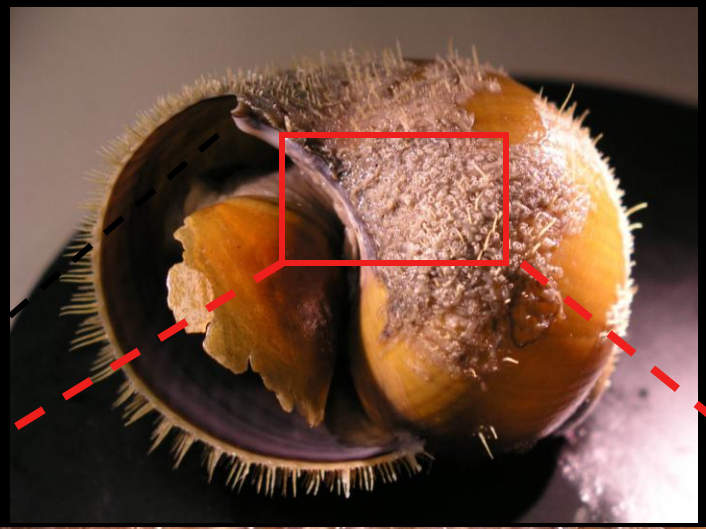


Human Hb



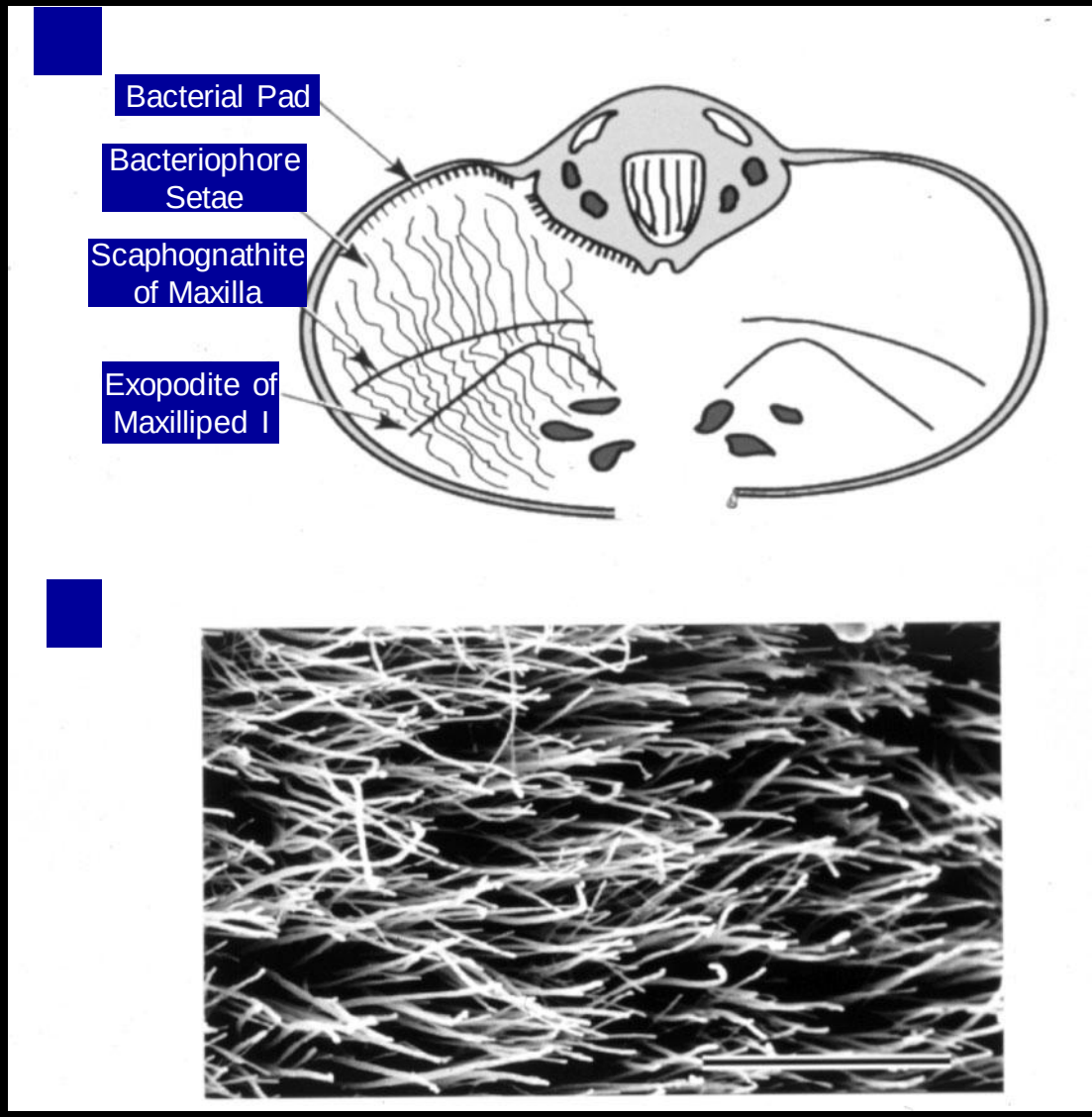
68kDa

Here, on the ELSC, a vestimentiferan tubeworm is tiny, seemingly rare, ecologically a minor player, but likely very unique metabolically

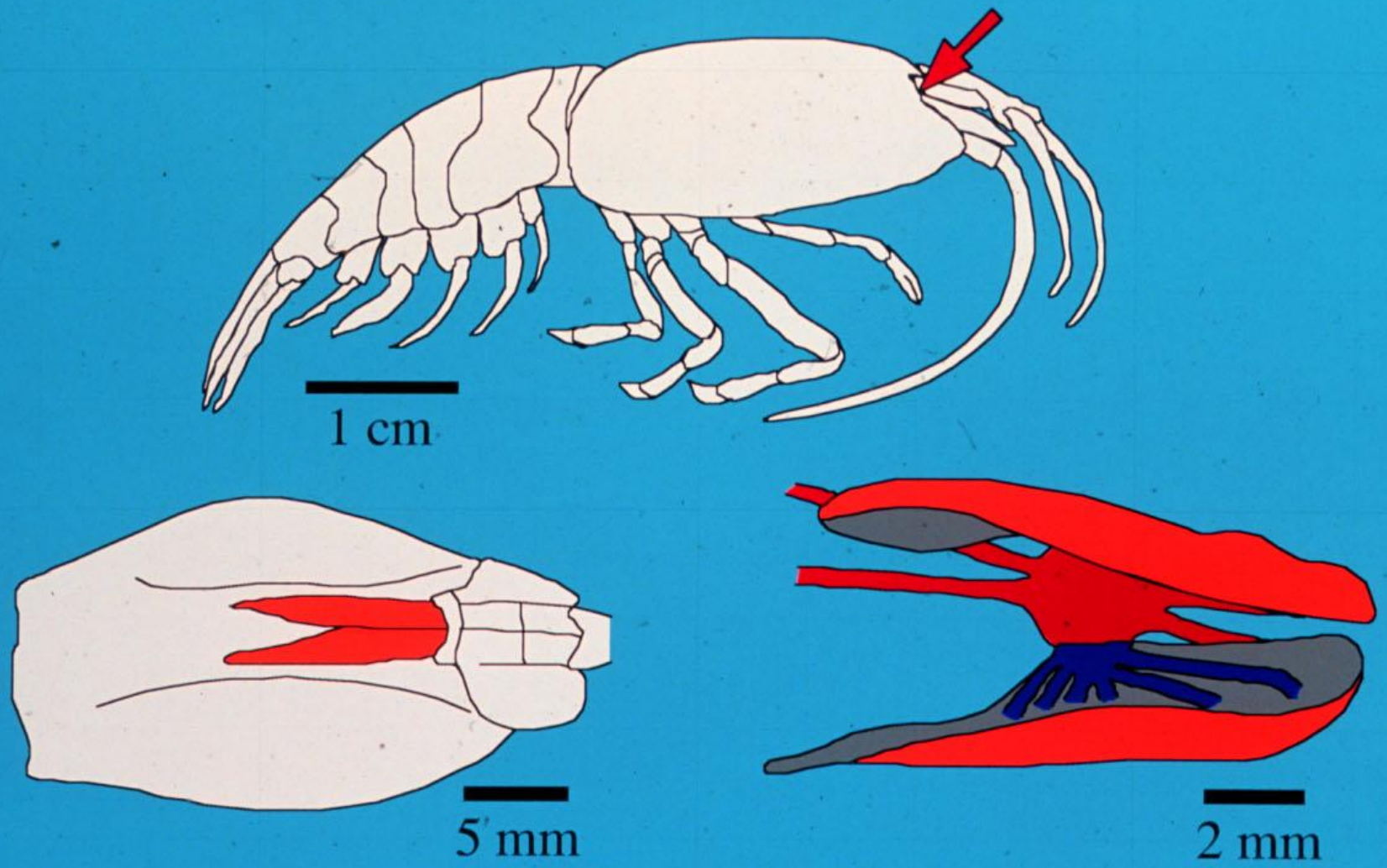


Oasisia fujikurai (?)

Mid-Atlantic Ridge Shrimp



Rimicaris exoculata

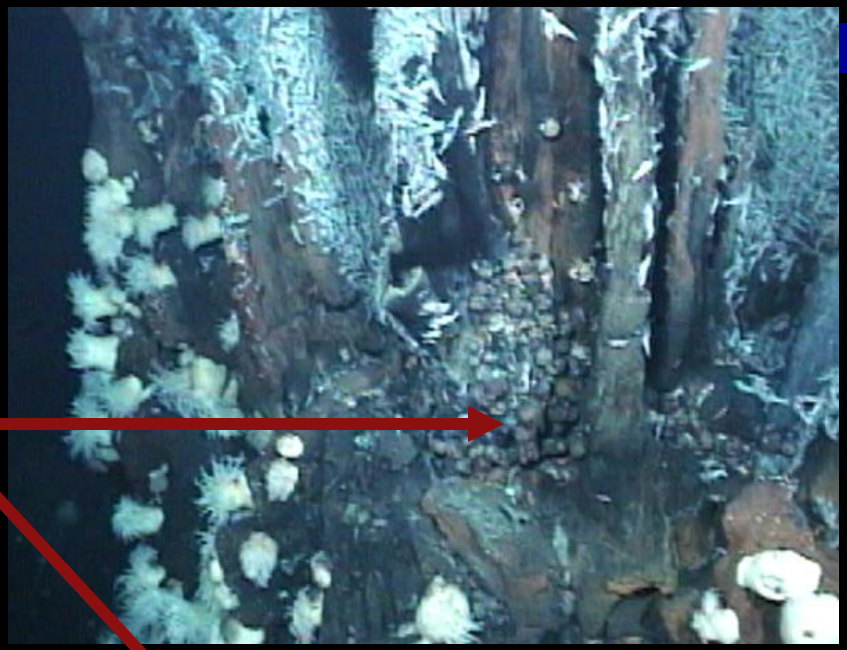


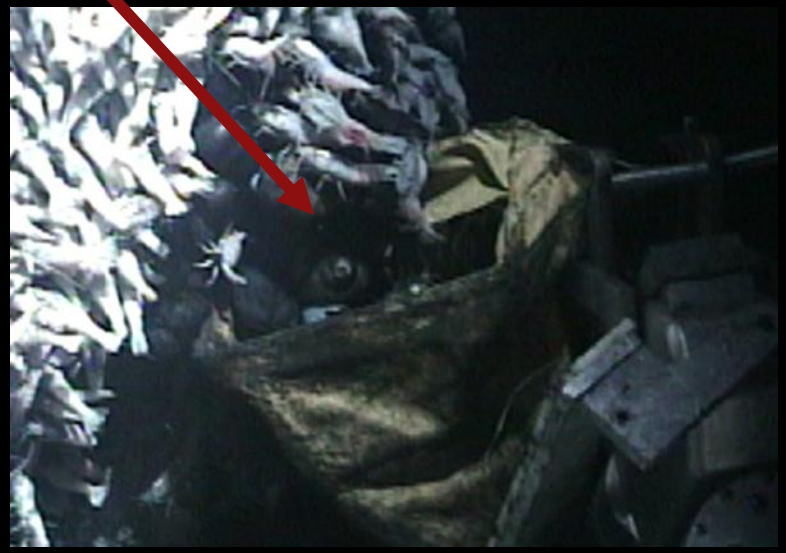
Rimicaris exoculata

A new snail from Indian Ocean vents

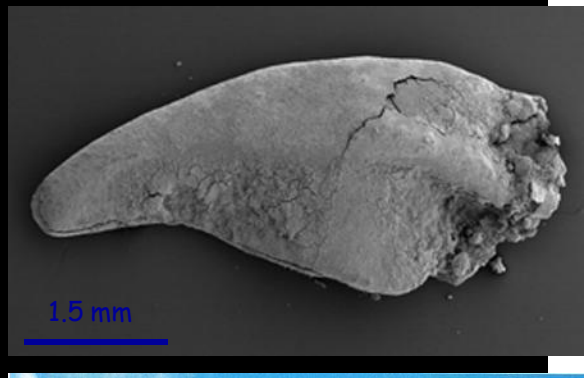
ord. Neomphalina
fam. Peltospiridae

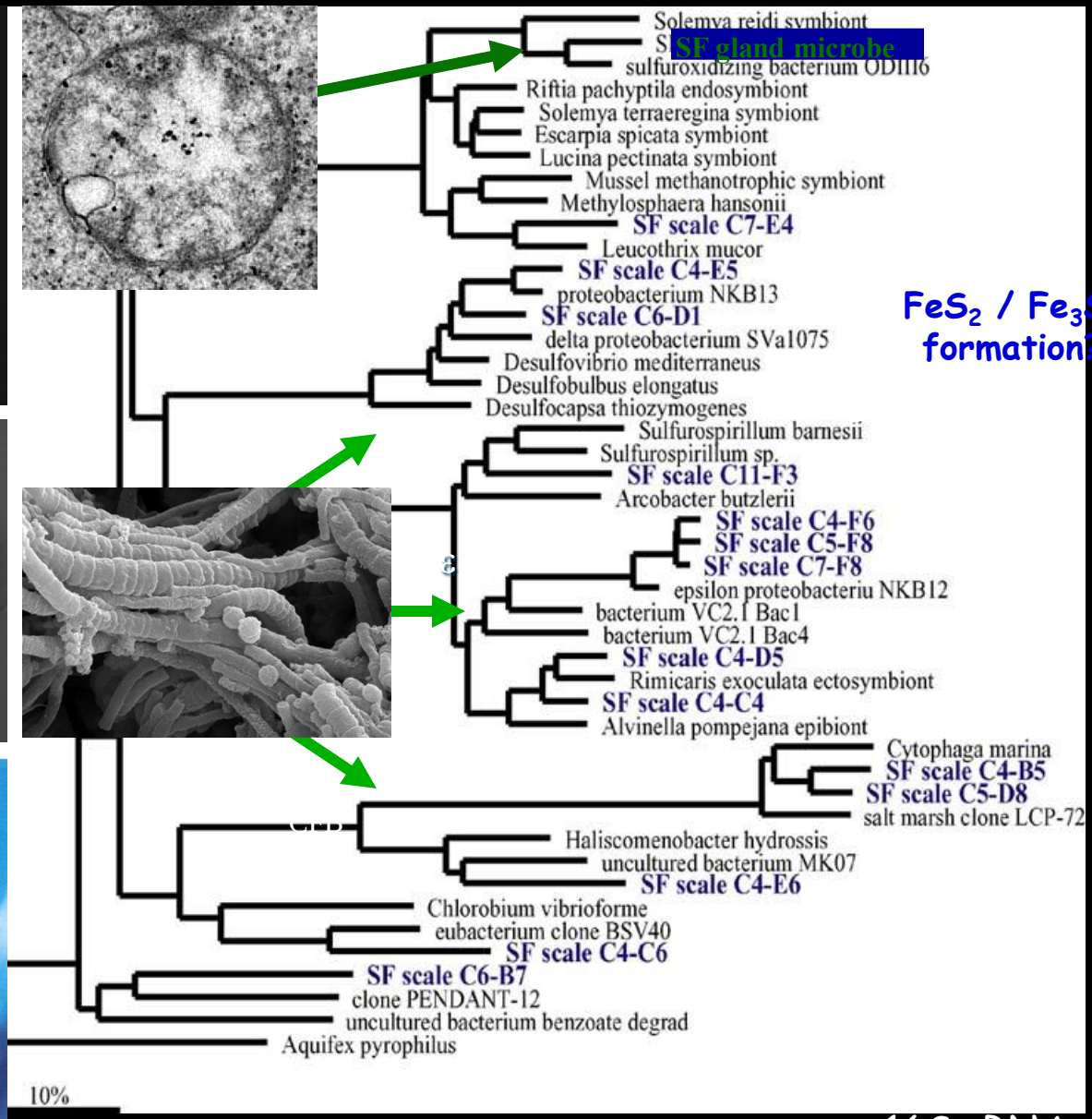
Common Name: Scaly-foot snail





Bacterial partners





Biodiversity

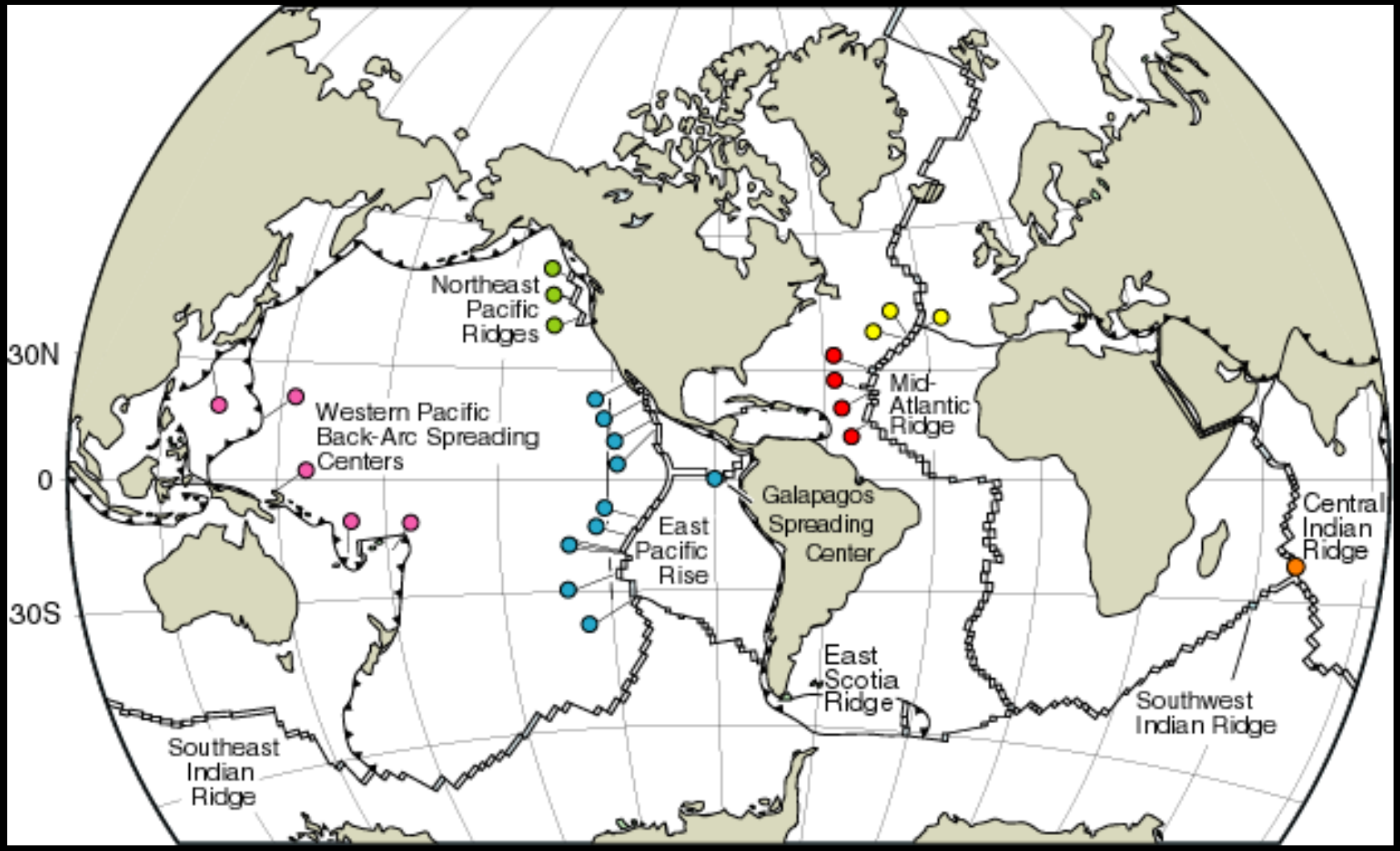
Importance ecologically is sometimes debated although most people would agree it is important to ecosystem stability and that we should avoid extinction of species whenever possible.

The kind of biodiversity I am talking about is extreme. Very strange animals, with very unique types of adaptations, that have the very real potential to teach us new metabolic "tricks" and through biotechnology have the potential to have large impacts on mankind.

The uniqueness and value of vent ecosystems has been recognized globally and 4 vent ecosystems are currently protected

1) The Endeavour Vent field Marine Protected area on the west coast of Canada (4 x 6 nm)
2) The Azores vent fields Marine Park (7 sites, 4 are also OSPAR Marine Protected Areas)
3) The Guymas Basin and 21° N on the East Pacific Rise by Mexico (about 1500 km^2 total)
4) The US Mariana Trench National Monument includes several vents and undersea volcanoes

Biogeography of vent fauna



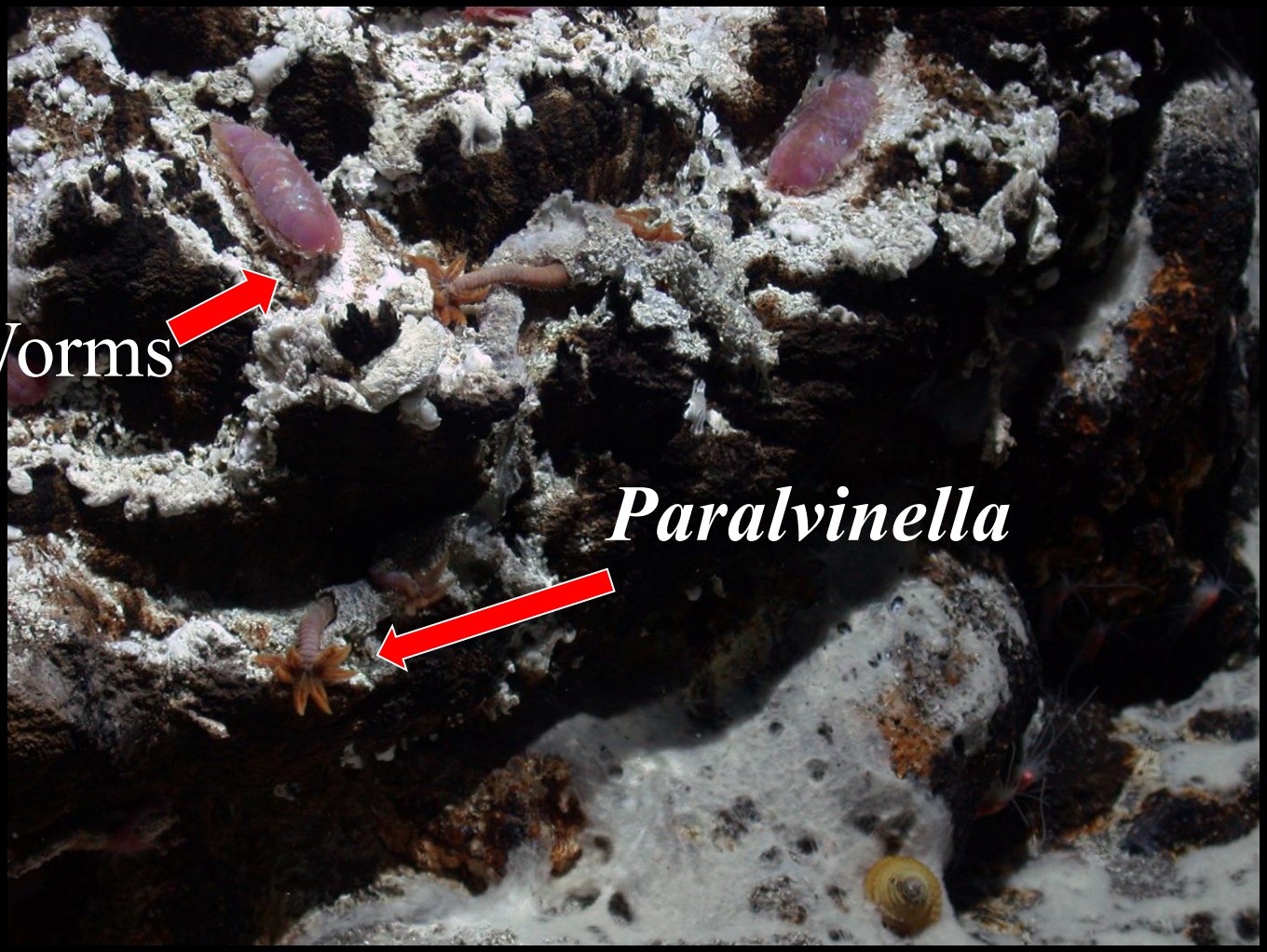
Van Dover et al. 2002

Western Pacific Back-Arc Basins

The main symbiont-containing "foundation fauna":
Giant snails (*Alviniconcha* and *Ifremeria*) and mussels.

Western Pacific Back-Arc Basins

The “hotshots”, living it the hottest environments



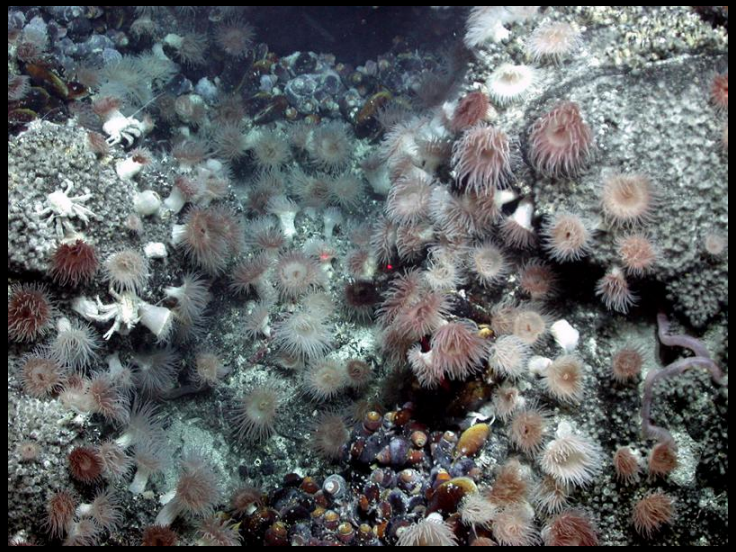
Western Pacific Back-Arc Basins

The "cooler" vent specialists:

Barnacles

Anemones

Sponges



Western Pacific Back-Arc Basins

The fauna on inactive vents:
Who? (vent specialists?)
How? (Nutrition from vents?)
Unique?

Some environmental considerations

- Unfortunately, there is a lot we do not know
  - We know there are many more “rare” species to be discovered, but how many and what?
  - The W. Pacific vent “meiofauna” is very poorly known
  - The fauna of inactive vents is almost unknown
  - Connections between vent animals and the rest of the deep sea, and to the shallow water animals, are very poorly constrained.

Some environmental considerations

- Unfortunately, there is a lot we do not know
  - The natural life spans of W. Pacific vents is not known
  - Natural succession of W. Pacific vent fauna is largely unknown
  - Spacing and distribution of vents in most areas is not well known
  - Population connections and inter-relations (genetic biodiversity) are not known for most species

So what if a rare species of vent animal in _____ goes extinct?

- Will the fish in the shallow water care?
- How will it effect other ocean ecosystems?
- Will we loose any valuable biotechnology?
- Will our grandchildren care?

However, if we move forward with mining of deep sea sulfides carefully and intelligently, we can greatly minimize that risk

- The animals that live in <u>active</u> hydrothermal vents are adapted to "catastrophic events" (on local and natural time scales)
  - Most must be adapted to relatively short-lived habitats
  - Also must be adapted to dispersal from one vent to another

There has been a lot of work done on the West Pacific Back Arc Basin vent fauna

- We know the major players
- Many of the genetic “tools” to look at species differences and population connections have been developed and these studies are moving fast
- We have ongoing studies that will teach us about natural succession and changes in communities (in Tongan waters at least)

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And we can learn a lot from the "Solwara 1 Experiment"

The technology to discover and characterize new vents is also improving at a very fast pace.


Thank you for your attention!