BIODIVERSITY AND
BIOPROSPECTING

Andrew Beattie
Department of Biological Sciences
Macquarie University
Sydney, Australia

andrew.beattie@mq.edu.au
Eucaryotes Only!

- Plantae
  - Green Algae
  - Red Algae

- Chromalveolates
- Alveolates
- Stramenopiles
- Chromalveolates

- Excavates
  - Cercomonads
  - Euglyphids
  - Phaeodarea
  - Heteromitids
  - Thaumatomonads
  - Chlorarachniophytes
  - Phytomyxids
  - Haplosporida
  - Foraminifera
  - Polycystines
  - Acantharia

- Discicristates
  - Heterolobosea
  - Kinetoplastida
  - Diplomonads
  - Euglenids
  - Core jakob
  - Trinema
  - Dinophyta

- ‘Unikonts’
  - Ascomycetes
  - Basidiomycetes
  - Zygomycetes
  - Microsporidia
  - Chytrids
  - Nuclearids
  - Animals
  - Choanoflagellates
  - Capsaspora
  - Ichthyosporea
  - Dicysteostids
  - Myxogastrids
  - Protozoa
  - Archamoebae

- ‘Unikonts’
Tree of Life
Example: Rarefaction curves for V6 hypervariable regions of ribosomal RNAs from 8 deep-sea water samples. (Sogin et al. 2006. PNAS)

And they contain many different metabolic/biochemical functions
SO:

• Most species are (much) less than 1 cm in length

• Any landscape harbours many more species than meet the eye
  
  Invertebrates
  
  Microbes
  
  Single-cell animals and plants

• We know remarkably little about them

• Their biology, their uses
Biodiversity: The Resource

- NUMBERS:
  - Approximately: 30m species (n genes), 2m described, 20,000 species utilized...
  - ie the resource is little-known/under-used
  - >1% of species have supported civilization so far:

What about the other 99%?
BIOPROSPECTING FOR ECOSYSTEM SERVICES eg WILD POLLINATORS

- Custard Apple *Annona sp*, Longan, Macadamia Plantations
- All need wild insects for pollination
- All show highest yields when near rain forest

- Native pollinator visitation vs. Distance from natural habitat. Note that native visitors drop to 50% at 660m.

- Interactions: farmers, ecologists and bioprospectors
Increasing pollinator dependency worldwide

Pollinators

Farm Industries

Agricultural Industries

Transport and Distribution

Manufacturing and Processing

Wholesale and Retail

JOBS

Money
Biological control agents

Salvinia molesta

Cyrtobagous salviniae
Host-specific from Brazil

Who would have thought?
Brazilian wasp to control Cassava mealy-bug in Thailand
(Science (2010) Vol 329)

wasp: *Anagyrus lopezi*

Mealy bug: *Phenacoccus manihoti*

Khon Kaen province, Thailand
Bioprospecting is the exploration of biodiversity for new biological resources of social and/or commercial value**

Traditional Knowledge: mostly from developing countries, mostly botanical medicines

Evolutionary Ecology: ecologically-driven, hypothesis-driven

**ecosystem products, not services
Industries that carry out bioprospecting in a wide variety of environments worldwide

- Biomimetic Engineering
- Biological Mining
- BioMonitoring
- BioRemediation
- PhytoRemediation, Mycoremediation
- Crop Protection
- Commercial Pollination
- Botanical Pharmaceuticals/Medicines
MODERN BIOPROSPECTING IS LOOKING FOR MANY KINDS OF PRODUCTS

• Habitats
• Species
• Life-history traits
• Behaviours
• Adaptations
• Metabolic pathways

• MOST ECOSYSTEMS (terrestrial, freshwater and marine) ARE INVOLVED (all latitudes and altitudes)
• and
• MANY DIFFERENT KINDS OF INDUSTRIES ARE ACTIVELY BIOPROSPECTING:
For pharmaceuticals in general (Henkel et al. 1999, Angew. Chem. Int. Ed. 38:643)

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Major Taxa of Bioprospecting Interest

- Bacteria
- Fungi
- Algae
- Angiosperms
- Porifera
- Arthropoda
- Mollusca
- Crustacea
- Annelida

*biodiversity pie-chart*
Enhancing the Science – Ecologically-Driven or Hypothesis-Driven Bioprospecting

Basic Question:
Where would you expect the desired product to have evolved?

Natural History:
A vast commercial database. Key disciplines - evolutionary biology, ecology, genetics, microbiology, molecular biology, natural products chemistry

Hypotheses:
Bioprospecting driven by testing hypotheses
BIOPROSPECTING

1. This method (hypothesis testing) will yield greater numbers and diversity of leads

2. Often a “front-end” for combinatorial chemistry

3. Chemists have the tools; biologists have the leads

4. An example of an hypothesis:
Within-colony density

Disease Threat

Within-colony genetic diversity

solitary  Semi-social  social
Ecologically-focused (hypothesis-driven) bioprospecting: Ants and antibiotics
Bioprospecting and Ants: Summary

• Ants have two-tier antimicrobial system:
  • External antiseptics (→ patents)
  • Internal immune defence (→ patents)
• Rather than screen thousands of insects, use biological knowledge to focus on likely groups/habitats
• Evolutionary biology and ecology are practical commercial tools and natural history is a vast database
Bioprospecting and Ants

Ants are (novel) biological resources; in each case in commercial use

**pharmaceuticals**
**termiticide (pest control industry)**
**biological control agents (agriculture)**
**environmental monitoring (environment)**
Ecologically-Driven or Hypothesis-Driven Bioprospecting (Recall the Basic Question: Where would you expect the desired product to have evolved?)

Examples of Hypotheses:
3. Clarke 2007 PhD Thesis Macquarie Uni (foraging theory)
Modern Bioprospecting

• *E.G. Industrial Biomimetics*

“Nature is the world’s foremost designer. With billions of years of experience and boasting the most extensive laboratory available, it conducts research in every branch of engineering and science”

(J. Bar-Cohen (2007) Biomimetics, Lavoisier, France)
Bioprospecting is also carried out by many other industries: 1Manufacturing

- The Lotus Effect
- Biomimetic self-cleaning surfaces
- Patents for building paints (indoor/outdoor)
- Pipeline interiors
- Automobiles?
Engineering

- Long-distance fire detection (50km)
- Fire-Loving beetles (*Melanophila*)
- Infra-red Sensing Systems, University of Bonn
- Beilstein J. Nanotechnol. 2:186-197
Dewan et al. (2012) Nanostructured nipple arrays of moth eye facets helps to design better thin film solar cells. Doi: 10.1088/1748-3182/7/1/016003
• Wasps as drug/chemical sensors
• Pure: Entomologia Experimentalis et Applicata (2007) 122

• Applied: Biotechnology Progress (2008) 22
Adhesion technologies

Fig. 1. Terminal elements (circles) in animals with hairy design of attachment pads. Note that heavier animals exhibit finer adhesion structures.
Bioprospecting among the microbes

- **Medicine**: *Penicillium sp, Streptomyces sp, Bacillus thuringiensis*

- **Pollution control**: Cyanobacterial/Microalgal Consortia Biotech Advances (2011 29: 896-907)

- **Pestalotiopsis** First fungus to survive only on polyurethane (plastic) waste (Tarantola (2012) Science 105:217)
Bioprospecting the Microbes

• Deinococcus. Bacteria widely used for the bioremediation of radioactive waste sites. (McFarlan et al. (2000) Nature Biotechnology 18:85-90)

• Hymenoscyphus, Rhizopogon Two kinds of soil fungi that break down depleted uranium in war-contaminated soils. (Fomina et al. (2008) Current Biology 18:R375-R377)
Bioprospecting the Microbes

- *Escherichia coli* Bacteria formed into ‘biopixels’ for low cost pollution and contamination biosensors. (Prindl et al. (2012) Science 481:39-44)
Bioprospecting the Microbes

Biodiversity-based industries

- **Established:** agriculture, forestry, fisheries, tourism

- **Established but benefiting from biodiversity exploration:** pharmaceuticals, crop protection, botanical medicines, cosmetics

- **Novel and Relatively novel:** biomining, biomonitoring, bioremediation, ecological restoration, industrial biomimetics, ecotourism
What is important to modern bioprospecting?

- **Taxa** Products and industries have been derived from an immense variety of plant, animal and microbial species.

- **Environments** Polar, temperate, tropical, desert, freshwater and marine ecosystems all being actively explored.

- **Adaptations** These are the commodities in demand by many industries, especially with the advent of applied ecology and evolution.
Which taxa and what habitats should be conserved?

- Products of major commercial value have been derived from plants, animals and microbes from polar, temperate, tropical, freshwater and marine ecosystems: SO

It is not possible to predict which genes, species or ecosystems will be valuable for future bioprospecting.
Looking forward...

- Bioprospecting is **diverse** but **focused** as researchers ask: Where is the desired product likely to have evolved naturally:
- Exploration driven by ecology/evolution

Thus, exploration takes place where the adaptations have evolved; not just where there are more species.
Because bioprospecting is carried out by many kinds of industries

• The conservation of its resource - biodiversity - is in the interest of industry as well as conservationists

• So Biodiversity is very significant to Brazil’s economy (pollinators, crop protection agents, biomining, pharmaceuticals, bioremediation, industrial biomimicry etc etc)
Social Benefits from Bioprospecting

Enhances local science, scientists, funding
Enhances investment, employment

Supports environmental protection and management

• Encourages conservation in sectors not normally associated with it such as business, industry and economic development departments
CULTURAL WEALTH

• MINERAL WEALTH

• LIVING WEALTH

• IMAGINATION, AND KNOWLEDGE OF THE RESOURCE (biodiversity) IS CRITICAL TO BIOPROSPECTING
Bioprospecting and the Future

• “All we have yet discovered is but a trifle in comparison with what lies hid in the great treasury of nature”

• Antonie van Leeuwenhoek (1680)