

Welcome to this week's presentation and conversation
hosted by the
Canadian Association for the Club of Rome,
a Club dedicated to intelligent debate and action on global issues.

The Future of Medicinal Biodiversity: Plants and Other Organisms.

Our speaker today is Dr John Arnason, Distinguished Professor of Biology (emeritus) at U Ottawa, where he has researched phytochemistry, medicinal plants, & ethnopharmacology for many years, with projects in Belize, Borneo, Togo, East Timor, & Nunavut. He has also worked with Cree elders on the efficacy and safety of traditional foods and medicines for anti-diabetic complications, documenting traditionally used plants that can lowering blood glucose & overcome insulin resistance. He recently reported on medicinal plant conservation and use by Q'eqchi' Maya healers & Costa Rican colleagues. Plants, marine organisms, bacteria, & other species have provided or inspired development of many medicines. Medicinal organisms are subject to habitat loss, climate change, invasive species, & extirpation of many local populations from commercial exploitation. On a positive note, reconciliation with Indigenous people has renewed their interest in medicinal species and their collaboration on conservation in projects worldwide.

The presentation will be followed by a conversation, questions, and observations from the participants.

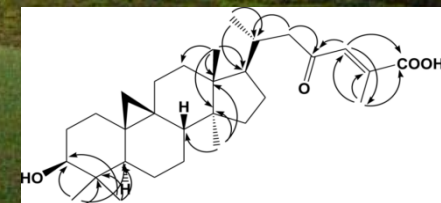
CACOR acknowledges that we all benefit from sharing the traditional territories of local Indigenous peoples (First Nations, Métis, and Inuit in Canada) and their descendants.



2022 Sep 07

Advisory

- **Yikes!!! Some natural product drugs will be shown as chemical drawings. For non-scientists, think of them as images of the complexity of the molecules which have evolved in nature**
- **Currently we are not marketing any products from our research and have no conflict of interest**
- **Email: John.Arnason@uottawa.ca**



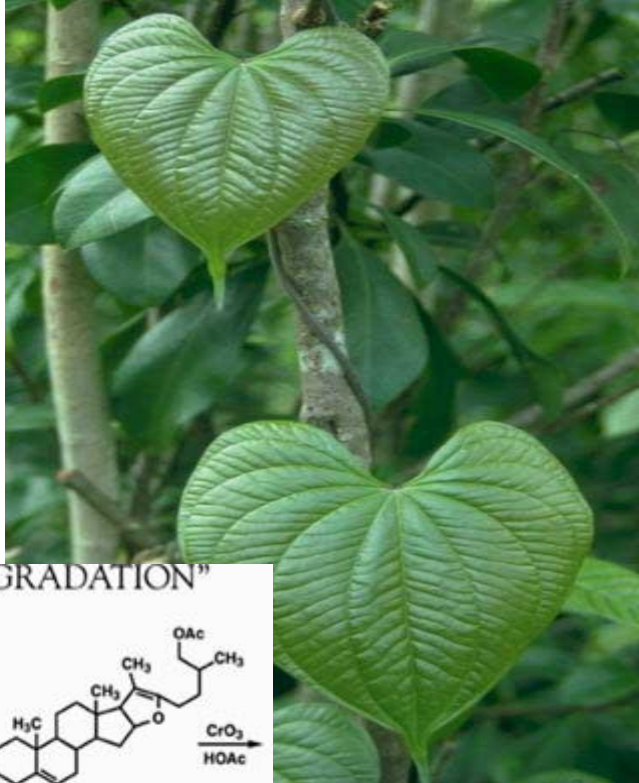
What is medicinal biodiversity and what are the issues concerning it?

- Medicinal biodiversity, is the group of plants, fungi, bacteria and marine organisms used for medicines, cosmetics and flavorings, as opposed to forestry and food uses. etc
- Medicinal biodiversity is used for:
 - 1) prescription drugs, 2) formal traditional medicines, 3) Indigenous cultural medicines (ethnobotanical medicines) 4) commercial natural health products etc.
- Case study from our research: Medicinal biodiversity is poorly explored for natural products.
- Medicinal organisms are now subject to the major threats to all biodiversity including climate change, habitat loss, and invasive species as well as commercial exploitation
- On a more positive note, conservation efforts and development of ethical standards for industry are having a positive impact. Reconciliation with Indigenous people has renewed their interest in medicinal species and their collaboration on conservation in projects world wide.
- Case study: a Maya medicinal garden in Central America

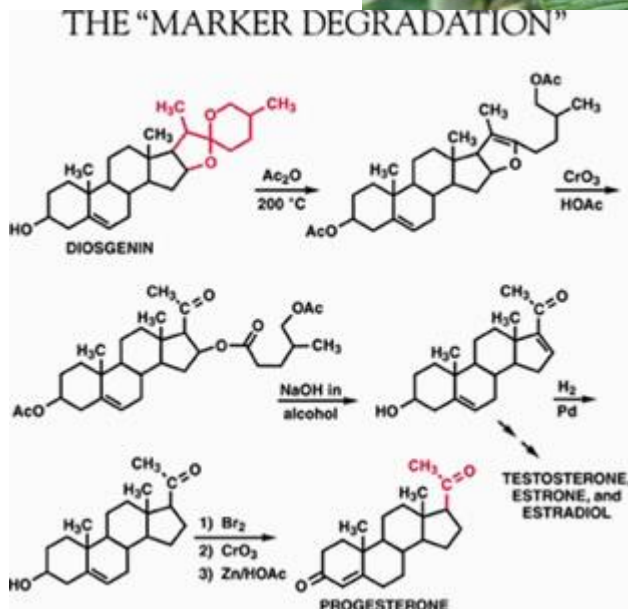
Botanical, fungal, bacterial and marine derived registered prescription drugs

- Natural products from biodiversity have historically been our main source of drugs or “leads” for drugs, with several hundred registered substances
- Even in recent decades they are the source of, or inspired synthetic analogs of 80% of newly registered “small molecule” drugs
- Plant, bacterial and fungal drugs are well established while many new drugs are coming from marine sources
- “large molecule drugs” especially antibodies derived from human and animal biotechnologies are not usually included in this but now they also being attached to natural product drugs that now act selectively with reduced side effects
- Some classic natural products from plants with societal impact follow

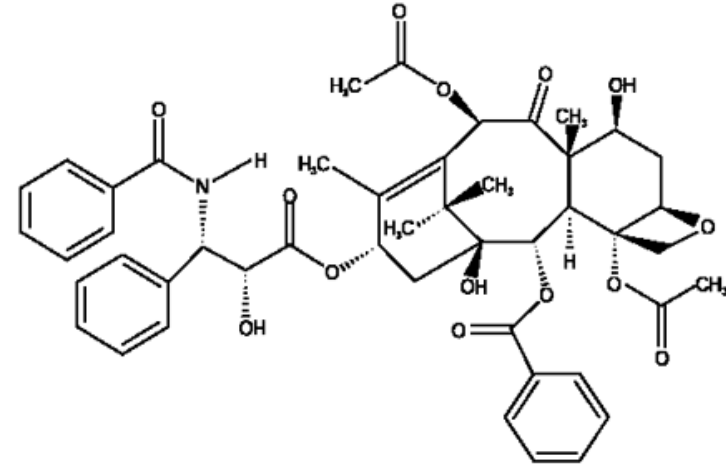
Yam, *Disocorea spp.*, source of the birth control pill



- Yam was used traditionally for treatment of female conditions in many cultures
- Diosgenin (**sterol**) content is very high
- Marker working at Syntex in Mexico City developed a chemical semisynthesis of **progesterone** from diosgenin which made the birth control pill widely accessible for the first time
- Impact: huge impact on family size, empowerment of women and society worldwide



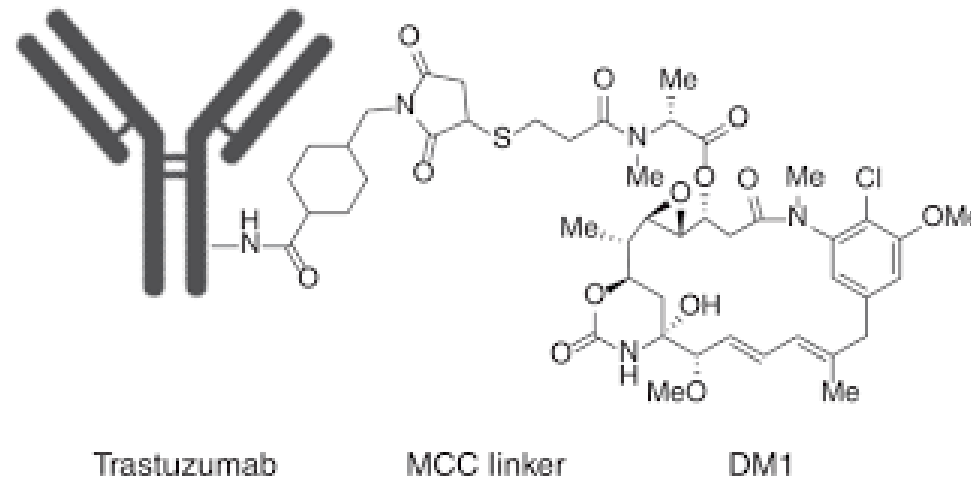
***Taxus brevifolia, brevifolia and canadensis*), the source of taxanes for preparation of the anticancer drug taxol**



- Taxol is a terpene that interferes with mitosis (division) of cancer cells
- It acts via inhibition of tubulin assembly
- It was a breakthrough treatment for breast and ovarian cancer (1993)
- Side effects and toxicity issues now being resolved with conjugates of natural products

New Antibody drug conjugates (ADCs)

- Maytansine a natural product anticancer from South American tree *Maytansus illexifolia* is used to make naturally-derived antimicrotubule agent DM1
- DMI is chemically linked with monoclonal antibody trastuzumab which targets HER2 breast cancer
- Ado-trastuzumab emtansine (T-DM1) was the first ADC approved for treating solid tumors.
- Used successfully in recurrent Her 2+ metastatic breast cancer after taxol

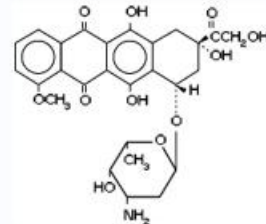


Microbial polyketides from free living soil bacteria (and symbiotic bacteria in marine organisms)

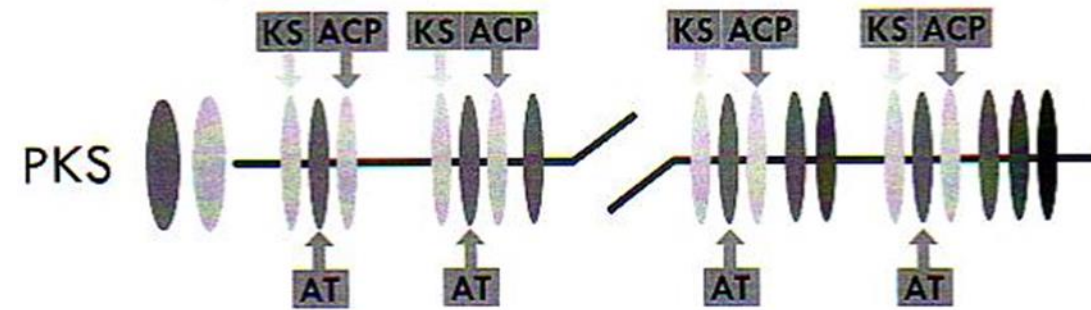
- This is a very important class of drugs with many new drugs being discovered every year
- These are found in soil bacteria such as *Streptomyces*, bacterial symbionts in marine organisms and terrestrial fungi etc.
- Synthesis is undertaken by polyketide synthase enzymes which are under control of a gene cluster which can be engineered by molecular biologists.

Adriamycin

- A soil sample was isolated from the Italian Castel del Monte, an Italian castle. A new strain of *Streptomyces peucetius*, which produced a red pigment, was isolated
- Adriamycin is an anthracycline antitumor agent, for leukemias, lymphomas
- Anti-transcription agent



The 3 repeating domains of each module are:



A "KetoSynthase" enzyme or KS

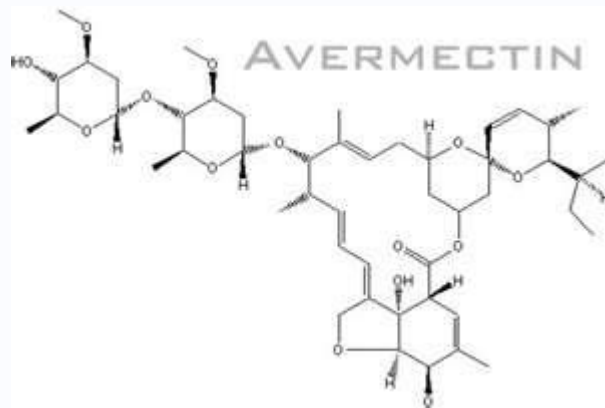
An "Acyl Transferase" enzyme or AT

An "Acyl Carrier Protein" or ACP

Ivermectin/ avermectin from Streptomyces



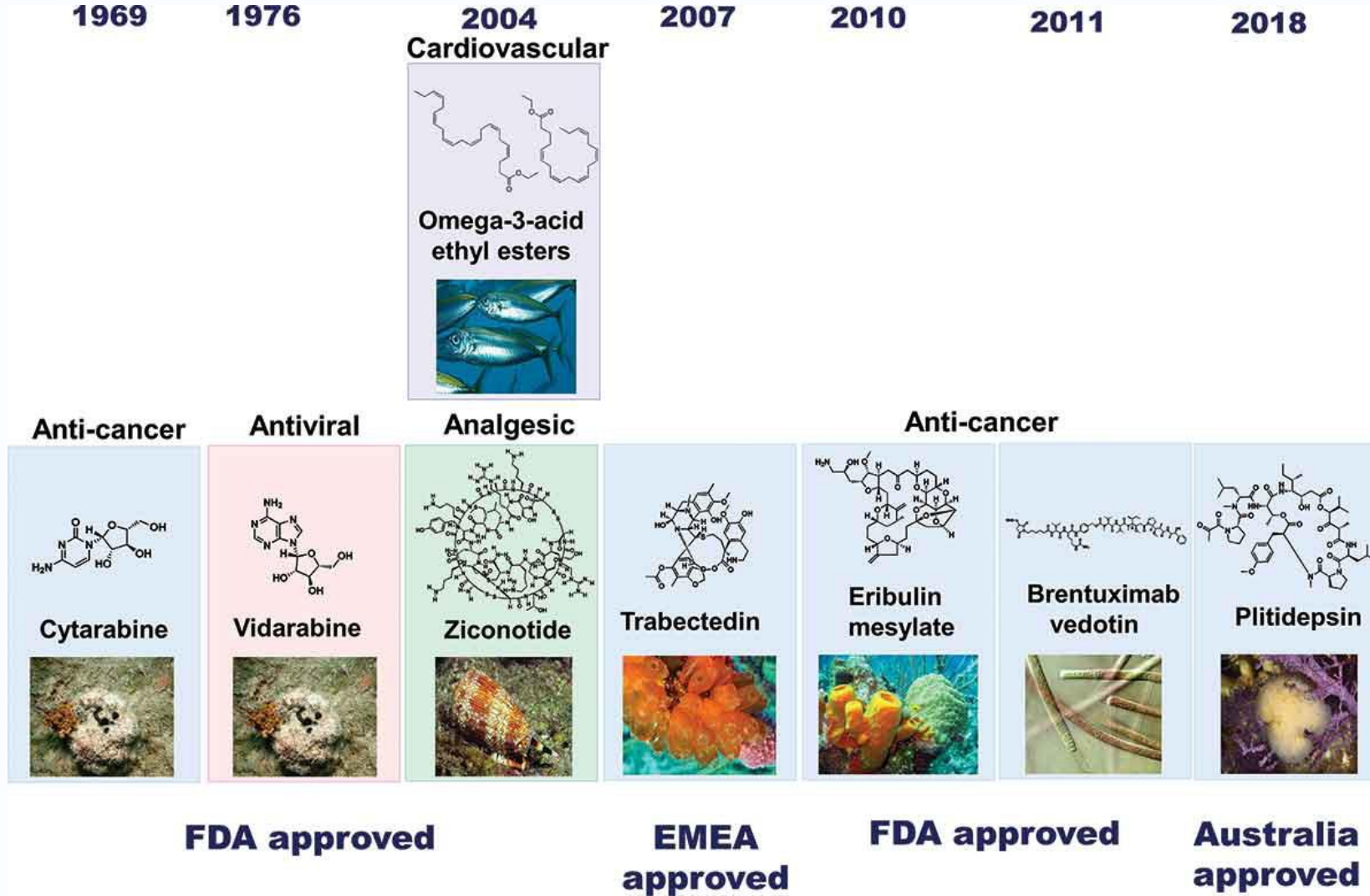
- Antiparasitic/insecticidal
- Effective to treat heartworm in dogs (nematodes)
- Merck donated supplies for river-blindness control in Africa
- Avermectin is used as insecticide
- Not effective for covid 19



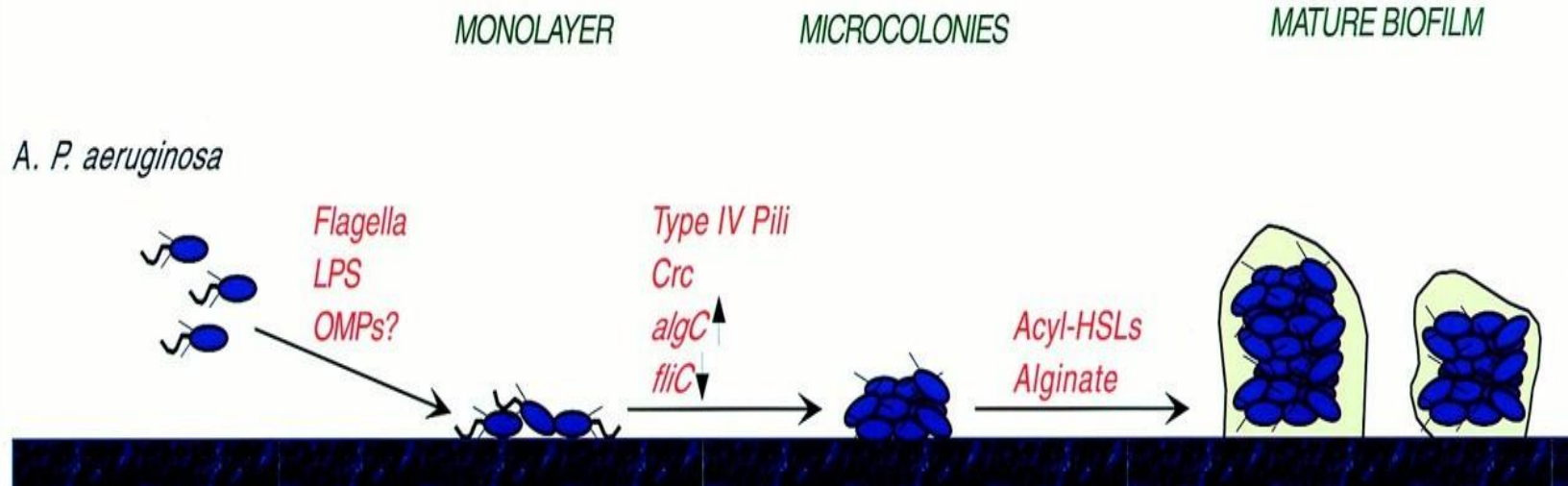
Marine drugs

Marine Natural Products and derivatives approved drugs, their chemical structures, biological sources, and clinical applications.

(from: F. Pereira EXPERT OPINION ON DRUG DISCOVERY 2019, VOL. 14, NO. 8, 717-722)

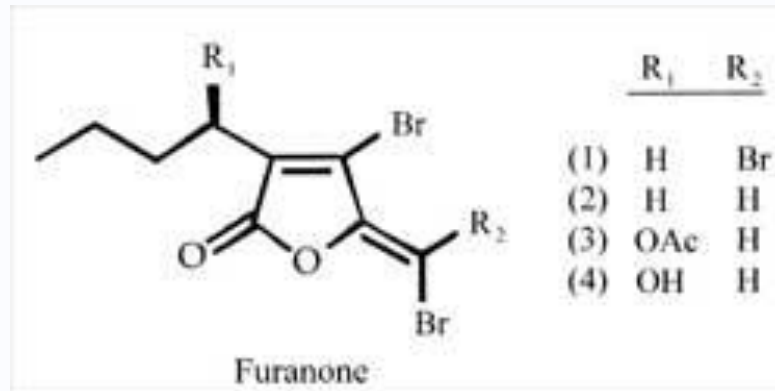


Red algae, *Delisea pulchra* makes a furanone which inhibits bacterial biofilm formation



Bacteria communicate by “quorum sensing” via Acyl HSL leading to congregation in biofilms which are difficult to treat with antibiotics

Algae and some plants can inhibit Biofilm formation- a novel approach for bacterial treatments with promise in humans.



2. Traditional Medicines from major civilizations

Medicines of codified, recorded systematic botanical knowledge of major civilizations with written tradition:

- Traditional Chinese medicines (TCM)- 2,598 official monographs of single plant (or fungus)
(represents about 40% of national health care in China)
- Ayurvedic medicines of India, Pakistan and Sri Lanka
- Kampo medicines in Japan, Arabic and Persian medicines in middle east
- culturally and therapeutically important to host cultures, in historic urbanized organized societies, while often dismissed in Western countries, they are important part of health care and culture in other societies.
- TCMs etc are undergoing advanced pharmacological and clinical assessment for example as crude drugs for adult onset diabetes treatments, see:

Chen, Huang, Yu and Arnason, 2022. **Medicinal Plants and Their Active Constituents in the Treatment of Metabolic Syndrome** <https://www.frontiersin.org/research-topics/21916/medicinal-plants-and-their-active-constituents-in-the-treatment-of-metabolic-syndrome>

- TCMs are allowed when licensed as safe self care Natural Health Products in Canada but not allowed as drugs unless purified to a single ingredient.

Representative TCMs

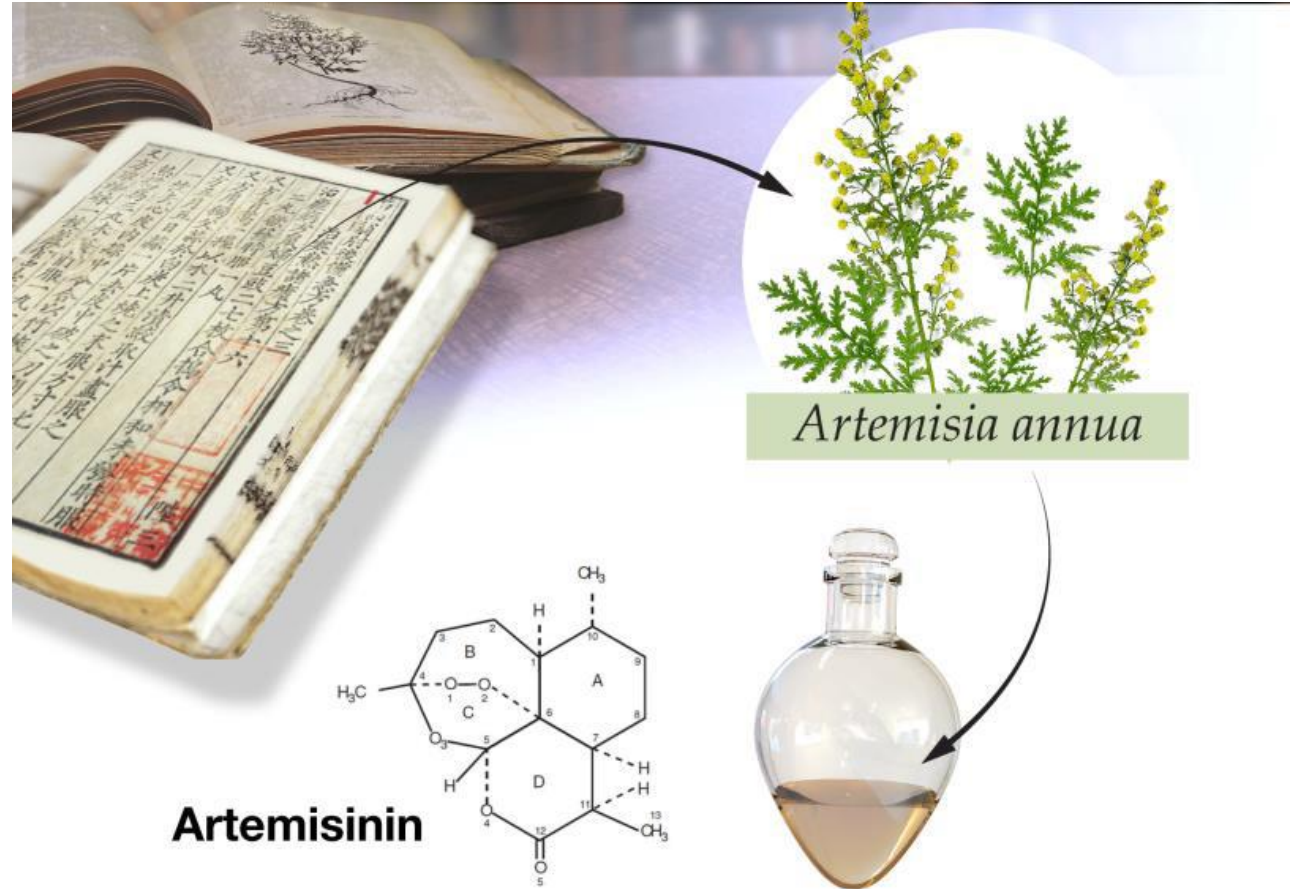
1. Chrysanthemums Flower 2. Kudzu vine Roots 3. Thunder God Vine 4. Danf Shen 5. Du Huo
6. Indian Bread With Hostwood 7. Chai Hu 8. Isatis Roots 9. Go Ji

Raw materials for TCM preparation



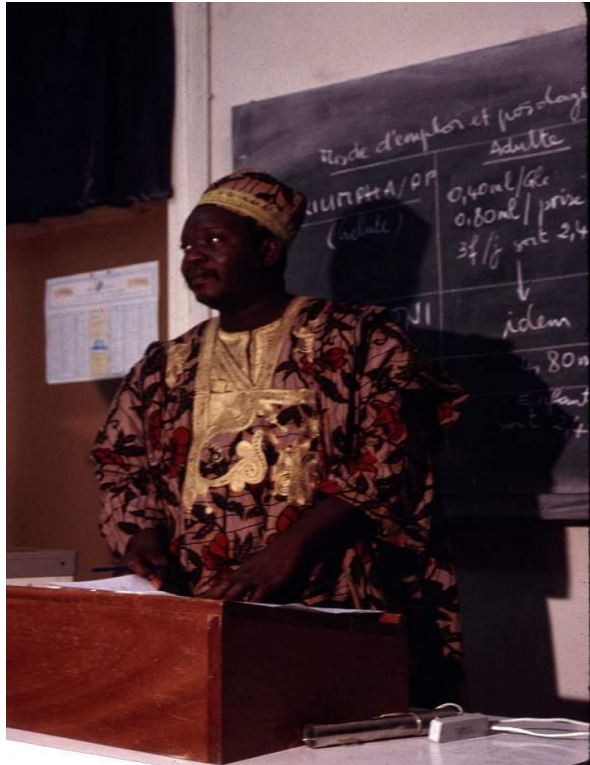
The 2015 nobel prize was awarded to Youyou Tu for discovery and development of antimalarial drug artemesin from a TCM

- *Artemisia annua* (*Quinhou*) was used in Traditional Chinese Medicine for fever
- Tu found the plant extract and it's active compound, artemisinin, had antimalarial activity
- She undertook clinical trials
- Artemisinin is 500x more active than quinine and effective against chloroquine resistant malaria
- Adopted by WHO for worldwide use against resistant malaria



3. Traditional (ethnobotanical) medicines in indigenous cultures

- WHO estimates indigenous cultural medicines provide 80% of medicines used in primary health care worldwide
- Knowledge is orally transmitted from elders rather than written or codified



In Africa, healers often hold university degrees, but learn trade as apprentice to elders.



In Indonesia, women are important healers.

In the Americas, traditional medicine is important in Indigenous communities and populations in rural Latin America

- In Indigenous societies, traditional healers (elders) remember and pass down by oral tradition to family members ~200 species of medicines (generalists)
- A culture can maintains knowledge of 800-1000 species through specialists: ex women-dye plants, cures for infants etc., men- hunting, construction, primary forest habitats, shamanistic healers with ritual and secret knowledge
- Knowledge is embedded in cosmovision worldview and traditional concepts



In the Americas, medicinal plants are sacred and a gift of tobacco is given in return for the gift of healing.

Ethnobotanists have transcribed previously unwritten plant uses.



Indigenous Maya healers and students with ethnobotanist Brendan Walshe Roussel



Amazonian healer demonstrating a administration of snuff to ethnobotanist Richard Evans Schultes

Ayahuasca-western Amazon

- An orally administered hallucinogen used for ritual healing
- Used in Western Amazon, ex by the Jibaro of Ecuador
- Binary drug with 2 plants containing N, N dimethyl tryptamine and other beta carboline alkaloids
- Now being used in experimental treatments for addiction

The two botanical components of the binary hallucinogen
"Ayahuasca" ("Caapi", "Yage")



Banisteriopsis caapi (Malphiaceae)



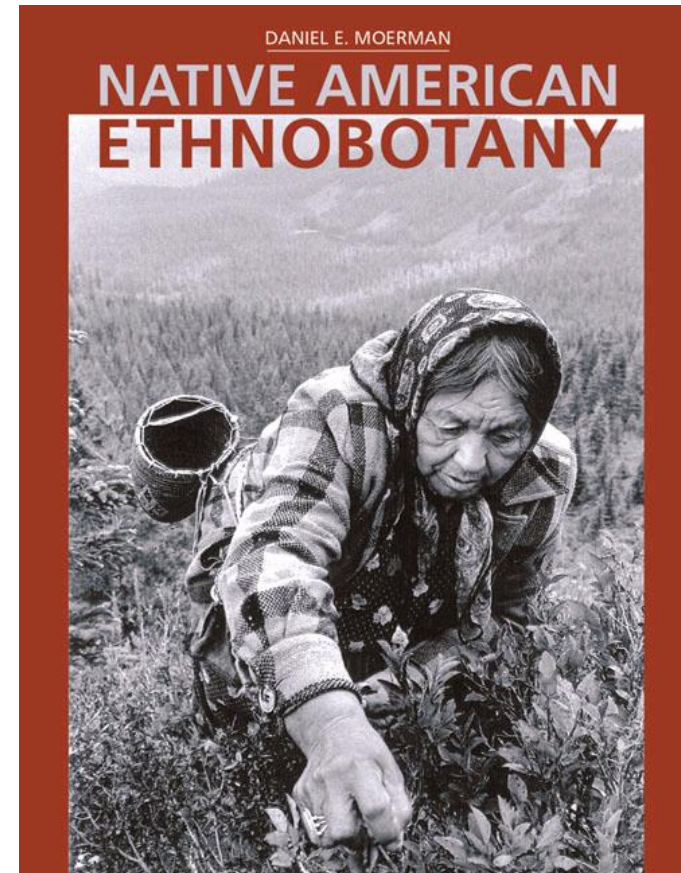
Psychotria spp (coffee family).



How extensive is indigenous knowledge of plants: recorded knowledge in N. America

D. Moerman, 2003 Native American Ethnobotany, Timber press

	#species	#uses
Medicinal	2, 582	24,945
Dyes	217	607
Food	1,649	11,078
Fibre	442	2,567
Other	1,074	5,494
Total	4,029	4,4691



- Ethnobotanical references to use and biological activity>> scientific references
- Other areas similar: The Mesoamerican database- 2188 medicinal plants
- Eastern Canada 400+ medicinal species 1700 uses

4. Commercial Herbal Natural Health Products, and Dietary Supplements in US and Canada



American Ginseng



Echinacea

- Regulated by NHP legislation in Canada and DSHEA in US
- Commercial value of these products in 2019 was estimated at 9.6 Billion with 8.6% increase over previous year
- Top sellers in US: CBD oil, turmeric, elderberry, wheatgrass, Ashwaganda, Aloe, flax, echinacea, milk thistle, oregano, cranberry, saw palmetto
- Top export from Canada: ginseng
- T Smith, 2019 HerbalGram 127:54-69

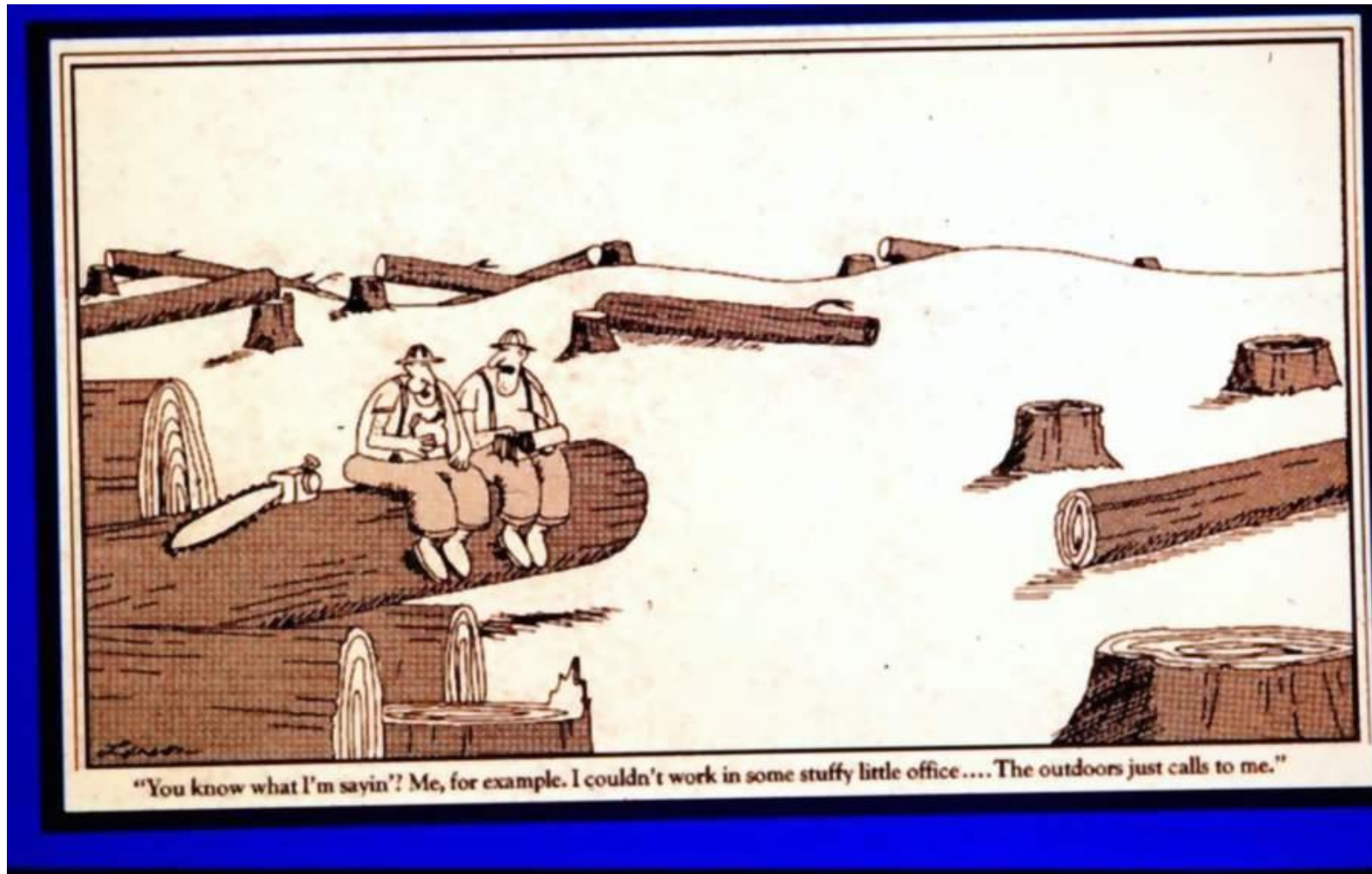
How well has medicinal biodiversity been explored?

Case study: our own research on plants shows many medicinal plants to discover



Arnason and Durst (uOttawa) have a 20 year collaboration with Costa Rican Botanists: Profs Luis Poveda, Pablo Sanchez and Marco Otarola at the Universidad Nacional

**Poveda and Sanchez: “find something in tropical forests
or they will cut them all down”**



Forestry guy says: You know what I am saying, I couldn't work in some stuffy little office, the outdoors just calls to me

Our focus for discovery is on rare families:

- 1) A “dereplication” strategy to find new biologically active phytochemicals
- 2) A way to highlight conservation value of forests by showing potential value of rare species in them.

**A new tree species from Osa Peninsula called “caracolito”
Ruptiliocarpon caracolito (Lepidobotyaceae) reported in National geographic**



Geographica

When botanists in Costa Rica were surveying plants, they stumbled across an unfamiliar tree with pointed leaves (below). New to science, *Ruptiliocarpon caracolito* belongs to a family of trees previously known only in Africa.



MARK THIESSEN

When screening >100 tropical plants for insect Antifeedant activity we found it was the most active of all. Feeding activity of cornborer on corn inhibited

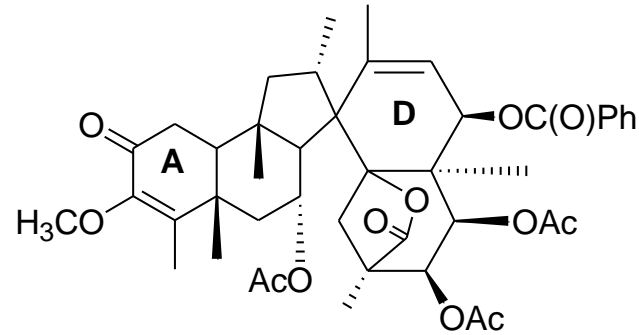


extract

Control



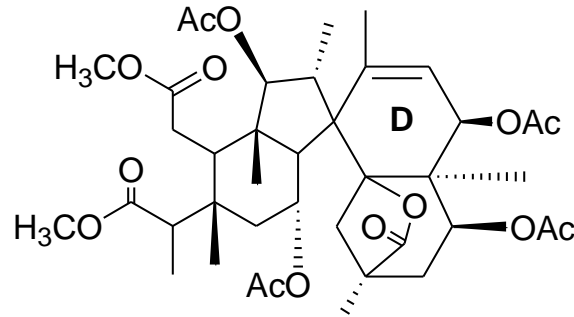
Bioassay guided isolation by lead to novel insecticidal and antiparasitic spiro triterpenoid compounds: 17, at least!!! . Nat. Prod. , 70(8): 1228-1232



Spiro-A

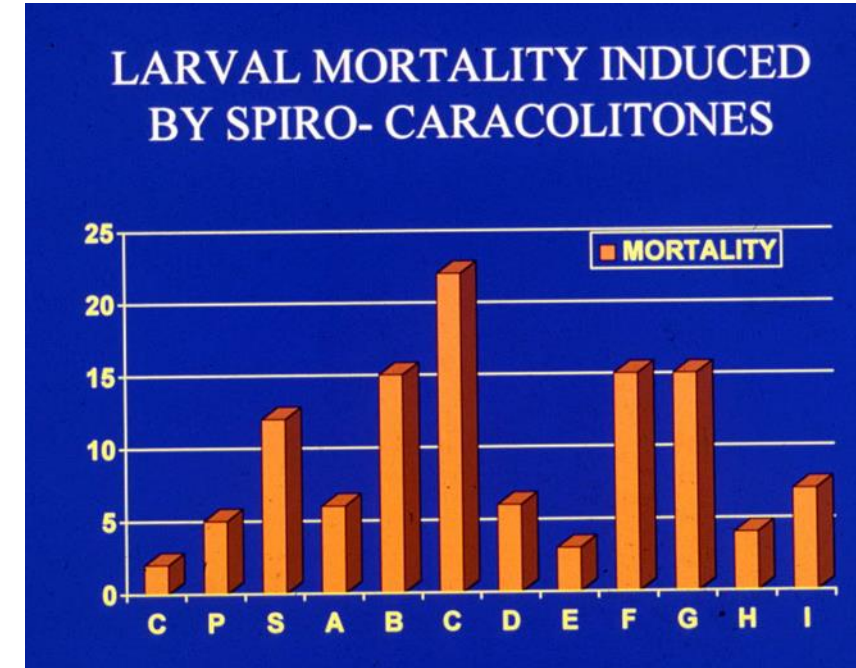
Spiro B,C and D

Different oxidation patterns
additional tertiary acetate in ring D,
benzoates, replacing acetates



Spiro E, Ring A cleaved

Spiro F, G, H, variations of E



Ring A cleaved derivatives are most active as anti feedants - approach Azadiractin.
Activity of mixtures of all is more active than the sum of the individual activities

Synergy/ Biochemical redundancy

S. MacKinnon

Compounds originally discovered by Dr Shawna Mackinnon, now at Agriculture Canada .

Pleodendron costaricensis (Canellaceae)
a new species from a rare family



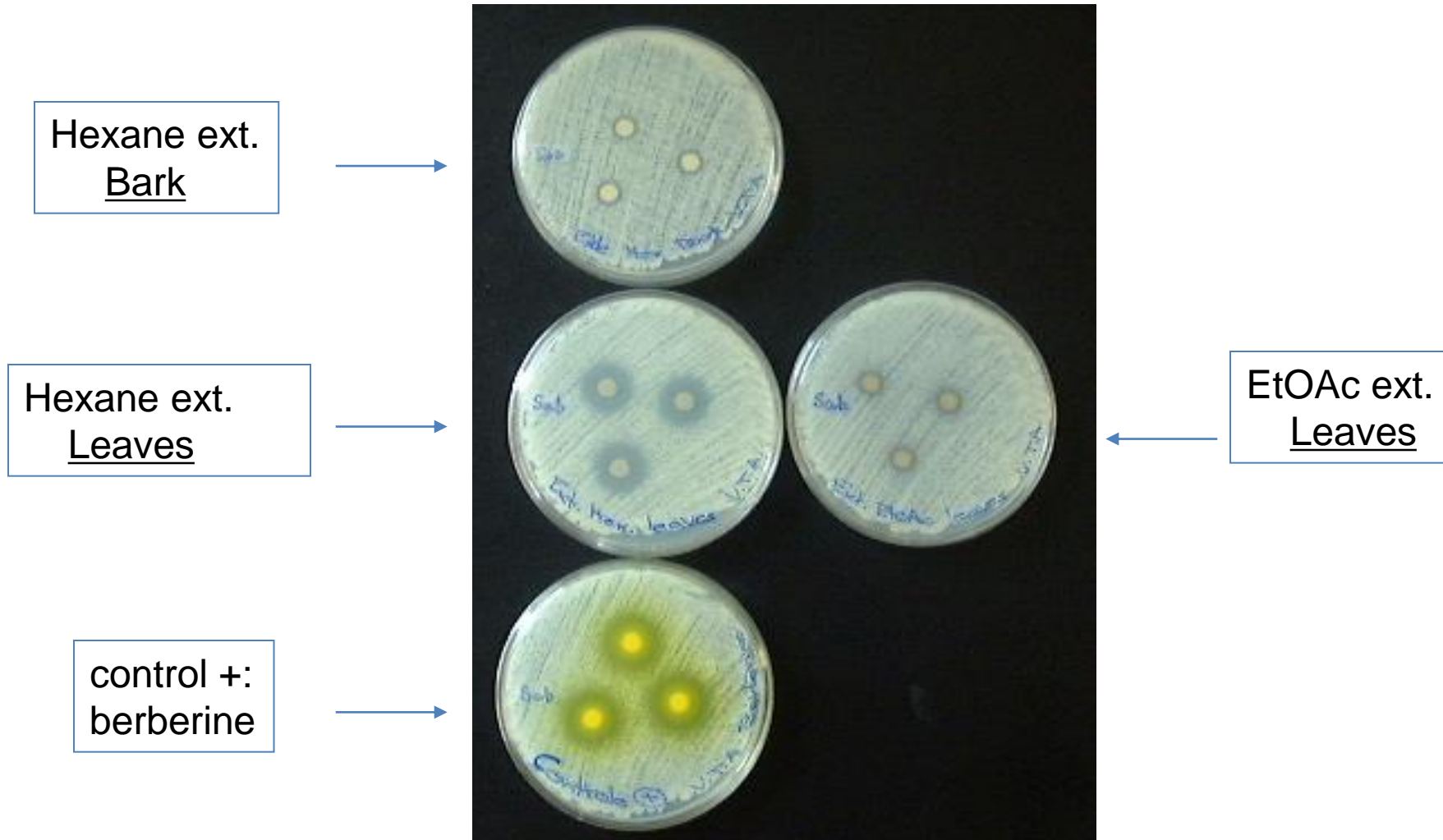
*Poveda and Nunez (UNA) with
Pleodendron costaricensis
(Canellaceae) a new species
from Costa Rica's from hyperwet
montaine and cloud forest:
Potential source of antimicrobials*

Screening with multidrug
resistant and opportunistic
fungi isolated from immuno-
compromised patients



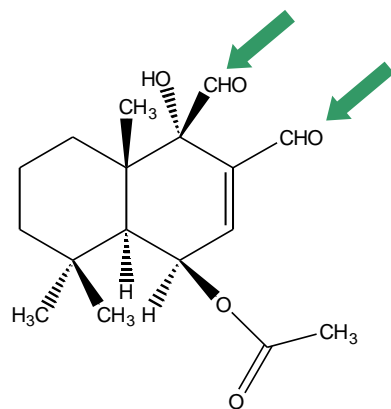
Active extracts of *Pleodendron* (Canellaceae)

against *Candida albicans* (Cal), *C. albicans* (resistant) (CN1A and D10),
Cryptococcus neoformans (Cne), *Trichophyton mentagrophytes* (Tme)



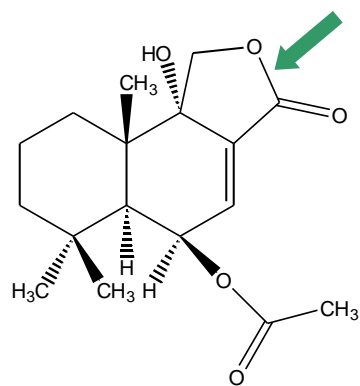
Purified compounds

From:



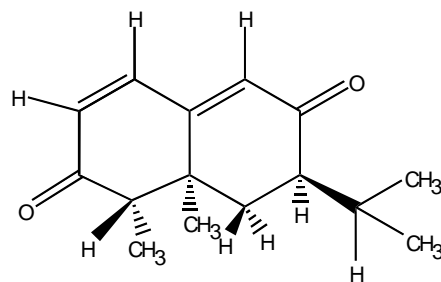
cinnamodial
drimane-type sesquiterpene
(dialdehyde)

Leaves and bark



cinnamosmolide
drimane-type sesquiterpene
(lactone form)

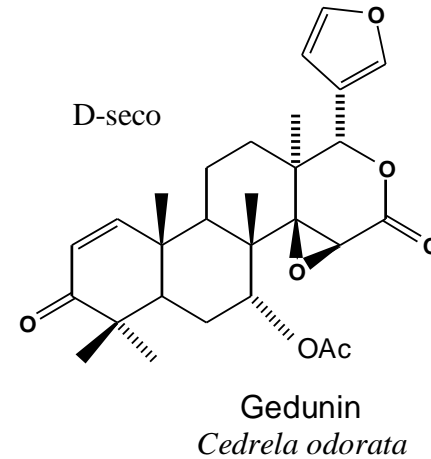
Leaves and bark



new eremophilane-type
sesquiterpene

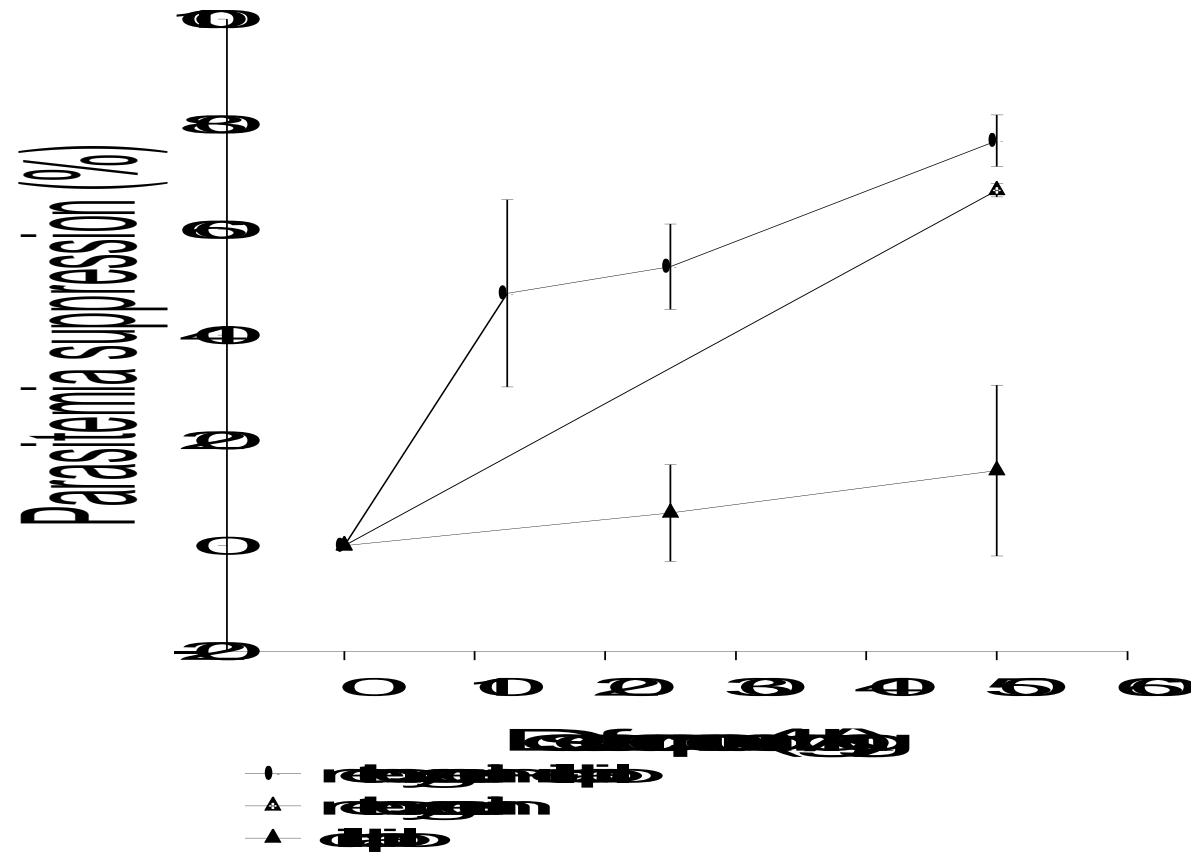
Bark

Cedrela odorata



- Spanish cedar bark was used for fever treatments
- We isolated the terpenoid gedunin
- It was more active than chloroquine in antimalarial tests

Improvement of gedunin as antimalarial drug tested in mice with malaria

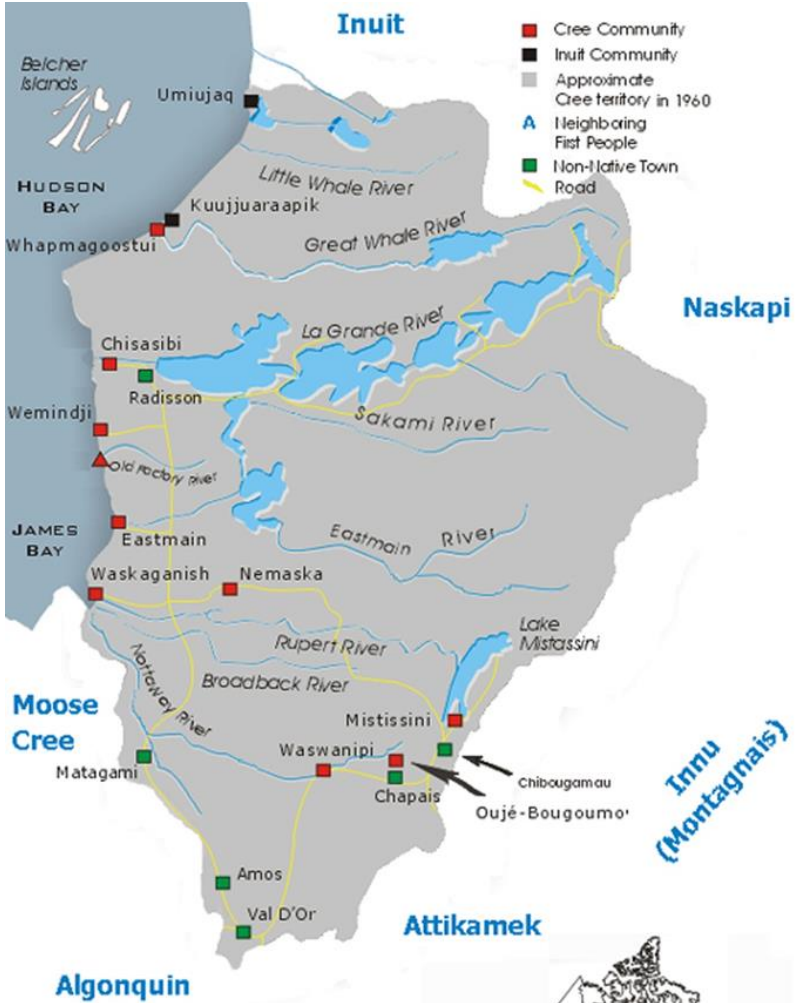


- antimalarial activity was improved by preparing a more stable derivative
- 7-methoxy gedunin (alone) has better activity than gedunin (alone)
- further improved when synergized by dillapiol

Case study #2 Indigenous Medicinal plants used by Cree (CIHR Team in Aboriginal Antidiabetic Medicines) (5 labs: 2006-2010, 2016-2022)



Cree Health Board requested help with type 2 diabetes



A people in transition



Traditional foods & active life



Refined food & sedentary life

- Type 2 diabetes incidence has exploded in Cree communities
- Many Cree diabetic patients were not taking their prescribed western medicines
- Cree health board asked for help with exploring culturally acceptable alternatives

Medicinal and wild food plants still have an important modern role in Cree and communities, but losing ground to commercial food products

We hypothesized that plant foods and traditional medicine beneficial for type 2 diabetes



Cree healers with traditional medicines in N Quebec
The law upholds the right of First Nations to use traditional medicines on reserve

We found that Showy Mountain Ash is one of several traditionally used medicinal plants that have antidiabetic activity:

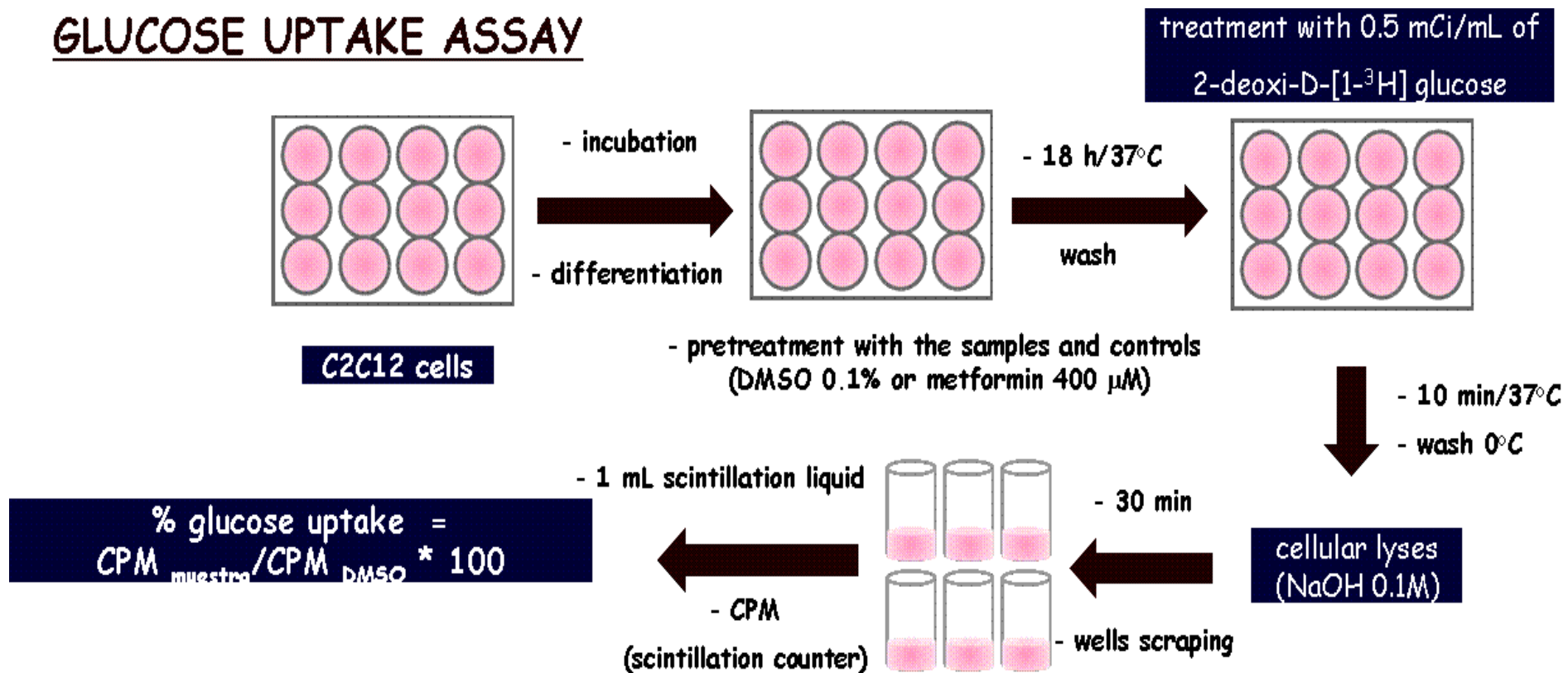
It enhances glucose uptake in muscle

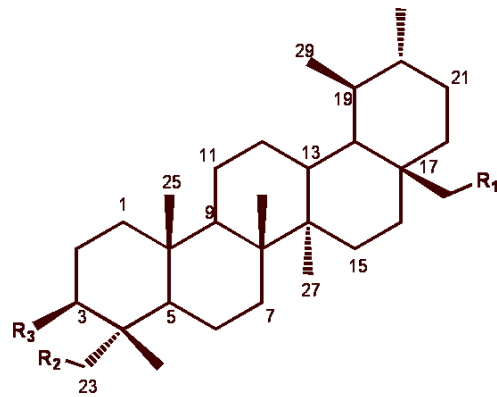


Bioassay-Guided Isolation of the Antidiabetic Principle from *Sorbus decora* (Rosaceae) Used Traditionally by the Eeyou Istchee Cree First Nations

Jose´ A. Guerrero-Analco, Louis Martineau, Ammar Saleem, Padma Madiraju, Asim Muhammad, Tony Durst, Pierre Haddad and John Thor Arnason. *J. Nat. Prod.* **2010**, *73*, 1519–1523

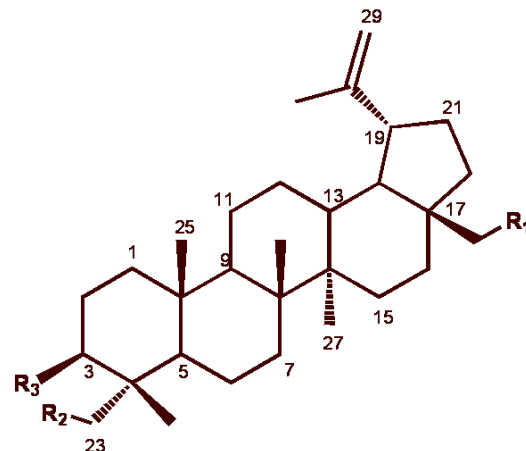
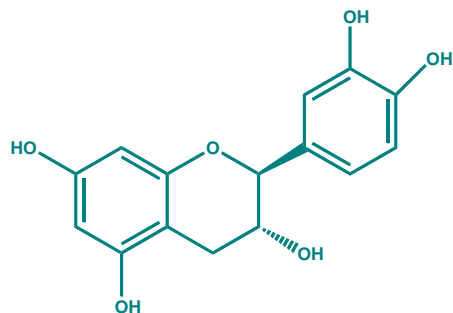
GLUCOSE UPTAKE ASSAY





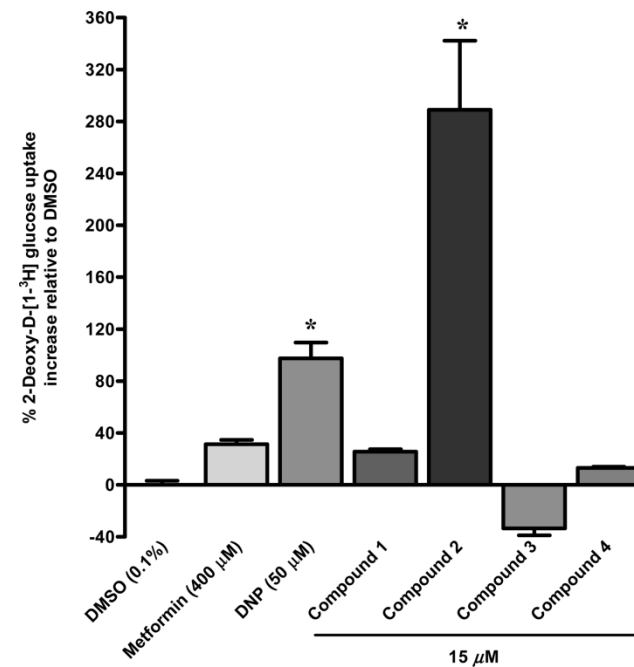
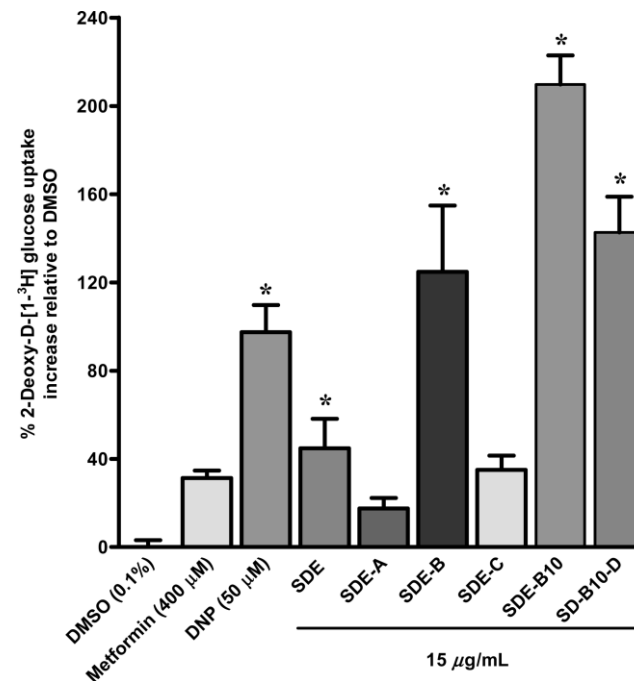
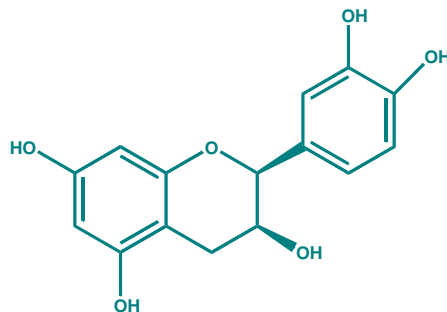
- 1 R₁ = OH R₂ = OH R₃ = O-caffeoyl
 3 R₁ = OH R₂ = OH R₃ = OH
 5 R₁ = OH R₂ = H R₃ = OH
 7 R₁ = H R₂ = H R₃ = OH

9 (+)-catechin



- 2 R₁ = OH R₂ = OH R₃ = O-caffeoyl
 4 R₁ = OH R₂ = OH R₃ = OH
 6 R₁ = OH R₂ = H R₃ = OH
 8 R₁ = COOH R₂ = H R₃ = OH

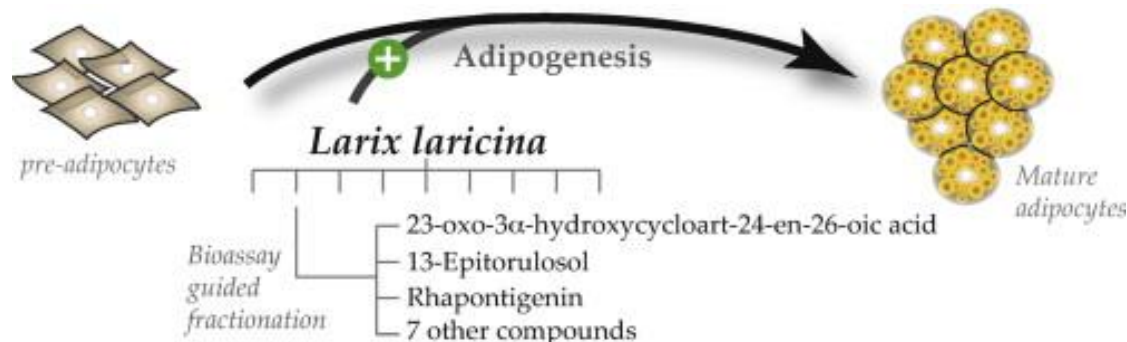
10 (-)-epicatechin



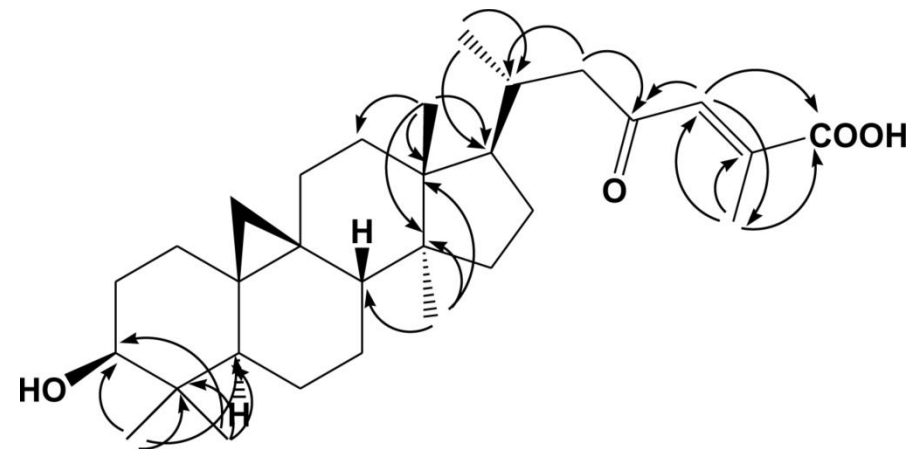
Bioassay-Guided Isolation of the Antidiabetic Principle from *Sorbus decora* (Rosaceae) Used Traditionally by the Eeyou Istchee Cree First Nations

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Tamarack is also used for diabetes and we isolated compounds that stimulate adipogenesis (rozaglitazone-like drug activity)



- PDF Jose Antonio Guerrero isolated a novel adipogenic compound, 23-oxo-3-hydroxycycloart-24-en-26-oic acid from tamarack
- (shown) with HMBC (H \rightarrow C) correlations)
- Insulin and this compound promote healthy lipid cells and act as anti-obesity drug
- appetite control and insulin sensitivity effects



Conclusion: Cree medicinal plant legacy

www.taam-emaad.umontreal.ca/

- **5 plants very effective in diabetic animal models, and safe**
- Several novel antidiabetic compounds, ex. 23-oxo-3-hydroxycycloart-24-en-26-oic acid isolated from tamarack
- The compound has been named **Awashishic acid** in honour of Cree healers **Sam and Minnie Awashish**
- Rather than making drugs, Cree healers will use the plants for public health: traditional medicines & food
- Currently, we are working with 4 communities to restore traditional foods and medicines along with traditional exercise programs to reduce diabetes. Results are promising



Minnie Awashish



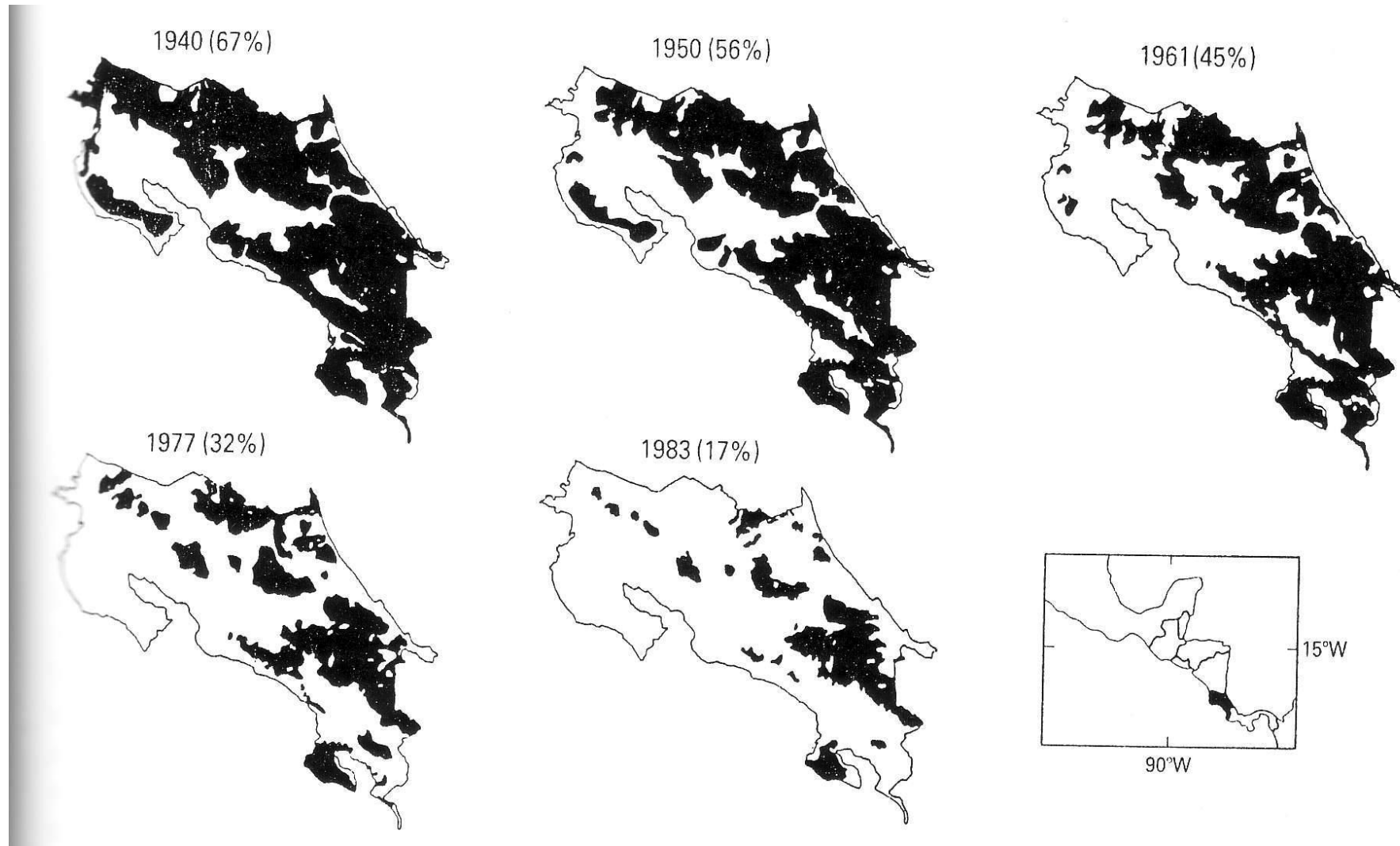
How well has medicinal biodiversity been explored- literature data?

- the work is far from complete:
 - So far, 400,000+ plant species worldwide have already been cataloged (nearly complete)
 - only 6% have been investigated pharmacologically and 15% phytochemically (Atanasov et al., *Biotechnol. Adv.* 33, 1582–1614.).
 - About 50,00 plant natural products (phytochemicals) are recorded in public databases like KNApSACk but many more remain to be discovered.
- Fungal and Marine species are only partially cataloged, and scientific study of their natural product is still in a very active discovery phase.
- The number of bacterial species is completely unknown and it is thought the majority are yet to be found and described, especially from extreme or exotic environments. For example molecular biologists estimate **4000 bacterial species in 1g of forest soil**- most are undescribed species. Those studied for natural products are among the most active sources of drugs.
- They are potential source of new targeted therapies possible due to advances in biotech
- Bear in mind diversity is greatest in tropics: For plants 68% are tropical
- **Will we lose the majority of medicinal organisms before they are ever studied?? -**

What are the threats to and issues with medicinal biodiversity?

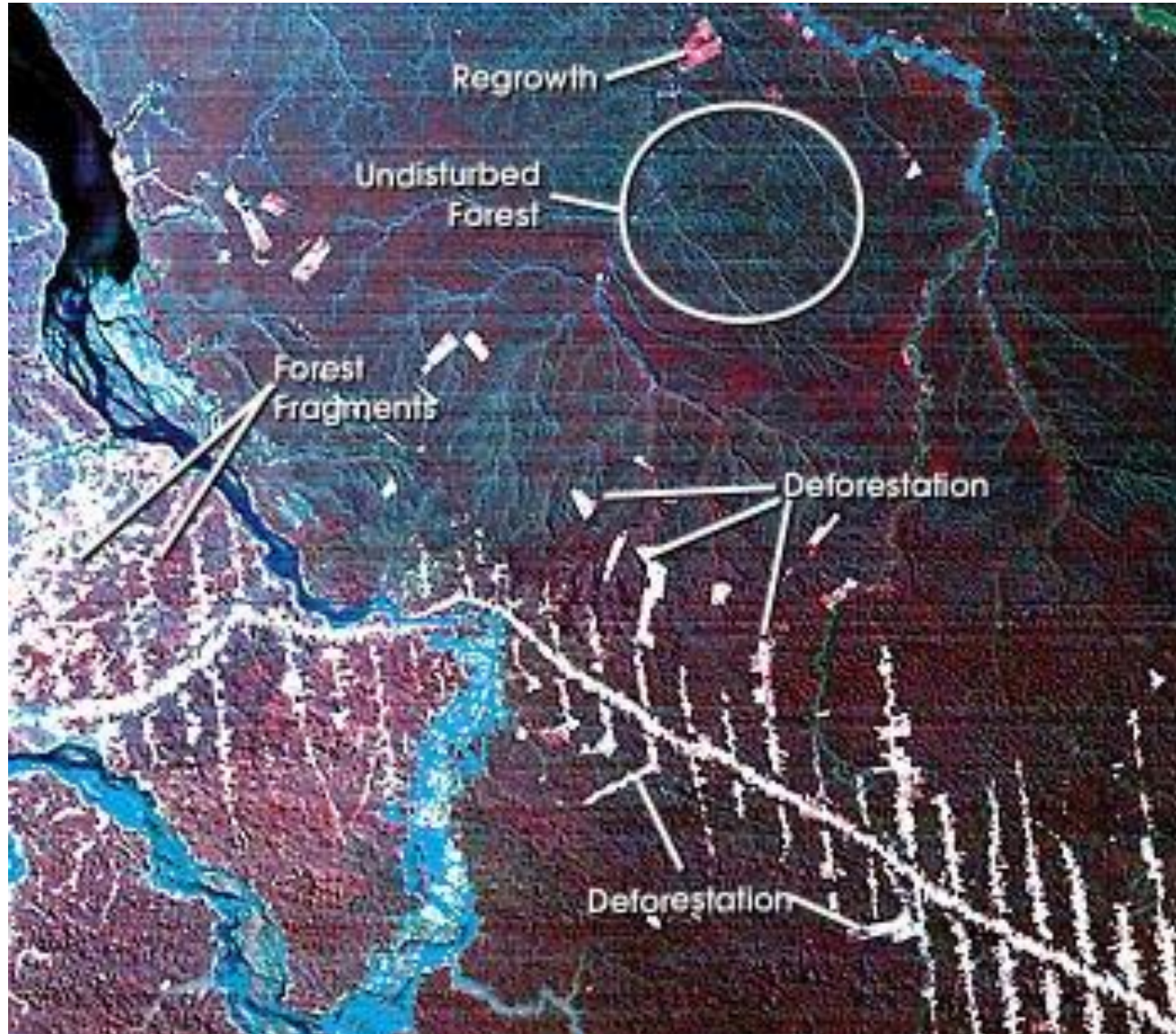
1. Habitat loss (conversion to agriculture, logging, habitations, industrial sites etc,)
2. Over harvesting
3. Climate change
4. Invasive species
5. Disputes over ownership and regulation

1. Habitat loss

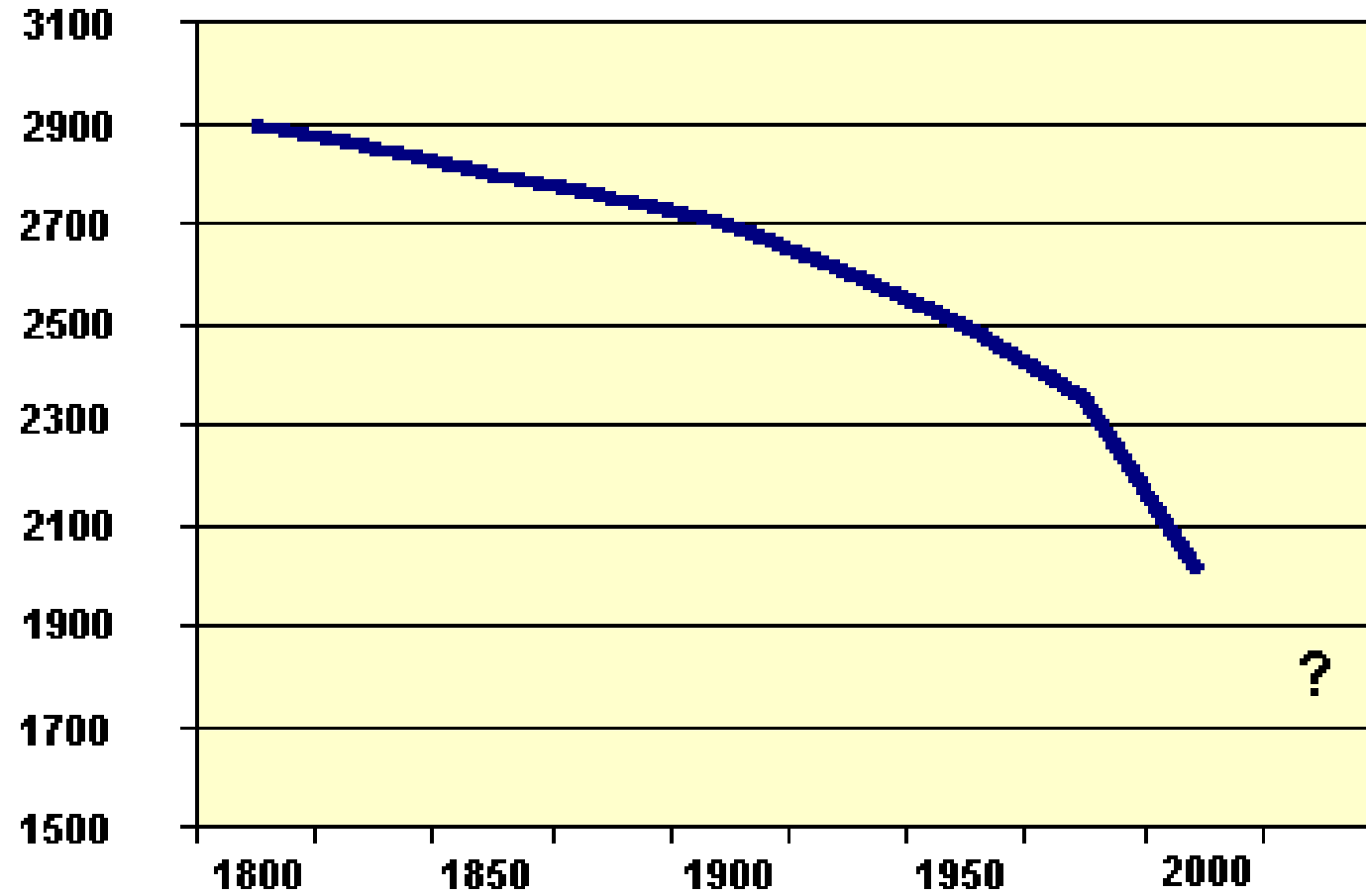


Forest fragmentation and conversion to Agriculture in Costa Rica 1940-1983

A major effect of logging in the Amazon is the creation of access roads which bring migrants farmers and ranchers in to further fragment the area



Area of Tropical Forests (millions of hectares)



Accelerating rate of forest loss

Deforestation by country

J.Roper and R.W. Roberts: Tropical forests in decline

www.rcfa-cfan.org/english.12html

Deforestation complete

Africa

- 26 countries

Asia

- Philippines
- Pakistan

L. America

- El Salvador
- Haiti
- Paraguay

Top ten deforesters

1. Brazil
2. Indonesia
3. Congo
4. Bolivia
5. Mexico
6. Venezuela
7. Malaysia
8. Myanmar
9. Sudan
10. Thailand (now logging ban)

Consequences of habitat loss for medicinal species

- Older healers in Belize report scarcity of medicinal plants
- Healers in Togo report complete extirpation of prized medicinal species with loss of forest
- Biodiversity extinction is predictable (EO Wilson, Future of Life):

Relation between #species, S that can survive long-term in an area of habitat, A is derived from:

$$S = cA^z$$

where $z, c = \text{constants}$

- Large numbers of species cannot survive in small patches of natural habitat but extinction is slow
- Extinction is already predicted to reach 50% by end of century due to current reduction in habitat



Maya healers report fewer medicinal plants compared to a decade ago



Extirpation of forest medicinal species reported By Elders in Togo

2. Commercial Trade - overharvesting

Medicinal plants exported from S. Africa (tons/yr)

- Total exports estimated - 27 000 tons
 - Devils claw tubers (arthritis)- 800 tons
 - Aloe gel/crystal (skin)- 700 tons
 - *Prunus africana* (*pygeum*)(Prostate) bark - 3 000 tons
 - *Boswellia* (Frankinsense) resin - 8 000 tons
 - Around 30 species actively traded, including *Catha*, *Cassia*, *Terminalia*, *Pelargonium*, *Hoodia*
 - Many others which remain confidential
- Before 2000, commercial export to Europe was largely unregulated
 - Local extirpation of many of the wild harvested species was reported
 - Devils claw, pygeum and fankincence depleted
 - Similar experiences in Asia and Americas
 - In Canada overharvesting affects American ginseng, echinacea, goldenseal and wild leak



3. Global warming effects on species diversity

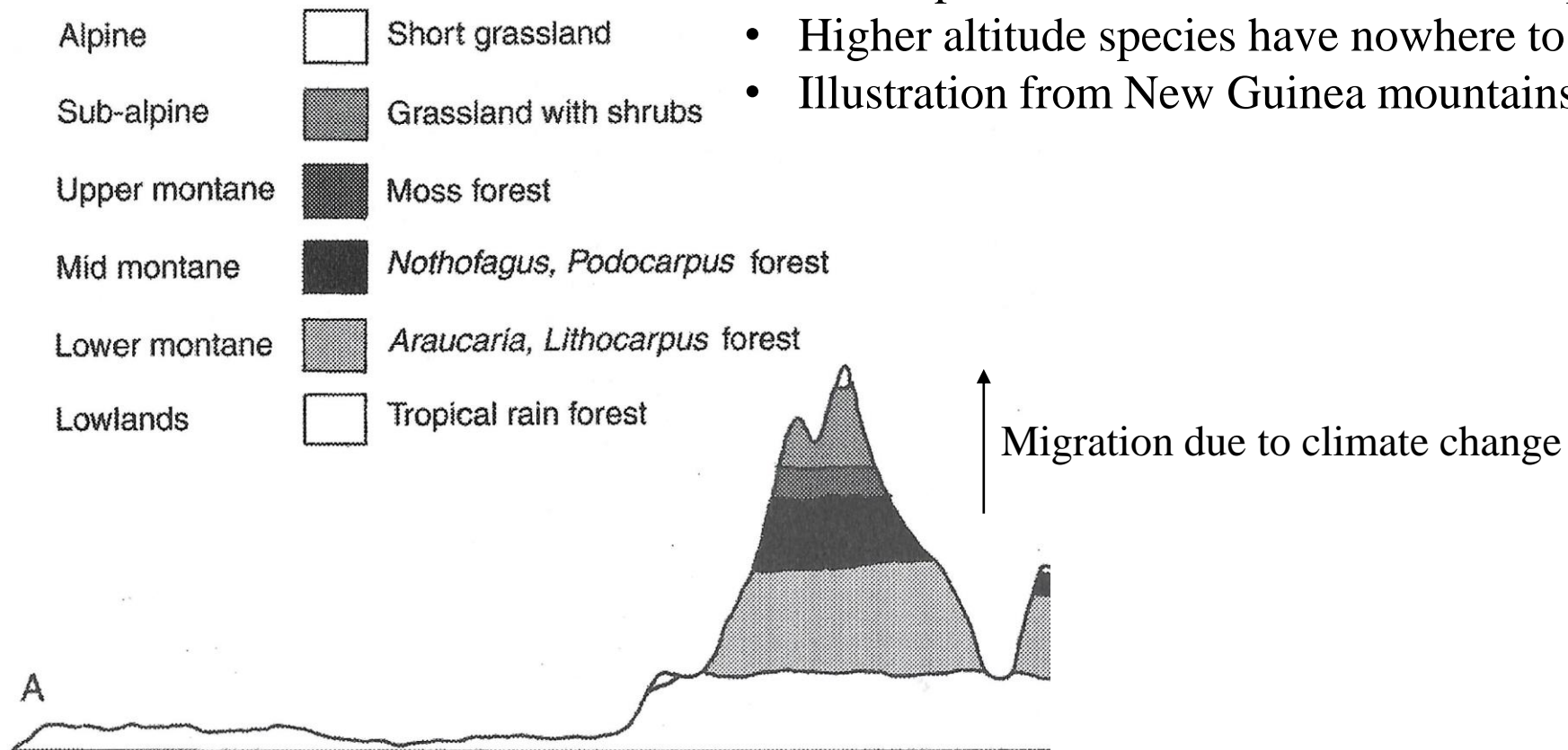
- Biomes will move north in latitude and up in altitude as climate changes
- Endemic species (local to a specific area) are most threatened because they are poor dispersers and are expected to go extinct
- “Finbos” in S Africa is a natural shrubland with isolated Mediterranean climate and many endemics
- It is seen as key threatened area as warming pushes its climate envelope into the Indian Ocean



The Finbos has unusual plants seen nowhere else

High altitude endemic species are especially threatened by global warming

- Montaine to alpine zones have many endemics due to isolation
- As temperatures increase, zones move up mountains
- Higher altitude species have nowhere to migrate and will go extinct
- Illustration from New Guinea mountains but widely applicable



Where are threatened endemics?

Table 3 Leading hotspots in terms of endemics

Hotspot	Endemic plants (% of global total, 300,000)	Endemic vertebrates (% of global total, 27,298)
Tropical Andes*	20,000 (6.7)	1,567 (5.7)
Sundaland*	15,000 (5.0)	701 (2.6)
Madagascar*	9,704 (3.2)	771 (2.8)
Brazil's Atlantic Forest*	8,000 (2.7)	567 (2.1)
Caribbean*	7,000 (2.3)	779 (2.9)
Sub-totals (% rounded)	59,704 (19.9)	4,385 (16.1)
Mesoamerica	5,000 (1.7)	1,159 (4.2)
Mediterranean Basin	13,000 (4.3)	235 (0.9)
Indo-Burma	7,000 (2.3)	528 (1.9)
Philippines	5,832 (1.9)	519 (1.9)
Totals	90,536 (30.1)†	6,826 (25.0)

* Hotspots with at least 2% of the world's endemic plants and vertebrates, and comprising only 0.4% of the Earth's land surface (all nine amount to 0.7% of the Earth's land surface).

† This would total 30.2% but for rounding of numbers in the individual hotspots.

Data from N. Meyers et al Biodiversity hotspots for conservation

Nature 403: 853-858.

J. Alan Pounds¹ and Robert Puschendorf¹

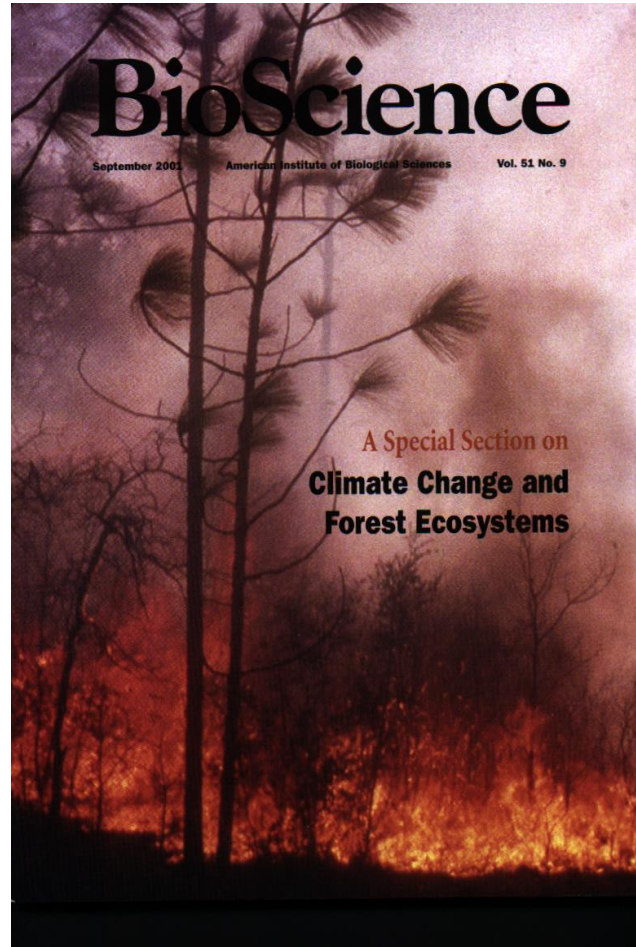
Clouded futures *Nature* **427**, 107-109 (8 January 2004)



- Both the golden toad (*Bufo periglenes*, top) and the Monteverde harlequin frog (*Atelopus* sp.) were found in the mountainous Monteverde region of Costa Rica, but have not been seen since the late 1980s.
- The disappearance of these amphibians, linked to declines in mist frequency ascribed to global warming

Boreal forest is one of most threatened world biomes by global warming

- Mountain pine beetle is a **native** species
- Warming winters have reduced winter kill of beetle
- Beetle mounts a group attack on trees that was not always successful
- With more beetle, attacks successful



Beetles could chew up 80% of B.C. pine: report

'Worst case scenario'
by 2020 blamed
on global warming

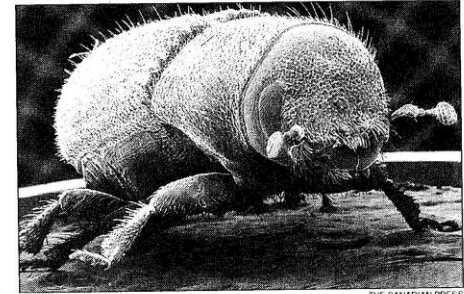
BY ETHAN BARON

VANCOUVER · A new projection for B.C.'s mountain pine beetle infestation presents a "worst-case scenario" of massive pine forest loss across B.C.

"We have no reason to expect that less than 80 per cent of the pine will be affected" by 2020, says the draft report from a joint beetle project from the provincial and federal governments.

"Mountain pine beetle outbreaks are stopped by severe winter weather or depletion of the host. The vast spatial extent of the outbreak implies that a weather-stopping event is unlikely."

The beetle infestation has



The latest projection of the outbreak of mountain pine beetles, which are about the size of a grain of rice, says 80 per cent of B.C.'s pine forests could be affected by 2020.

spread through a broad swath of the Interior, heaviest around the Prince George area, but extending south to the United States border.

B.C.'s chief forester, Larry

Pedersen, is expected next week to announce a dramatic increase in logging to combat the beetle outbreak.

That said, pine tree death won't necessarily reach the-

port's 80-per-cent mark, said B.C. Ministry of Forests and Range Development co-ordinator Bob Clark.

"It's a projection of the future right, according to models. Is that exactly what will happen? Time will tell," Mr. Clark said. "We're operating in that backdrop of a worst case scenario."

Western Canada Wilderness Committee campaign director Joe Foy said global warming has allowed the beetle to survive B.C. winters, and logging won't solve the problem.

"Logging does not stop or even slow the beetle outbreak," Mr. Foy said.

The report, based on computer modelling, notes "significant uncertainties" about the extent of pine mortality the beetles may cause, and how long dead pine can be left before it decays to the point where the wood is useless.

THE VANCOUVER PROVINCE

- 2004 prediction above has happened
- BC interior has been deforested by Mountain pine beetle

Bleached white coral due to warming water in “el nino” event in Australia



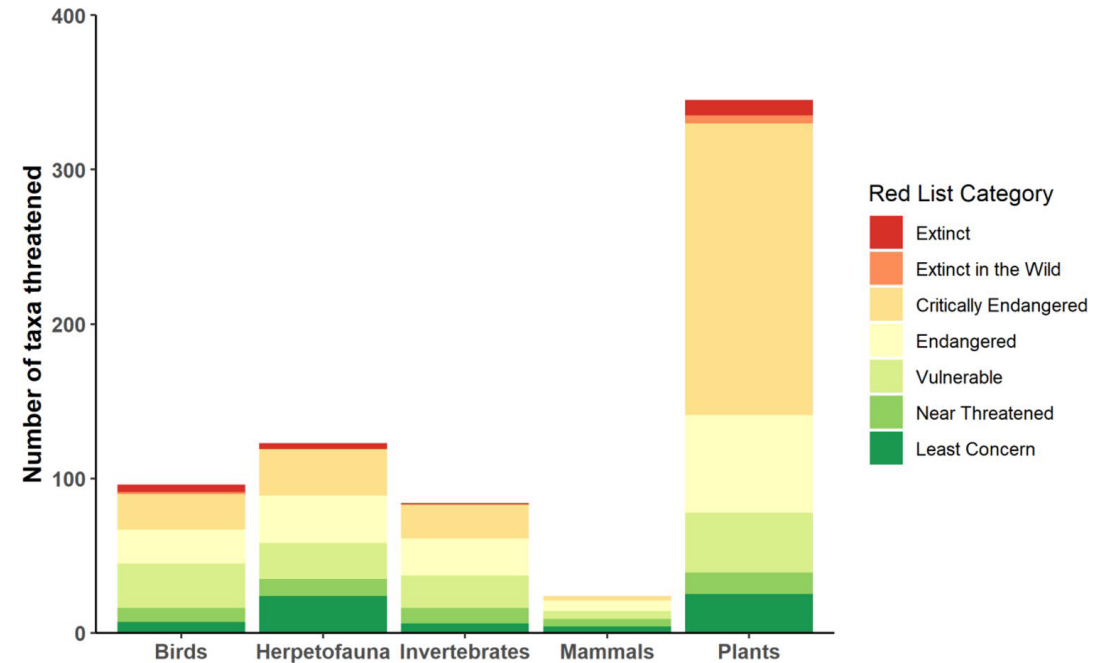
4. Invasive native species, Crown of Thorns starfish (COTS) is destroying great barrier reef

- COTS are covered in spikes containing toxins that are venomous to both humans and marine creatures. COTS are the world's second largest starfish, reaching up to 1m. COTS eat by extruding their stomachs out from their bodies, wrapping it around corals and digesting their tissues.
- Destruction of coral lead to loss of all marine organisms in the habitat
- Cots population have increase due to overfishing of predators,



Species threatened by invasive European hogs worldwide

- Number of species threatened taxa by wild pigs is categorized by their IUCN Red List Category
- In N America hogs are invasive in US, Alberta and Ontario
- Endemic root medicinal plants are especially threatened



Risch et al., Scientific Reports | (2021) 11:13256

Goldenseal



Wild L eaks



Ginseng



Action by Governments and UN: The Biodiversity Convention

- signed at 1992 Rio conference on the environment chaired by Canadian Maurice Strong
- affirms right of developing countries to control use of biodiversity with access and conservation of biodiversity provided by global south in exchange for benefit sharing by developed countries
- US not a signatory
- Indigenous knowledge not specifically addressed

Biopiracy and the San bushmen

- *Hoodia*, a succulent plant from S. Africa is a traditional medicine of San Indigenous People used for hunger control
- Pfizer obtained South African CBD permits to study it
- They developed an anti-appetite drug coded Pfizer p57 from plant extracts
- lack of benefit sharing agreement with San to major controversy,
- Pfizer eventually abandoned the product



Nagoya protocol 2010-4

- In response to Indigenous concerns, such as those over *Hoodia*, ethical guidelines were developed internationally which led to the Nagoya protocol, an amendment to the CBD (co-chaired by Canada in 2010)
- It provided a framework for access to biodiversity and benefit sharing with Indigenous people.
- Unfortunately, the co-chair country, Canada, did not consult with Canadian Indigenous First Nations on a timely basis and did not receive their approval.
- The protocol has been rejected by a consortium of First Nations (Grand Council of the Crees (Eeyou Istchee) et al, 2012) as both a colonial process and document that violates their sovereignty and treaty rights.
- Fortunately, efforts to reset the relationship with Indigenous people in Canada are underway, in which the voices and leadership of First Nations in research are being heard (Styawat /Joseph, L., 2022 Botany 2).

The latest CBD controversies 2022

<https://www.science.org/content/article/it-s-thorny-issue-why-fight-over-dna-data-imperils-global-conservation-pact>

- The debate over Digital Sequence Information (DSI)
 - DSI are DNA base sequences of all species openly shared on databases by geneticists
 - They are used for evolutionary studies, etc., but they also contain information on genes for natural product synthesis
 - Developing nations want sequences obtained from their biodiversity held by law until a benefit sharing contract is made
 - Developed world scientists object that the proposal will effectively stop research especially comparative studies in evolution.
 - Developing nations have threatened to stop conservation efforts in retaliation
- Treaty to conserve biodiversity on the high seas (Aug 25,2022).
 - no consensus at meeting
 - Sticking points were benefit sharing and selection of conservation area

Legacy of CBD

- Biopiracy stopped as Global South passed biodiversity access laws
- Pharmaceutical and developed country benefit sharing has not materialized in any substantive way
- Consequently conservation has not been a Global South priority, (Ex. Ecuador released oil leases in Yasuni NP, the most biodiverse spot on earth.)
- Academic research and international collaboration now much weaker, especially in the Amazon due to arduous biodiversity laws
- However, Indigenous groups have become aware of value of their traditional knowledge and have protected it legally with binding intellectual property agreements.

Select “hotspots” for conservation where endemics are frequent and habitat loss is high

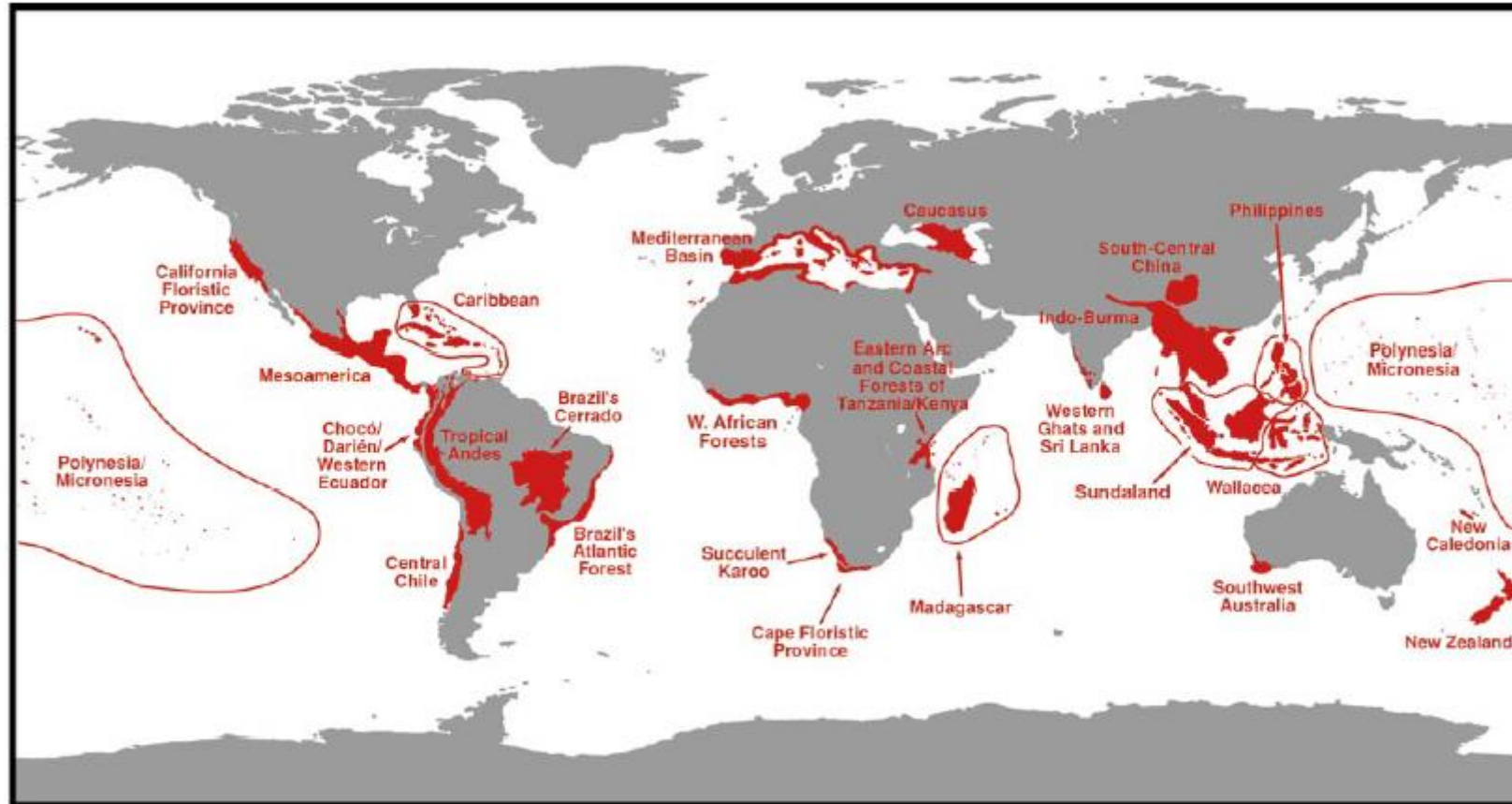
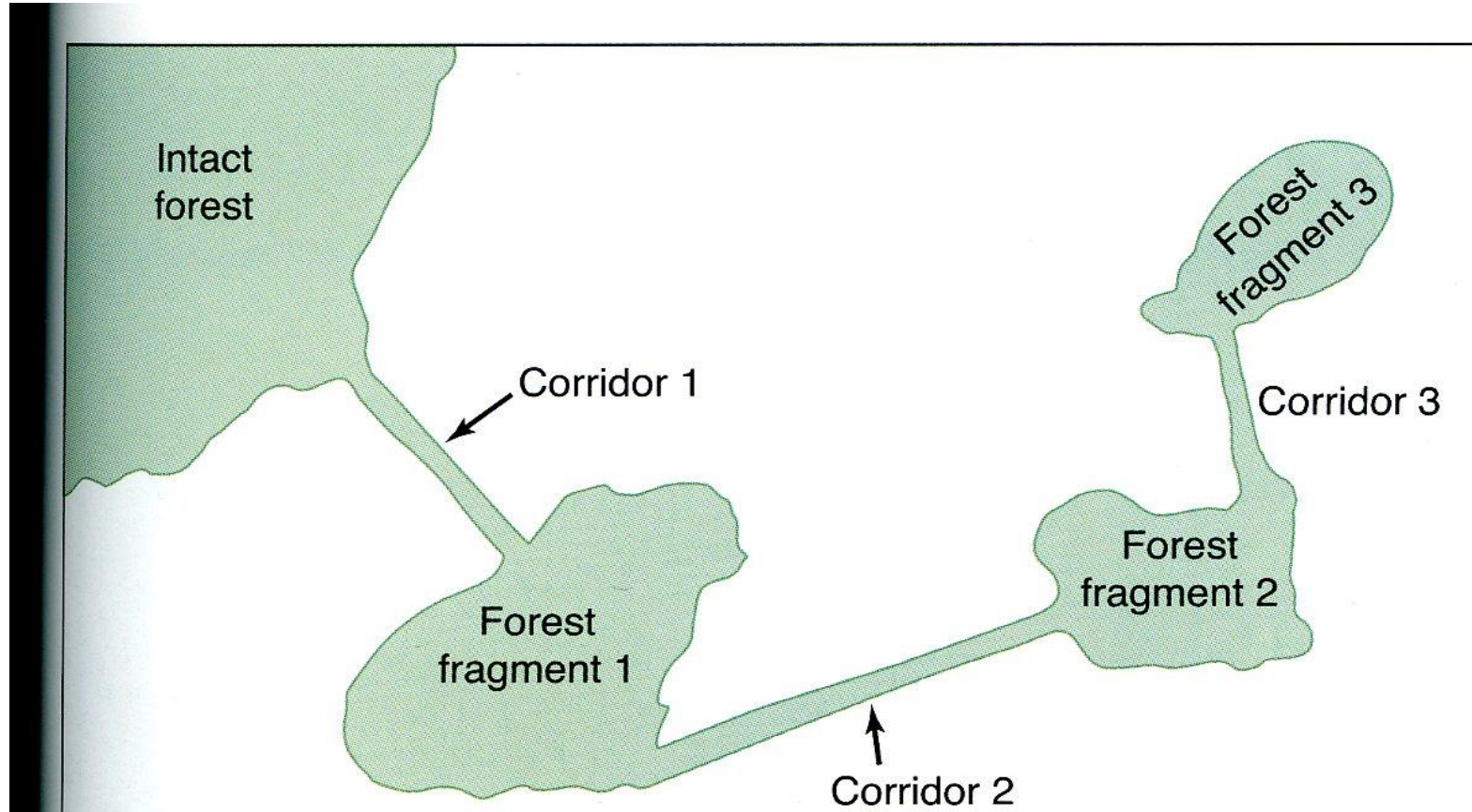


Figure 1 The 25 hotspots. The hotspot expanses comprise 30–3% of the red areas.

N. Meyers et al Biodiversity hotspots for conservation
Nature 403: 853-858.

For forests, solutions to habitat loss and fragmentation: link small fragments into single large area to increase diversity, prevent extinction



Non-Governmental Organizations: Conservation efforts

- International Union for Conservation of Nature (1961) now 4000 employees worldwide
- Nature conservancy (1940) (current assets of \$3 billion)
- Conservation International (1986), major funding from GEF, World Bank.
- American Botanical Council: sustainable herbs program

Smaller agencies in Canada include

- USC Canada- seeds of survival program, now “Seedchange”

The IUCN developed Red Book rating status of species with Red List categories

Extinct (EX)

Extinct in the Wild (EW)

Critically Endangered (CR)

Endangered (EN)

Vulnerable (VU)

Near Threatened (NT)

Least Concern (LC)



Image on Roman coin of extinct plant Silphium with aphrodisiac and aromatic properties

- Of 26 000 medicinal species, approximately 9 percent considered threatened with extinction in the wild based on the Red List
- 400 endangered, and several extinct
- Plants are currently threatened due to habitat loss and uncontrolled commercial wild harvest

Conservation efforts

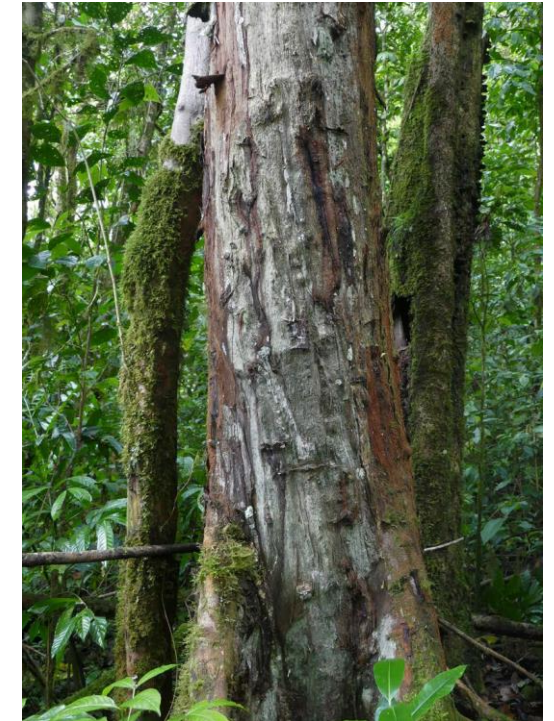
- IUCN species assessments and other input led to CITES treaty which prevent importation of endangered species by signatory countries
- Only (3–6%) of medicinal species are exclusively sourced from cultivation
- Wild harvesting practices are now improved by “ecolabelling” and certification of products as “sustainable harvest” by FairWild, Rainforest Alliance and UEBT
- These are generally considered successful measures although assessment of risk of wild harvesting is often very variable and difficult to assess

- Reference: U. Schipmann et al, A COMPARISON OF CULTIVATION AND WILD COLLECTION OF MEDICINAL AND AROMATIC PLANTS UNDER SUSTAINABILITY ASPECTS chapter 6 in : Bogers RJ, Craker LE, Lange D (eds) Medicinal and aromatic plants, Wageningen UR Frontis Series, vol 17. Springer, pp 75–95

Latest assessment and recommendation: **Wild Check report**

FAO, IUCN and TRAFFIC report of Global Medicinal and aromatic plant trade

- Global trade \$3.5-5.8 BILLION, with clear evidence of illegal harvest, overharvesting, exploitation of gatherers etc
- For example 12 plants featured: frankincense, shea, Brazil nut, juniper, licorice, baobab, argan, candelilla, pygeum, jatamansi, gum arabic, and goldenseal are threatened by use in everyday consumer products and overharvesting of wild populations
- Detailed recommendations for consumers, traders and decision makers given
- Reference Schindler, C., Heral, E., Drinkwater, E., Timoshyna, A., Muir, G., Walter, S., Leaman, D.J. and Schippmann, U. 2022. Wild check – Assessing risks and opportunities of trade in wild plant ingredients. Rome, FAO.
<https://doi.org/10.4060/cb9267e>
- TOP TRADERS of wild-harvested plant ingredients by value in 2024
- Export:
 - China
 - India
 - Germany
 - USA
 - Egypt
- Import
 - USA
 - Germany
 - Japan
 - China
 - China, Hong Kong



Pygeum



Swietenia macrophylla King
(Meliaceae)

- Mahogany: Source of timber, insecticides and medicines
- Now considered an endangered species

Ex situ conservation of genetic resources of medicinal plants

- For the 72,000 species recorded in use worldwide for medicinal purposes, there are about 700,000 collections in genebanks, botanical gardens etc.
- However, most are cultivated species and few collections are of wild species
- For more than 1000 species, no sample exists in any collection; and most species have a very low number of samples.
- Clearly more effort is needed for broad and systematic collections
- Reference: Lohwasser, U., Weise, S. (2020). Genetic Resources of Medicinal and Aromatic Plants. In: Novak, J., Blüthner, WD. (eds) Medicinal, Aromatic and Stimulant plants. Handbook of Plant Breeding, vol 12. Springer, Cham.
https://doi.org/10.1007/978-3-030-38792-1_1

Local initiatives:

Joint preservation of cultural and biological diversity

(J. McMeeley, The double helix of cultural and biological diversity. in “Biodiversity and Health”, J Arnason et al eds. NRC press.)

- J.McNeely, former chief scientist at IUCN argued that preservation of Indigenous cultures and biological diversity go together
- Especially relevant for medicinal and useful species
- Natural alliances between conservation groups and indigenous cultures can provide protection of rights of vulnerable people, preservation and stewardship of biodiversity and tropical forest, income, medicines, construction material for vulnerable people, preservation of cultural heritage and language, and “ecosystem services” for developed countries.
- The Indigenous Itzamma garden in Belize is an example with similar projects worldwide.

Case study: The Itzamma Garden, a Maya medicinal garden in Belize

(Audet et al 2013 Human Ecology)

- *Itzamma* is the place of *Itzamna*, God of wisdom
- 1 ha managed garden within a 20 ha disturbed secondary rainforest and shrubland
- Over 130 medicinal plant species transplanted
- Also contains common medicinal plants:
 - Ginger (*Zingiber officinale*)
 - Fevergrass (*Cymbopogon citratus*)
 - Allspice (*Pimenta doica*)
 - Guava (*Psidium guajava*)
 - Cat's claw (*Uncaria tomentosa*)
- Supported by our lab at uOttawa



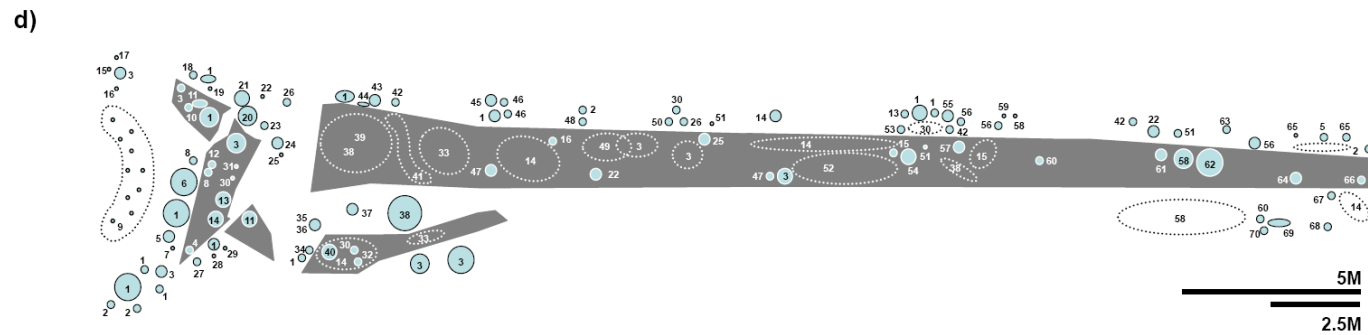
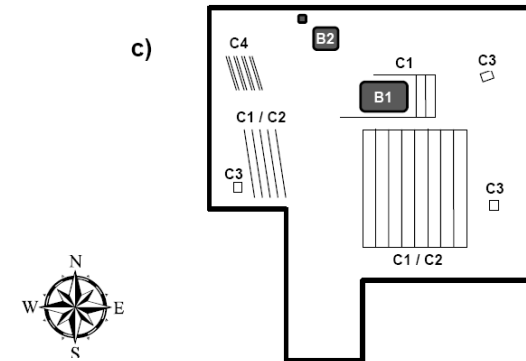
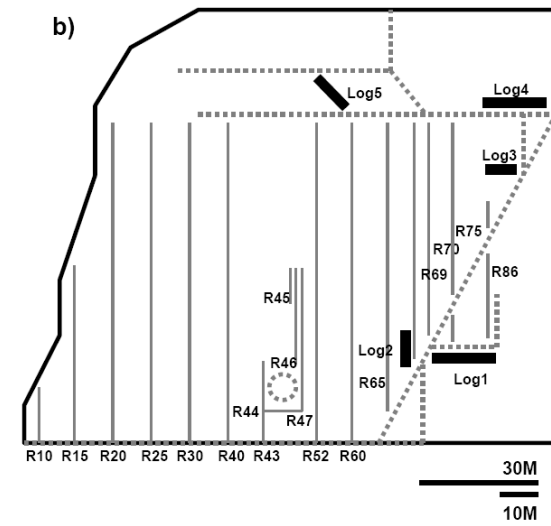
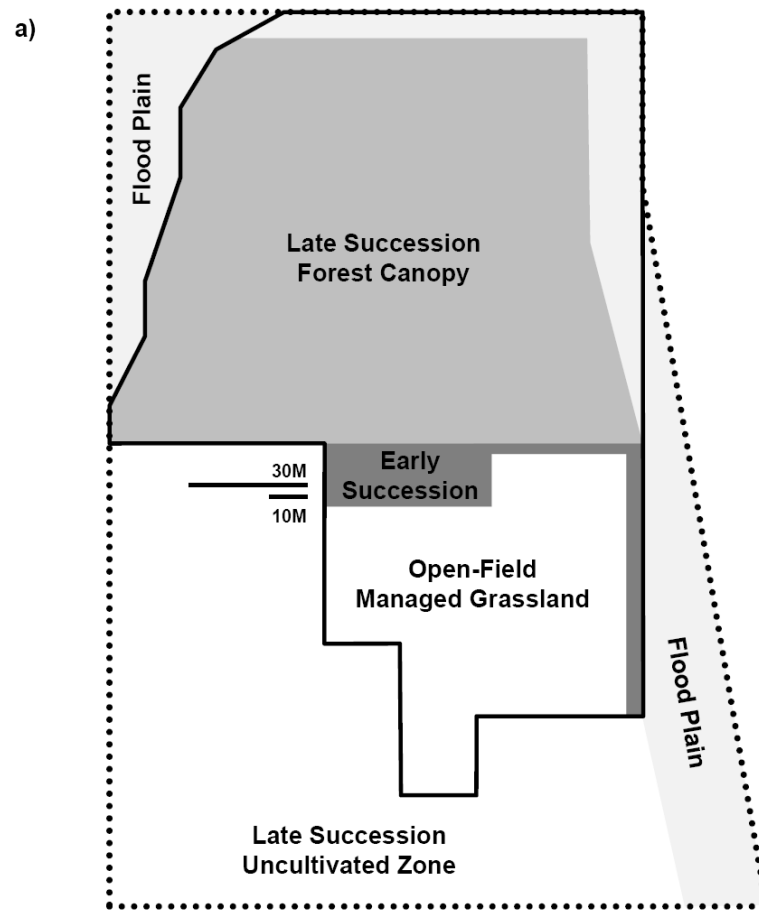
Plants for garden were collected in pristine sacred places in remote Maya mountains



The Itzamma botanical garden: an indigenous project



- Healers started garden to have preserve medicinal plants which are disappearing with deforestation
- Also provides source near to patients
- Establishing wild species in a botanical garden was challenging but eventually successful



Conclusions

- Medicinal biodiversity remains a major source of new drugs for our future that can be more targeted, safer as we learn about pharmacological targets revealed by the human genome project
- Medicinal biodiversity has a surprisingly large commercial, cultural and health value in both developed and less developed countries.
- The tools to conserve medicinal biodiversity are known and have been used successfully in many pilot projects worldwide lead by conservation agencies
- Treaty efforts at protection have had variable results and success, but management by local and indigenous groups have been effective

Prospects for terrestrial biodiversity.

- Major issue is loss of wild habitat loss and overharvesting while climate change is a newer challenge
- an extra 120MHa of wild lands will be converted to agriculture by 2030
- Unused suitable area for cropland found in Brazil, Zaire, Angola, Argentina, Sudan, Columbia will be converted
- Large blocks of untouched forest in Amazon and Congo basin are likely to be broken up by conversion and deforestation
- Forest will remain in reserves, parks and mountainous area where slopes are too steep for agriculture
- Medicinal plants will remain where cultivated or protected by local people
- Major extinctions expected but humans have provoked major extinctions in the past (ex. New Zealand, N. America) without total ecological collapse.
- Ecosystems have adapted to climate change many times in the past but species loss is inevitable
- See Martin Jenkins,. Science 302:1175-7



Souroubea sympetala
An anti-anxiety plant

Prospects for Marine medicinal Biodiversity in coral reefs

- Reefs are already in serious decline and close to 60% may be lost by 2030.
- Major issue is temperature change which causes bleaching (dissociation of symbiont algae, starvation of the coral).
- Invasive species, nutrient loading from agricultural runoff and overfishing are other major problems.
- Although extinction and reef loss are expected, resilience is already seen in some species and migration north is expected.
- Major management recommendation is that a minimum of 30% of reefs be designated “no take areas “ to preserve biodiversity
- T. Hughes et al., Climate change, human impacts and resilience of coral reefs Science. 301 929-33.

Final thought on biodiversity from Larson



"Think about it, Ed. ... The class Insecta contains 26 orders, almost 1,000 families, and over 750,000 described species — but I can't shake the feeling we're all just a bunch of bugs."