GE/BI307 – Jan. 16, 2007

What is biogeography?

Biogeography: Definitions

"the study of the facts and patterns of species distribution. It's the science concerned with where animals and plants are, and where they are not."
- David Quammen, Song of the Dodo

"the science that attempts to document and understand spatial patterns of biodiversity"
- Brown and Lomolino 1998

"the study of geographical distribution and diversity"
- Charles Smith, Author of "Early Classics in Biogeography"

"a science that deals with the geographical distribution of animals and plants"
- Mirriam-Webster Online Dictionary

Biogeography's major processes:

- **Evolution**
- **Extinction**
- **Dispersal**

All with special regard to Spatial Context

Biogeography: Some Questions addressed

Why is a species, genus, family, etc. confined to its present range?

What enables a species to live where it does, what prevents it from occuring elsewhere?

How does climate, topography, interactions with other organisms limit species distributions?

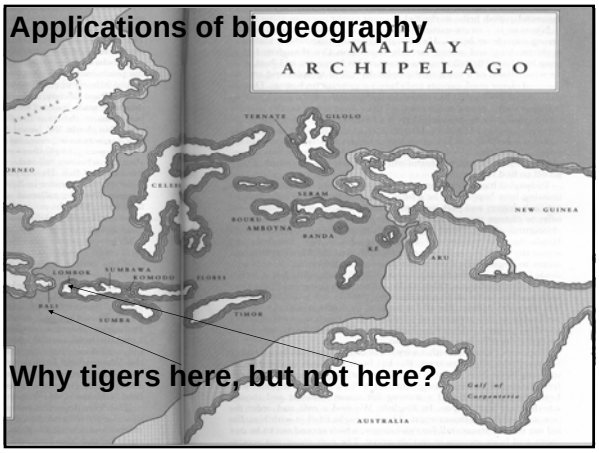
What are a species closest living relatives, where are they found?

Why are animals and plants of large, isolated regions (e.g. Australia, Madagascar) so distinctive?

Why so many species in the tropics, so few in temperate, arctic regions?

How can we best preserve species/communities?

Applications of biogeography



Why tigers here, but not here?

Applications of biogeography

Jan. 8, 2004


letters to nature

Extinction risk from climate change

Chris D. Thomas*, Alison Cameron*, Rhys E. Green†, Michel Bakkenes‡, Linda J. Beaumont*, Yvonne C. Collingham*, Barend F. N. Erasmus§, Marinez Ferreira de Siqueira‖, Alan Grainger¶, Lee Hannah#, Lesley Hughes**, Brian Huntley††, Albert S. van Jaarsveld‡‡, Guy F. Midgley§§, Lara Miles‖‖, Miguel A. Ortega-Huerta¶¶, A. Townsend Peterson##, Oliver L. Phillips*** & Stephen E. Williams†††

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†Royal Society for the Protection of Birds, The Lodge, Sandy, Bedfordshire

areas[1,2]. This 'climate envelope' repres... which populations of a species curre... competitors and natural enemies. Fut... mated by assuming that current envelo... projected for future climate scenarios... either has no limits to dispersal such ... becomes the entire area projected by the... that it is incapable of dispersal, in which... the overlap between current and future... example, species with little dispersal a... landscapes[1,2]. Reality for most species ... extremes.

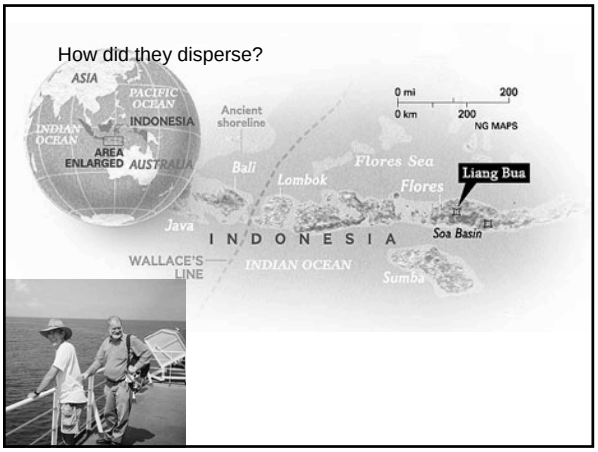
We explore three methods to estim...

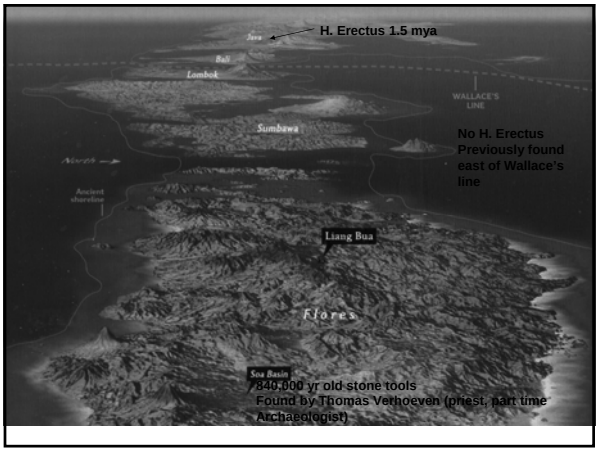
"…Application of a basic law of ecology [species-area r'ship] predicts that many [species] will vanish if temperatures continue to rise"

– J. Pounds, Nature News and Views

8 individuals
18-13 kya
Coincident with h. sapiens!

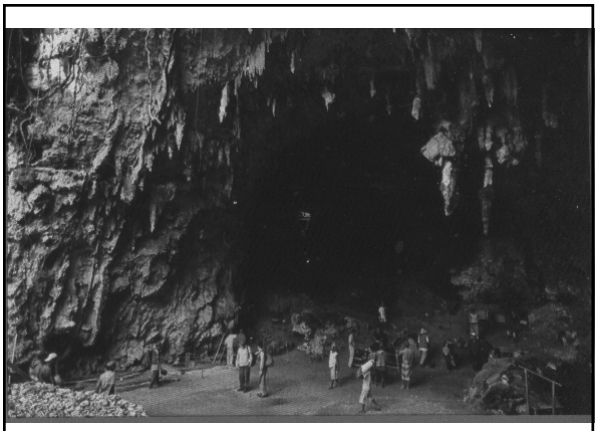
How did they disperse?



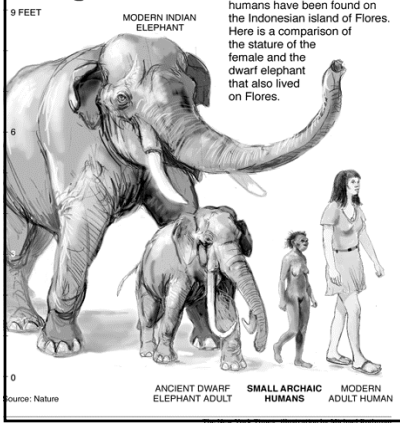


No H. Erectus
Previously found east of Wallace's line

840,000 yr old stone tools
Found by Thomas Verhoeven (priest, part time Archaeologist)



Standing Small



Skeletons of tiny, archaic humans have been found on the Indonesian island of Flores. Here is a comparison of the stature of the female and the dwarf elephant that also lived on Flores.

Why so small?

Limited resources on small islands drives dwarfism.

Same thing happened to elephants on Flores.

Humans are not exempt from Natural Selection!

Unique aspects of Biogeography as a science

- **Mostly an observational science**
- **Rare for investigators to collect all their own data**
- **Beginners can do original research**

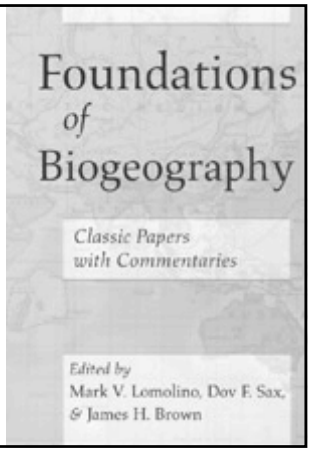
Outline

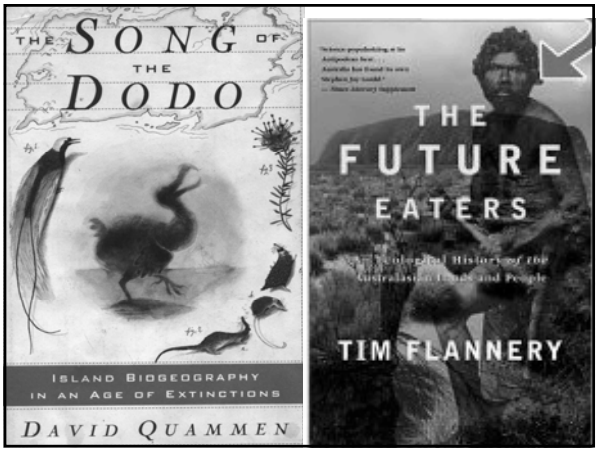
1. A bit about our books and authors

2. Overview of Australasia as a case study of ecological and human biogeography

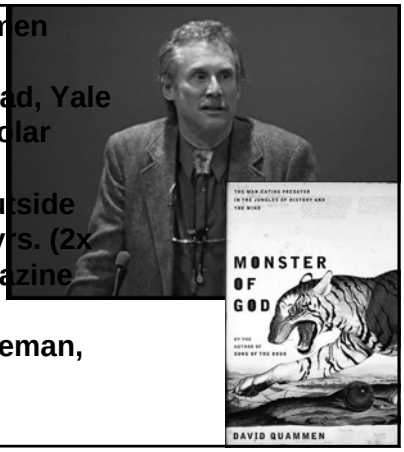
Let's start with some basic geography…

"text book" for GE/BI307





David Quammen



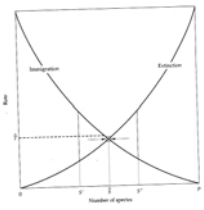
- **Literature grad, Yale**
- **Rhodes Scholar Oxford**
- **Wrote for Outside mag. For 15 yrs. (2x National Magazine Award)**
- **Lives in Bozeman, Montana**

Quammen Major Themes:

Islands provide major insights into biogeography everywhere

History of development of a revolutionary theory explaining species diversity and isolation: the Equilibrium Theory of Insular Biogeography

How/why this matters for conservation today in a fragmented world



Tim Flannery

- **BA, English**
- **MSc. Earth Sciences**
- **PhD, UNSW, Zoology**
- **Director, South Australian Museum, Adelaide**

Flannery's Major Thesis:

A major defining feature of human biogeography: humans colonizing new lands have universally 'eaten their future' by extracting resources wastefully, inappropriately, and ultimately unsustainably.

Surviving indigenous people learned hard lessons about living within the limits and characteristics of their environments.

Modern human colonists have not yet learned those lessons, and are the newest "future eaters".

Outline

1. A bit about our books and authors

2. Overview of Australasia as a case study of ecological and human biogeography

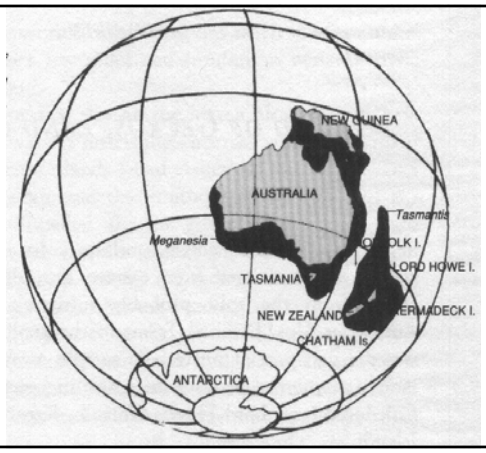
Let's start with some basic geography…

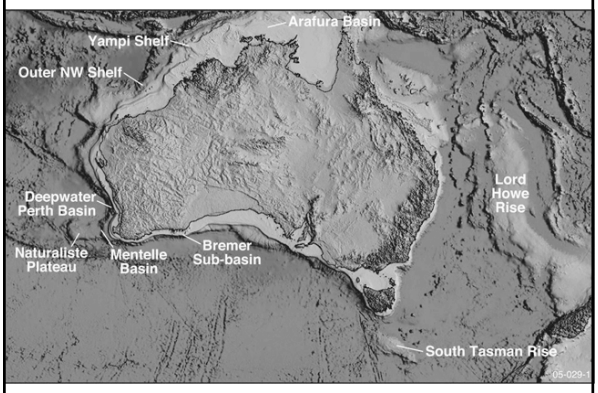
***Australasia*: A once-connected landmass consisting of Australia, New Guinea, New Caledonia, New Zealand, and other minor islands**

Australasia is itself composed of two distinct geographical units:

***Meganesia*: The landmass that includes Australia, New Guinea, and Tasmania. If sea level were a few hundred feet lower (as it has been very 'recently' and will likely be again 'soon'), these 3 landmasses would be connected by dry land. This has large biogeographical implications.**

***Tasmantis*: A now-mostly submerged landmass that includes New Zealand, New Caledonia, and smaller islands like Lord Howe, Norfolk, Kermadeck, and Chatham Islands.**





Why focus on Australasia as a biogeography case study?

-**the separated landmasses of Australasia provide separate, but linked 'experiments' in biogeography**

-**Separate histories originated from the same 'starting line' as a single connected landmass.**

-**Evolutionary divergence in plants/animals can be interpreted in terms of isolation, climate differences, and idiosyncracies in the geologic parent material, while similarities can be traced to common origins.**

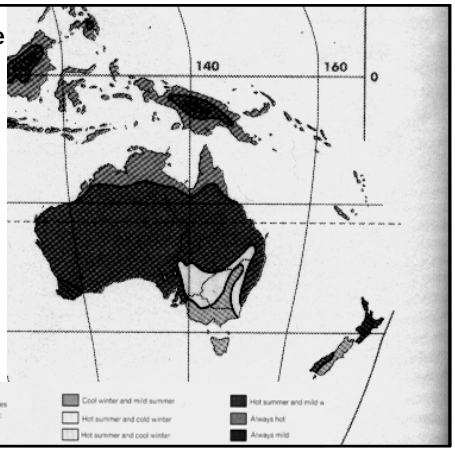
-**Allows for comparative study of the biogeography of founding human groups (Papuans, Aborigines, Maori) and modern European colonists.**

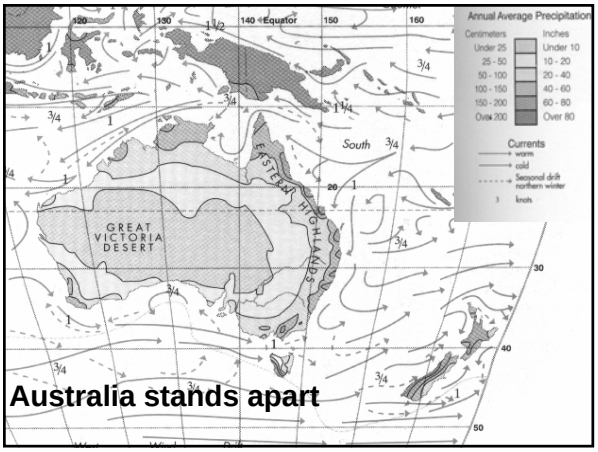
There are many dimensions to the biogeographical comparison and contrast of the lands of Australasia.

Let's start by comparing and contrasting the current climates in Australasia…

Temperature Regimes

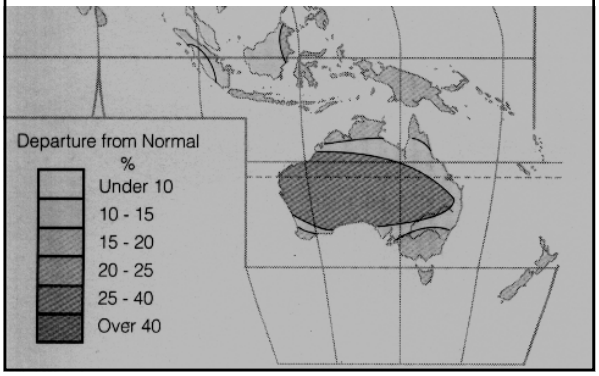
N. Zealand stands apart, with some similarity to parts of Australia.





Australia stands apart

Variability in precipitation – we'll see has major implications for biogeography, especially human



Climatic differences and similarities give us insight into *ecological* differences and similarities among these lands, and how ecological resources impacted humans colonists from 1000 – 50,000 years ago.

For example, it explains why density of Papuans was (and is) much greater than Aborigines.

It is important to also realize that current climate bears little relation to the climate of these lands in the distant past (millions of years ago). Evolutionary patterns are thus more complex.

Conclusions

-Australia, New Guinea, and Tasmania are very close 'relatives' historically (and, as we'll see, evolutionarily).

-New Zealand and New Caledonia are more distantly related.

-Australasian lands provide a range of similarities and striking differences in climate.

-New Caledonia, by geological circumstance, is marked by poor soils – and this has contributed to it being a land of reptiles.

-In coming lectures, we'll look at sketches of the other lands of Australasia, and then get into details of comparative biogeography of these lands.

GE/BI 307, Jan. 18, 2007

Biogeography's Deepest Space and Time: Continental Drift

Outline

1. History of the idea
2. Basic Processes of Plate Tectonics
3. Evidence for its occurence
4. General Biogeographic Implications
5. Tectonic history of Australasia

1. History of plate tectonics

1596: Abraham Ortelius "symmetrical fit" (also, F. Bacon 1620, Buffon 1700s)

1838: Thomas Dick: "continents orginally conjoined"

1858: Snider-Pelligrine: Europe-N. America fossils/ Map of supercontinent

1885: Eduard Suess – Gondwana

1908-1910: F. B. Taylor : Mountains at forward margins – moon powers plate movements

1912: Wegener: Pangea Supercontinent

1965: Edward Bullard – better fit

Plate tectonics was only widely accepted in the late 1960's – lots of resistance

R. T. Chamberlain (American): "Can we call geology a science when there exists such differences of opinion on fundamental matters as to make it possible for such a theory as this to run wild"

Baily Willis (American 1944): "Wegener's theory is a fairy tale and should be ignored…"

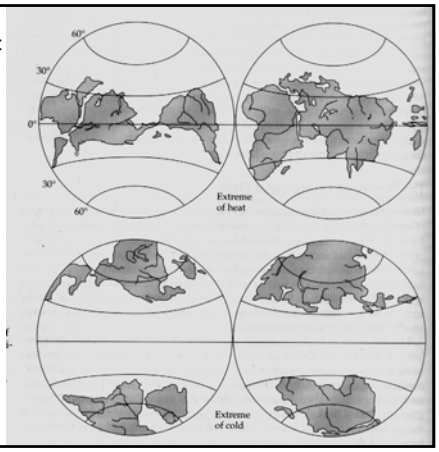
W. B. Scott (former pres. Of American Philosophical Society): "utter damned rot"

Plate tectonics was considered a heretical idea for decades before acceptance came from multiple lines of evidence (which we will discuss).

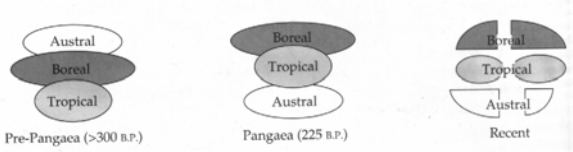
It is worth noting some of the other far-out-of-the-mainstream ideas – who knows if what we consider radical today may be accepted fact tomorrow?

Charles Lyell (1800's) thought that continents were fixed in relative positions, but together drifted over the globe.

This was his way of explaining evidence for ice ages in tropical lands/warm conditions in polar regions.



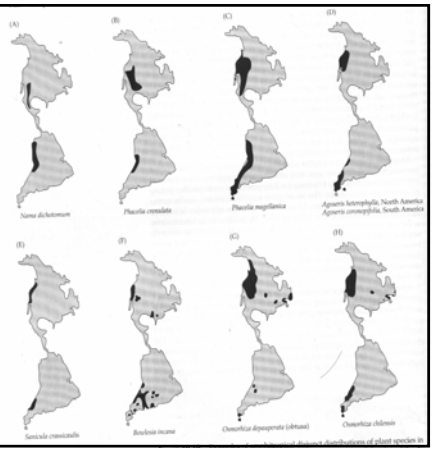
More recently: workers in the late 80's proposed radically different super-continent dynamics than is currently accepted.



Why propose such drastic re-arrangements?

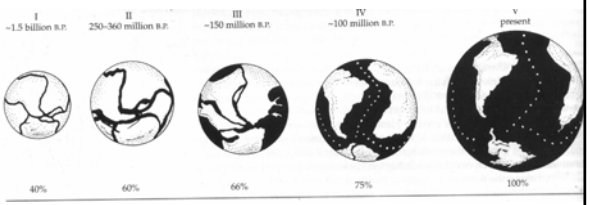
…as a way to explain amphitropically disjunct species distributions.

(which we still don't have a great explanation for)



Finally, in the early 50's the 'expanding earth' hypothesis was formulated, which actually explains the fit of the continents extremely well.

However, it requires that the gravitational constant be variable, an idea which hasn't gained much currency.



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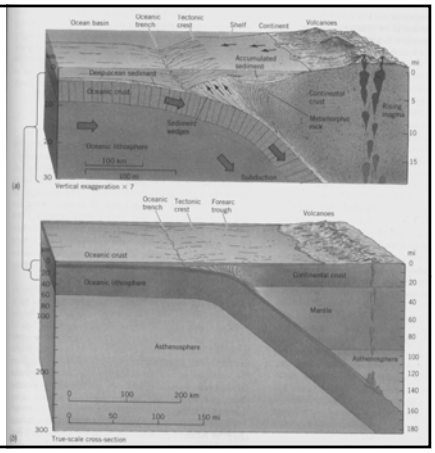
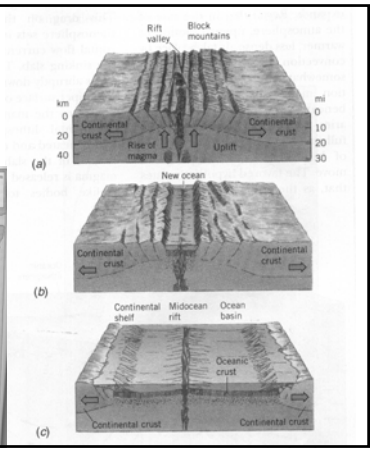
2. Basic Processes

1. Oceans disappear over time … (e.g. the Northern Pacific)



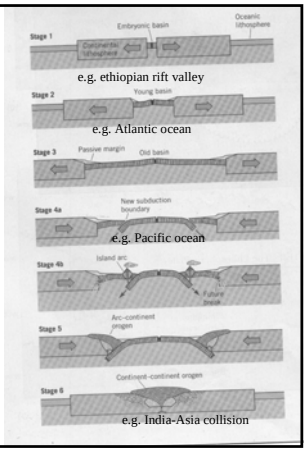
Process of Tectonics

2. Oceans grow elswhere

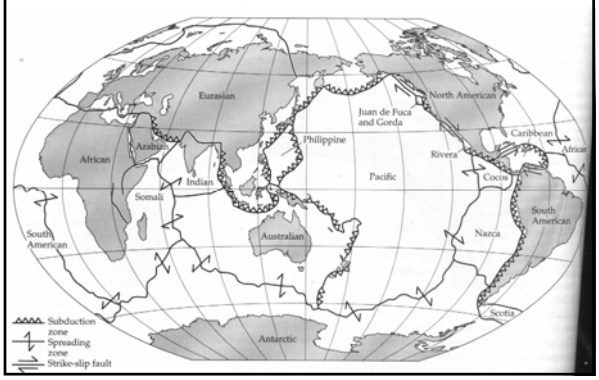


This can be envisioned as a several hundred million year cycle…

"The Wilson Cycle"



The Global System of Plates and Movements



Outline

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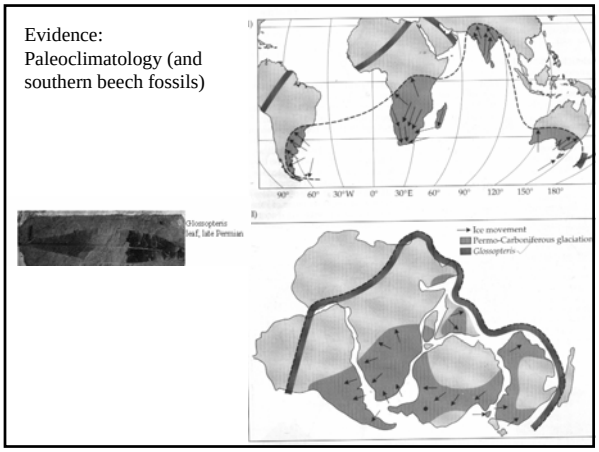
Evidence of tectonics

- **Biogeographical**
- **Stratigraphic (glacial scour, flood basalts, similar sequences of sand, coal, volcanic material)**
- **Paleomagnetism**
- **Marine geology**

Evidence: flood basalts

Evidence:
Paleoclimatology (and southern beech fossils)



Evidence: Paleontological

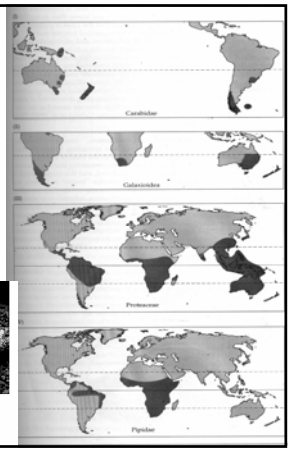
Beetles

Freshwater Fishes

Plants

Frogs

Pipa pipa (family Pipidae)



Genera in the Tribe Embothrieae (family Proteacea)

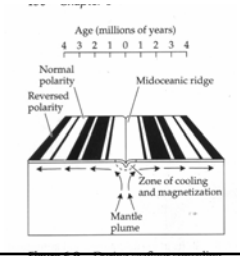
Genus	No.of Species	Distribution
Telopea	5	Eastern Australia
Embothrium	1	South America (Chile)
Oreocallis	6	South America (Ecuador and Peru)
Alloxylon	4	Eastern Australia, New Guinea

Tree waratah, *Alloxylon flammeum* (Australia)

Embothrium Coccineum (Chile)

Evidence: Other

Marine:
- mid-oceanic ridge and seafloor spreading
- Ocean crust is always relatively young
- Movement of seamounts confirm movement
- Circum-oceanic earthquakes/volcanoes associated with trenches/subduction zones



Biogeographic Consequences of Plate Tectonics

1. Isolation/connections between land masses
2. Area of landmasses
3. Latitudinal position of landmasses = climate change

3b. Altered global ocean/air circulation patterns.

We are going to go into more detail in this course on how these factors influence biogeography.

Outline

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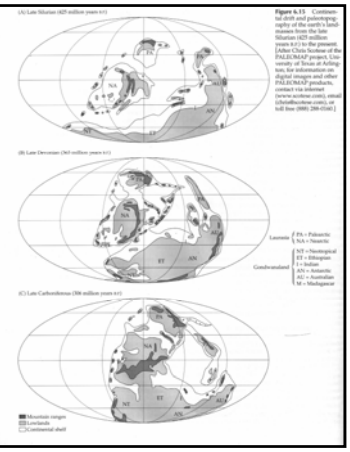
In early geologic history, Gondwana was more coherent and stable than Laurasia.

425 Mya, Australia (AU) was fully tropical!

Parts of Antarctica (AN) were subtropical.

By 300 Mya, they had drifted far south.

Keep in mind: land plants emerged at least 425 Mya.

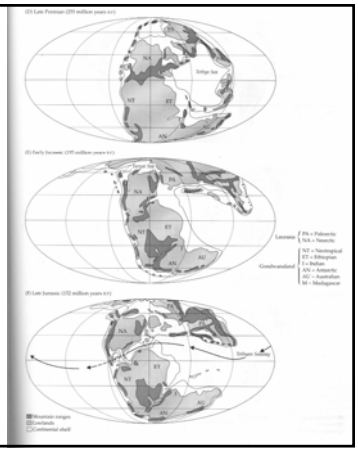


250 Mya – Pangea proper.

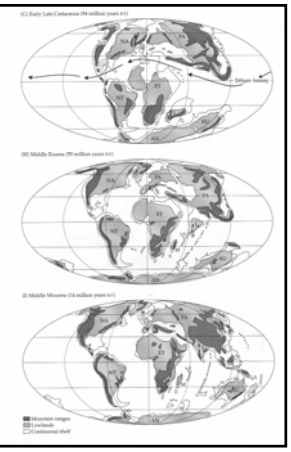
For next 100 My, AN and AU drift above and below the polar circle.

Fossil/isotope data suggest AU/AN were cold, but not frozen (greenhouse effect)

At 150 Mya, a major seaway (Tethys) develops. This radically alters global climate circulation patterns.

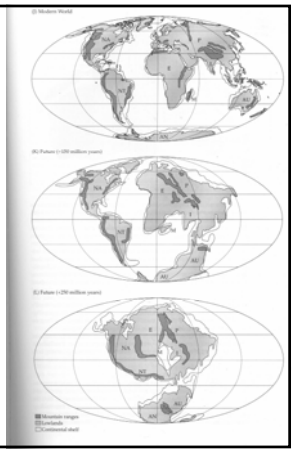


From 90 Mya to 14 Mya, the supercontinent of Gondwana begins to break up and lead to its current arrangement.

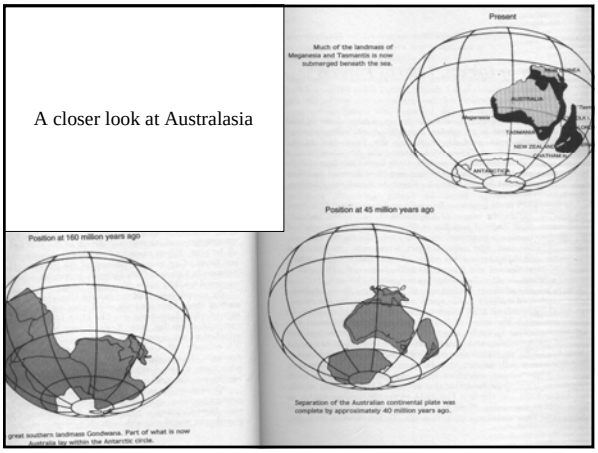


Today, and speculation into the future.

http://www.kartografie.nl/gondwana/index.asp



A closer look at Australasia



Summary:

The reality of Plate Tectonics has revolutionized Biogeographical thinking. Dispersal or land bridges are not the only way species have moved!

Drifting continents means lands we see today experienced very different climates in the past – Antarctica was subtropical once!

The concept of continental drift was heretical at the time, but multiple lines of evidence has firmly established it. Yet there are still many unknowns (the driving force, for example!)

Biogeography's Deepest Space and Time: Continental Drift

Biogeographic correlates with tectonic history: examples from Australasia

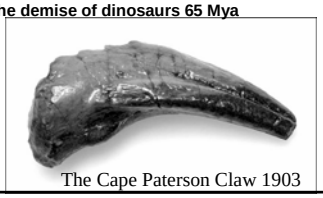
I. Australia:

Dinosaur fossils from 100-120 Mya tell us 3 biogeographically-significant things.

1. Small body sizes indicate cold temperatures and resource limitation. The most cold-adapted dinosaurs known.

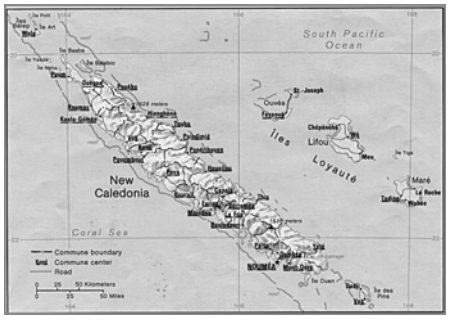
2. Two dinosaur species predate related groups found in Northern Hemisphere by at least 10 My! Gondwana may likely have been a point of origin

3. Cold-adapted dinosaurs calls into question the 'nuclear winter' hypothesis for the demise of dinosaurs 65 Mya

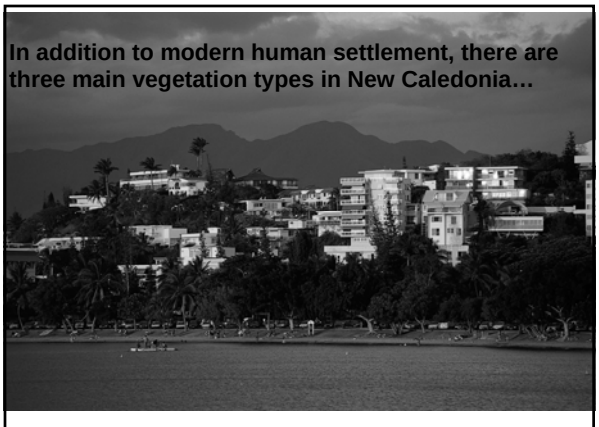


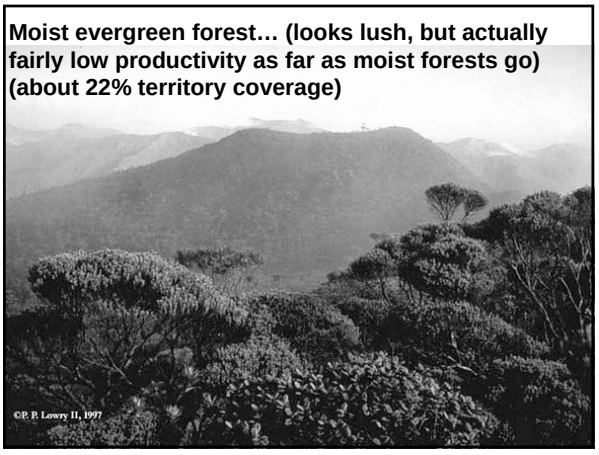
The Cape Paterson Claw 1903

II. New Caledonia



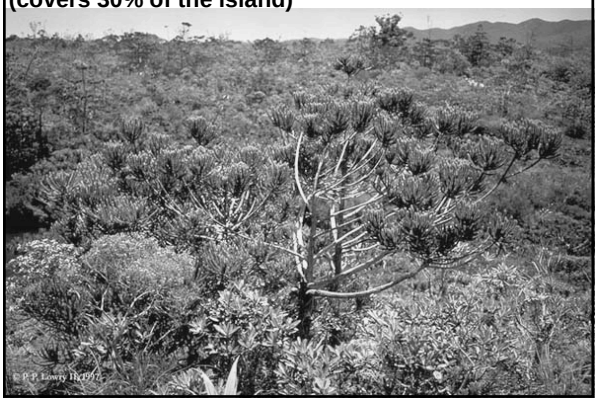
Southern latitude ~ Cuba (sub-tropical)





Sclerophyll (scrub) forest on drier sites… (almost all gone)

Maquis vegetation (low, evergreen), infertile soils (covers 30% of the island)



The single most striking feature of New Caledonia is its infertile soils and consequent low productivity of vegetation.

Along with its small size, this places large restrictions on large, warm blooded animals.

Also, tropical climate is good for cold-blooded animals.

New Caledonia is thus a land of cold-blooded reptiles . Acre for acre, it has perhaps the most diverse reptile assemblage in the world

Some bizarre features and roles of New Caledonian animals foreshadow topics in Island Biogeography we'll consider soon.

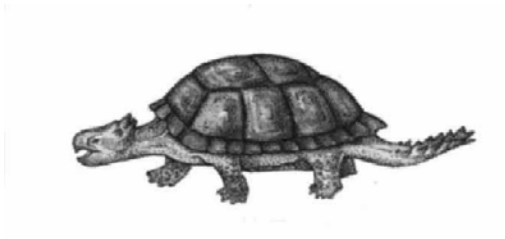
For now, let's just consider some of the strangeness.

New Caledonian Horned turtle

- top herbivore, occupying an "elephant" niche

-100 kg, but substantially smaller than Australian relative (e.g. dwarfism)

-Similar horned turtles throughout Australasia, even S. America (certainly a Gondwanan relic)



New Caledonian Dwarf Crocodile

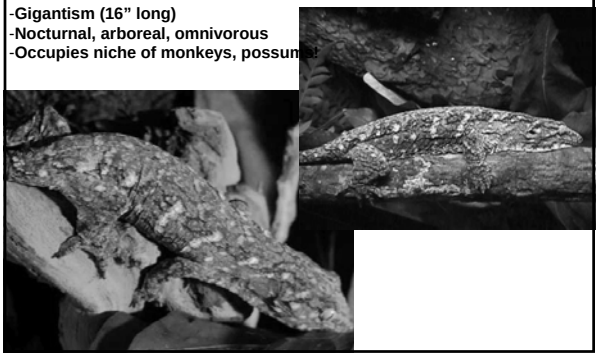
-Dwarfism – only 30 kg, 2 m length

-Low resources pushed it to the extreme of munching mollusc shells (blunt teeth)

-Sorry, extinct (no picture)

New Caledonian Giant Gecko (Rhacodactylus leachianus)

-Gigantism (16" long)
-Nocturnal, arboreal, omnivorous
-Occupies niche of monkeys, possums!



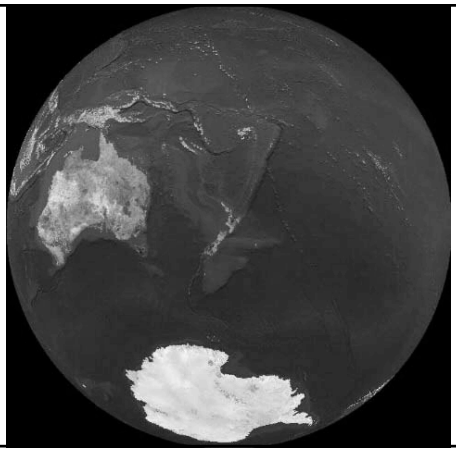
What biogeographical processes are indicated by these strange creatures?

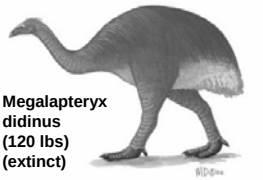
1. Islands show a tendency toward both Dwarfism and Gigantism. We'll find out how a general rule of biogeography can predict both outcomes.

2. Adaptive Radiation. Factors like climate, resource availability, isolation can favor some groups (reptiles) over others (birds). With niches usually occupied by birds or mammals absent, other groups evolutionarily 'radiate' to fill those niches.

What group of animals showed large adaptive radiation in New Zealand?

Why?





Megalapteryx didinus (120 lbs) (extinct)

Haast's Eagle (Harpagornis moorei – 30 lbs - extinct)

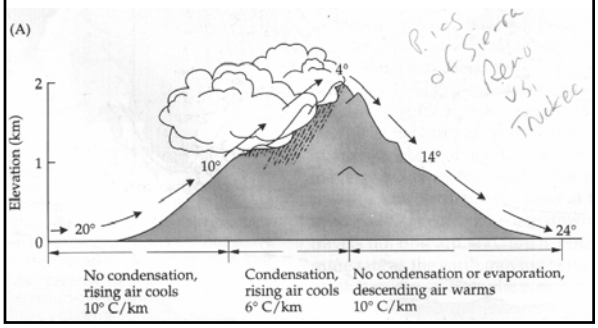
Steven's Island Wren ('mouse Sized - extinct)

Divaricating habit of plants

Pittosporum obcordatum

Cockayne (1912) defines divaricates as plants with ". . . much-branched often stiff and wiry stems which are pressed closely together or even interlaced, the branching being frequently at almost a right angle". These plants resemble a wind-shorn shrub, and may even be likened to the fastigiate groups of axes which form as "witches' brooms" on diseased woody plants. – Tomlinson 1979

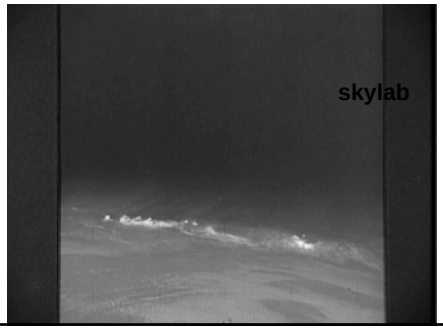
1. The importance of mountains (lack thereof)



1. The importance of mountains (lack thereof)

Aoteoroa – "The Land of the Long White Cloud"

Due to "orographic" effects.



Fox glacier, South Island

Climatic Impacts on Biogeography in Meganesia

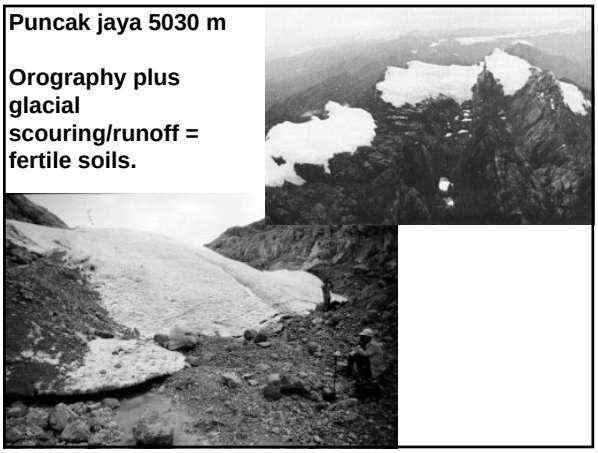
1. The importance of mountains (lack thereof)

2. El Nino

3. The diversity Enigma in Australia

Puncak jaya 5030 m

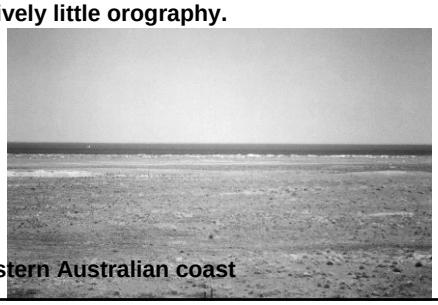
Orography plus glacial scouring/runoff = fertile soils.



Contrast Australia:

“the flattest of continents”

No mountains high enough to sustain glaciers. Relatively little orography.



Western Australian coast

Biogeography implications

- Many australian species are adapted to low resource needs (e.g. low metabolic rate)

What is this?

2. El Nino

Hadley Cells + Coriolis Effect = Trade Winds

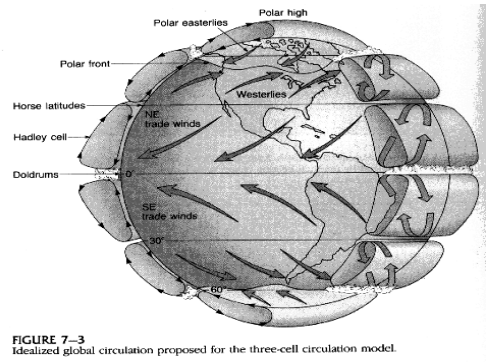
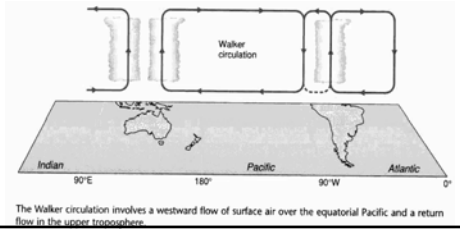


FIGURE 7–3
Idealized global circulation proposed for the three-cell circulation model.

III. Walker Circulation

An east-west convective loop.

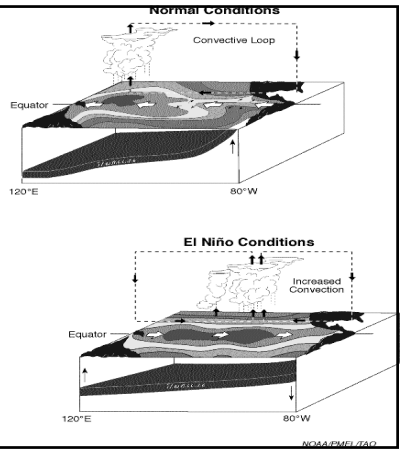
-As trade winds (easterlies) proceed westward, air humidifies, becomes more bouyant.
-Warms over land, making it even more bouyant.
-Air mass rises, cools, water condenses out.
-High pressure aloft moves east (and west), descends over east pacific, completing the loop.

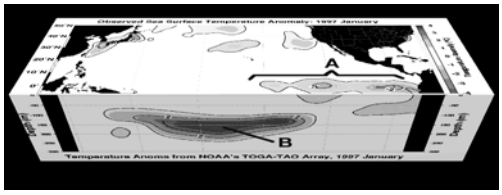


The Walker circulation involves a westward flow of surface air over the equatorial Pacific and a return flow in the upper troposphere.

Alterations in atmospheric winds creates alteration in oceanic thermocline, which re-inforces alterations in atmospheric winds!

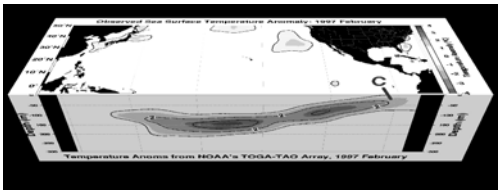
El Nino is a positive feedback process.





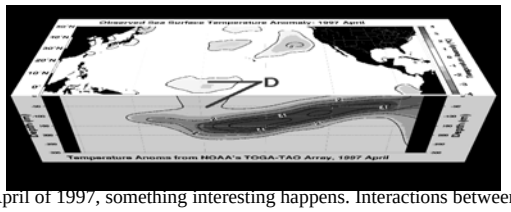
In January of 1997, surface temperatures were still cold in the Eastern Pacific (off Peru), but warm waters at depth were hinting of the El Niño to come

Figure and text from http://www.pmel.noaa.gov/tao/elnino/el-nino-story.html



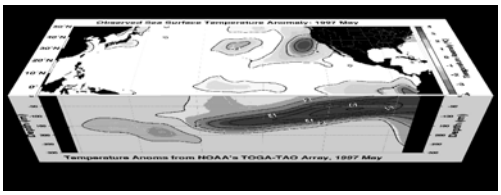
By February of 1997, the warm water anomaly below the surface had spread almost to Peru, but temperatures at the surface were still near normal.

Figure and text from http://www.pmel.noaa.gov/tao/elnino/el-nino-story.html



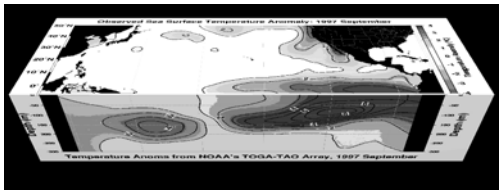
In April of 1997, something interesting happens. Interactions between the atmosphere and ocean -- the process that makes an El Niño grow -- generate a surface warm anomaly in the middle of the Pacific. It quickly connects with the warm anomaly below.

Figure and text from http://www.pmel.noaa.gov/tao/elnino/el-nino-story.html



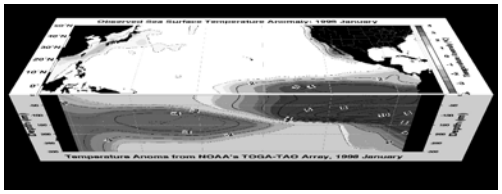
It's May of 1997, and hold on to your hats, folks! The warm water near the dateline has started to expand to the East, and the warm anomaly off the coast of Peru has reached the surface and is spreading to the West. It looks like it's going to be a big one.

Figure and text from http://www.pmel.noaa.gov/tao/elnino/el-nino-story.html



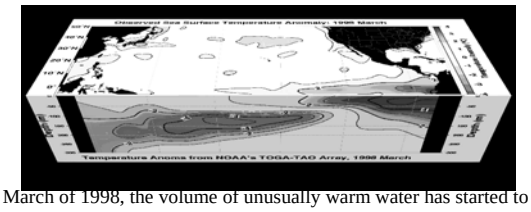
By September of 1997, unusually warm waters stretch from the coast of Peru to the dateline -- that's a quarter of the way around the planet!

Figure and text from http://www.pmel.noaa.gov/tao/elnino/el-nino-story.html



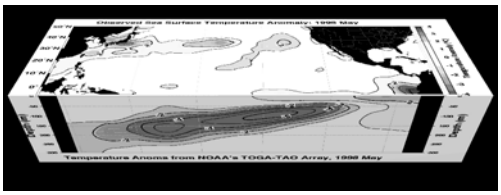
In January of 1998, the El Niño is fully underway. The cold anomaly in the subsurface western Pacific has also expanded towards the east; this may be an early sign of an upcoming cold-water event ("La Niña").

Figure and text from http://www.pmel.noaa.gov/tao/elnino/el-nino-story.html



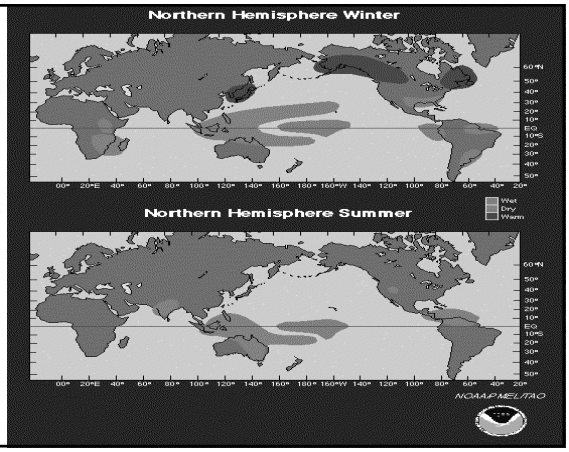
By March of 1998, the volume of unusually warm water has started to shrink noticably. The cold anomaly in the subsurface western Pacific continues to expand towards the east.

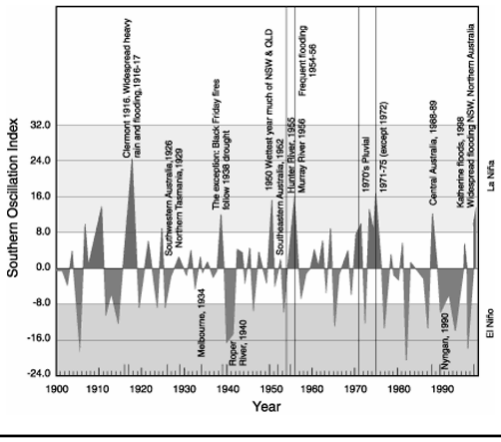
Figure and text from http://www.pmel.noaa.gov/tao/elnino/el-nino-story.html



By May of 1998, the warm water has all but disappeared, and the El Nino of 1997/1998 is over. The region of unusually cold water, underneath the surface, continues to expand towards the east.

Figure and text from http://www.pmel.noaa.gov/tao/elnino/el-nino-story.html

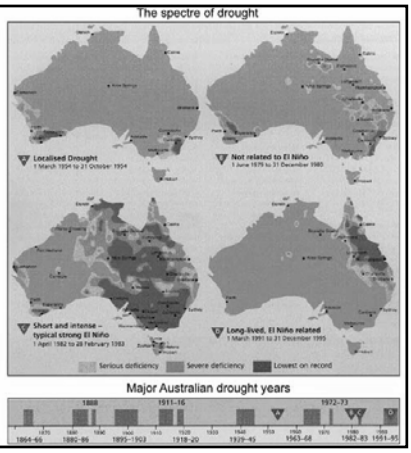


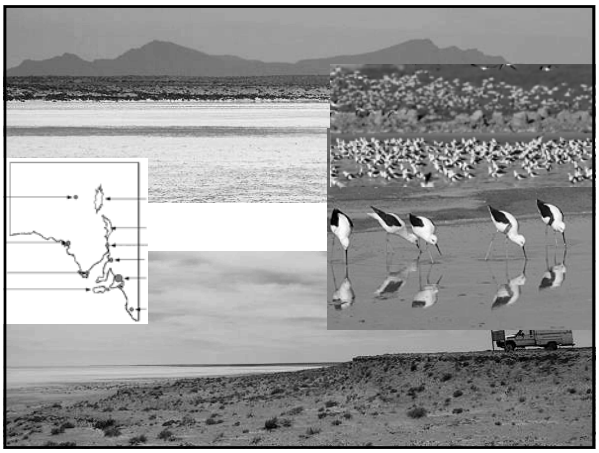


El Nino/La Nina are responsible for the most extreme drought and flood events in Australia.

Many species are adapted to the erratic timing of feast vs. famine.

e.g. Banded Stilts



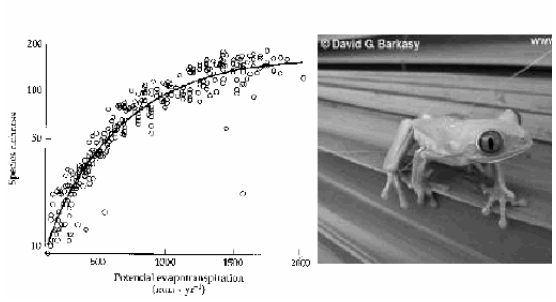


3. The Diversity Enigma in Australia

Or,

Biodiversity and the Goldilocks Principle

It has long been assumed that a principal driver of biodiversity is resource productivity



How is it, then, that Australia, such a resource limited environment, has such high biodiversity?

e.g. heathlands of south-western Australia supports 10 –12 thousand plant species!

Silver Banksia

Banksia marginata

The Goldilocks Principle:

Too many resources allow "exterminator species" to outcompete resource specialists.

Too few resources cannot support life.

There is an intermediate level of resources that maximizes biodiversity and resource specialization.

Scientists are testing how Nitrogen Deposition affects biodiversity

Figure 7-Different rates of nitrogen addition lea marked changes in the plant and insect species compositions and speicies diversity of these plots of grassland vegetation in Minnesota. Each plot is 4m x 4m (about 13 ft x 13 ft), and has received experimental addition of nitrogen (ammonium nitrate) since 1982.

Figure 1 - An aerial view of experimental grassland plots in Cedar Creek, Minnesota. Two experiments are visible in this photograph. A series of 147 small plots ranging from monocultures to plots containing 24 plant species is visible in the foreground. The largest area in the center is occupied by 342 plots which range from monocultures to 32 species of prairie grassland plant species. These plots were established in 1993.

Scientists are testing how Nitrogen Deposition affects biodiversity

Photo by D. Tilman

Figure 8-Native grasslands in Minnesota often contain 20 to 30 or more plant species per square meter, as does this plot. This plot is a "control" plot that received no nitrogen, and that retained its original plant diversity.

The Goldilocks hypothesis: Too little Nitrogen (or other resources) is bad for biodiversity, but so is too much.

Removal of Selection Pressure For N fixers

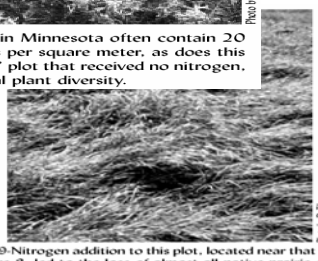


Photo by D. Tilman

Figure 9-Nitrogen addition to this plot, located near that shown in Figure 8, led to the loss of almost all native prairie species and to dominance by the weedy European quackgrass. In 1982 this plot looked much like the one shown in Figure 8.

We may be promoting the success of a 'weed world'!

N cycle (Haber process, automobile exhaust)

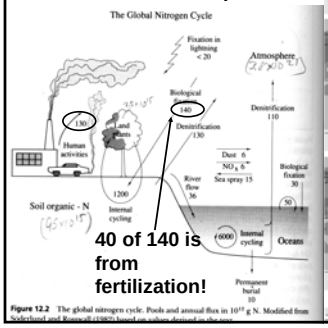
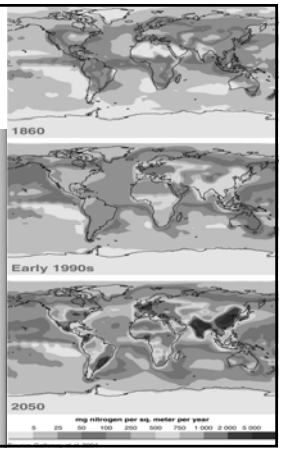


Figure 12.2 The global nitrogen cycle. Pools and annual flux in 10^{12} g N. Modified from



40 of 140 is from fertilization!

Reconciling two schools of thought:

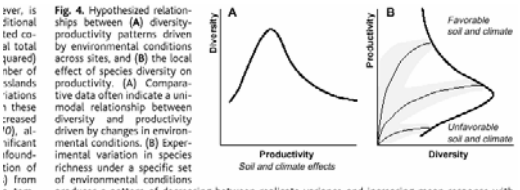


Fig. 4. Hypothesized relationships between (A) diversity-productivity patterns driven by environmental conditions across sites, and (B) the local effect of species diversity on productivity. (A) Comparative data often indicate a unimodal relationship between diversity and productivity driven by changes in environmental conditions. (B) Experimental variation in species richness under a specific set of environmental conditions produces a pattern of decreasing between-replicate variance and increasing mean response with increasing diversity, as indicated by the thin, curved regression lines through the scatter of response values (shaded areas).

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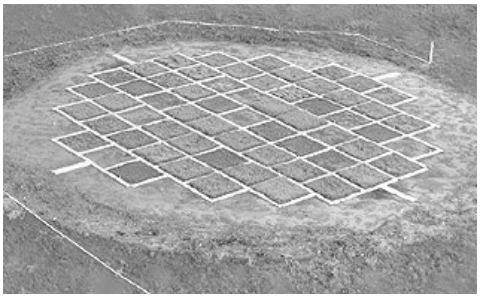
Diversity, elevated CO2 and N enrichment at Cedar Creek



Elevated CO2 may lead to loss of C4 species

Next time:

How resource limitation in Australia impacted community structure.

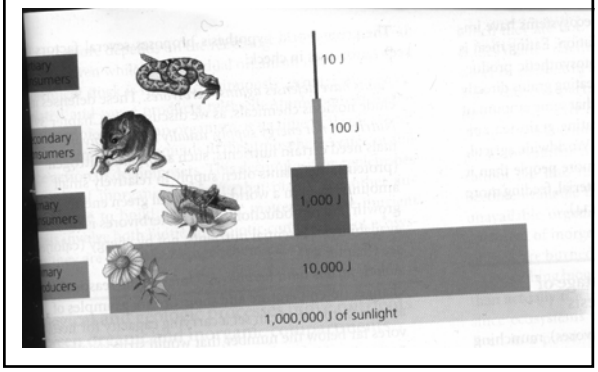
i.e., why so few carnivores?

Community Structure and diversity in Meganesia:

1. Why so few (many) mammalian (reptilian) carnivores? – "The mystery of Meganesian Meat-Eaters"

2. Community diversity in New Guinea: what happened to Goldilocks?

Trophic structure and energy flow: less than 20% efficiency across each level (here 10%)



Less energy means less numbers of top consumers (carnivores)

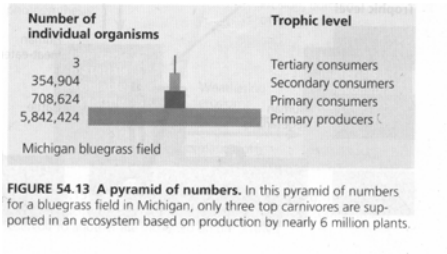


FIGURE 54.13 A pyramid of numbers. In this pyramid of numbers for a bluegrass field in Michigan, only three top carnivores are supported in an ecosystem based on production by nearly 6 million plants.

Low resources for carnivores compounded by disturbance (human or not) puts species in a very precarious situation.

Thylacine, for example…

Tasmanian 'tiger', Thylacinus cynocephalus:
•Dingo routed it from Australia – relict population on Tasmania
•Land clearing, bounties, disease, dog competition – conspired to 'depress numbers below a satisfactory breeding threshold' – Guiler

Year	Bounty
1888	81
1889	100
1890-1899	~100
1900	153
1901	>100
1908	17
1909	2
1910	0

Eastern quoll (survived)

Canis dingo

Marsupial Lion, Thylacoleo carnifex
Extinct 40,000 yrs ago

The extinction vortex: Rarity unto death.

***Even in a favorable environment*, small populations may lose genetic diversity due to the bottleneck effect and inbreeding, leading ultimately to even smaller populations until extinction.**

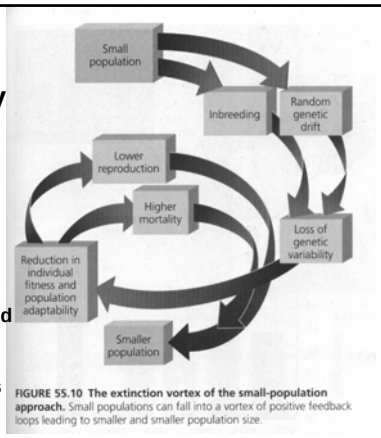


FIGURE 55.10 The extinction vortex of the small-population approach. Small populations can fall into a vortex of positive feedback loops leading to smaller and smaller population size.

What, then, led to the abundance of reptilian carnivores in Australia?

Why didn't New Guinea, with lots of resources, support lots of mammalian carnivores?

2. Community diversity in New Guinea: what happened to Goldilocks?

To answer this question, we really have to define what we mean by "Biodiversity"

Quantitative connotation but not easy to express in a single number.

American Heritage Dictionary, 4th Edition:

1. The *number* and *variety* of organisms found within a specified geographic region. 2. The variability among living organisms on the earth, including the variability within and between species and within and between ecosystems.

US Office of Technology Assessment:

"the *variety* and *variability* among living organisms and the ecological complexes in which they occur"

E.O. Wilson, Biodiversity II:

"Biodiversity is defined as all hereditarily based variation at all levels of organization, from the genes within a single local population or species, to the species composing all or part of a local community, and finally to the communities themselves that compose the living parts of the multifarious ecosystems of the world."

Biodiversity is scale dependent:

At the scale of 'uniform' ecosystems:

Image courtesy of N. C. Heywood, U. Wisconsin

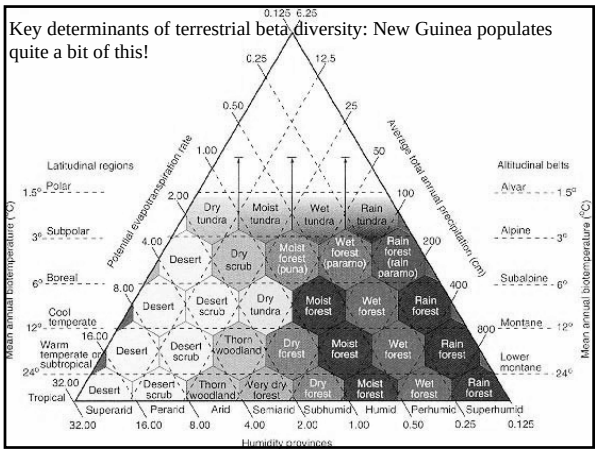
Biodiversity is scale dependent:

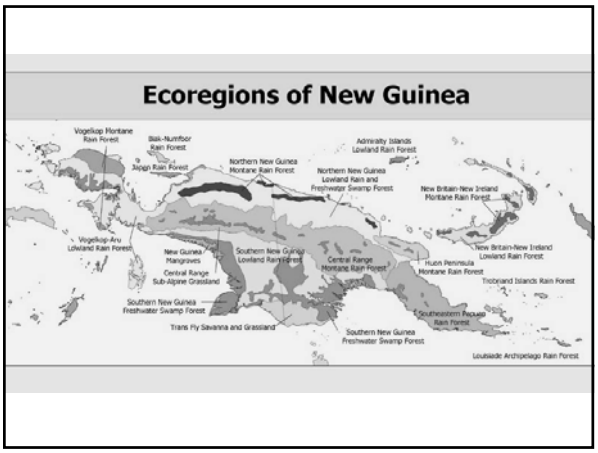
At the scale of landscapes:

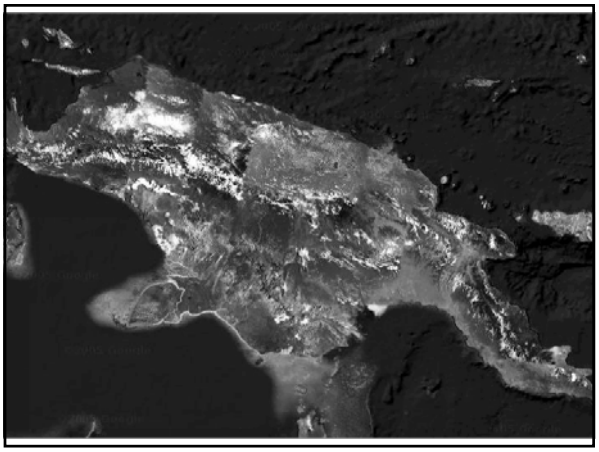
There may be e.g. low alpha diversity but high beta diversity, high alpha and high beta, or high alpha, low beta

Image courtesy of N. C. Heywood, U. Wisconsin

Key determinants of terrestrial beta diversity: New Guinea populates quite a bit of this!







New Guinea – beta diversity – alpine grassland

How does this look different than boreal grasslands? Why?

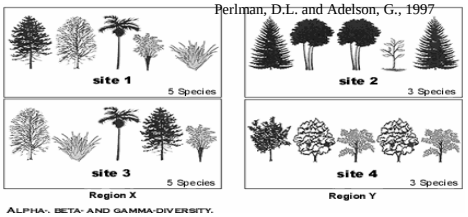
Montane Southern Beech (Nothofagus forest)

Southern Rain Forest

Freshwater swamp forest

Biodiversity may mean different things at different scales
Gamma Diversity = sum of alpha across beta habitats

Perlman, D.L. and Adelson, G., 1997



ALPHA-, BETA- AND GAMMA-DIVERSITY.

- **Site 1 has higher alpha diversity than site 2**
- **Region Y has higher beta diversity than Region X**
- **Region Y has higher gamma diversity than Region X**

Feb 6, 2007

Co-adaptation of Humans with the Environment: Lesson from the Aborigines.

Outline

1. **Agriculture as a key to understanding "The great leap forward" and history's haves and have-nots**
2. **Fire: a crucial link in human adaptation to the environment**

1. Agriculture as a key to understanding history's haves and have-nots

- **Jared Diamond was inspired to write Guns, Germs and Steel by a simple question asked by a Papua New Guinean:**

"Why did you people bring so much cargo to New Guinea, but we had little of our own?"

For the specific case of Aborigines in Australia:

Why did European colonists have so much more technology and power than Aborigines? What accounts for the Aboriginal nomadic, spare lifestyle? How does this question pertain to a course in biogeography?

The big picture: Why the disparities in humanity's have's and have nots?

1. Agriculture as a key to understanding history's haves and have-nots

The biogeographical link: Jared Diamond's answer to Yali's question:

***Environment*, not inherent biological differences, led to the enormously varied developments among human groups.**

Flannery asserts the same principle in explaining human cultural and ecological adaptation in Australia, New Guinea, New Zealand

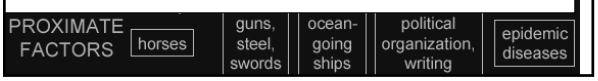
A key determinant of human social development: agriculture.

Let's investigate how environment relates to agriculture, and how agriculture relates to Aboriginal life in Australia

Evolution of Agriculture

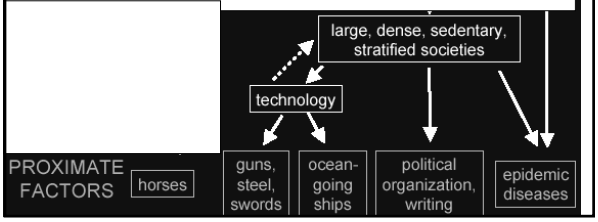
Proximate and Ultimate Causes

What Europeans brought to bear on interactions with native peoples (including Meganesia):



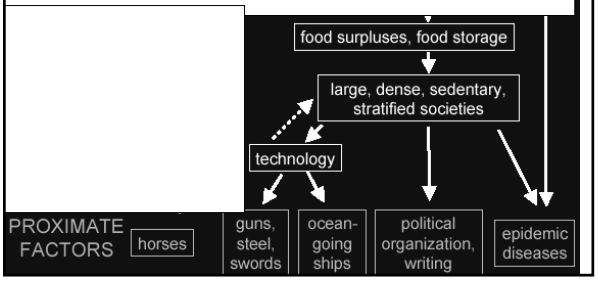
From proximate to ultimate causes:
Europeans enjoyed the large, dense, sedentary societies that allowed for technology, writing, and diseases to develop.

In nomadic societies, the focus for most people is on hunting/ gathering. Addtionally, a large 'toolkit' and sophisticated building is a burden

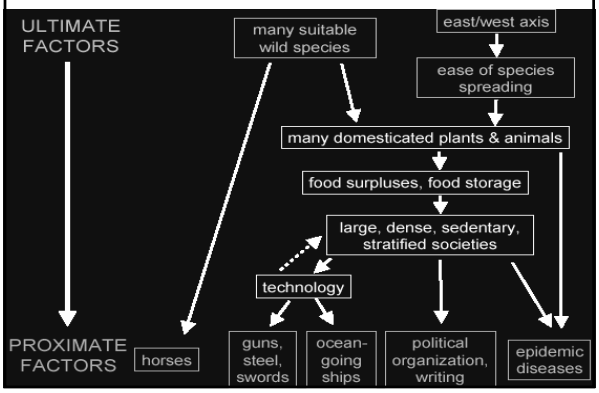


Food surplus and storage allows for large, dense societies.

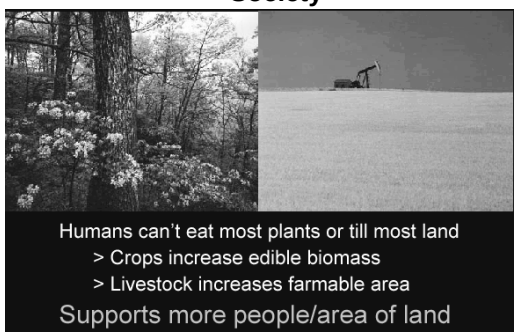
The link to agricultural is becoming clear.



Environment dictates whether agricultural is possible in a region.

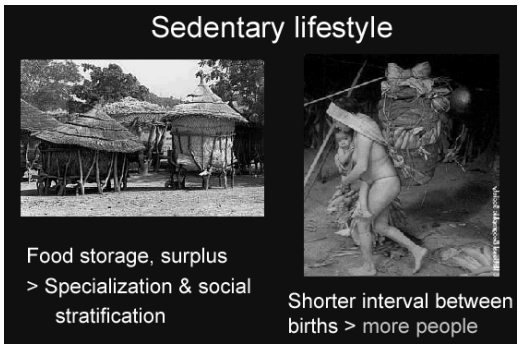


Biogeography, Agriculture, and Human Society



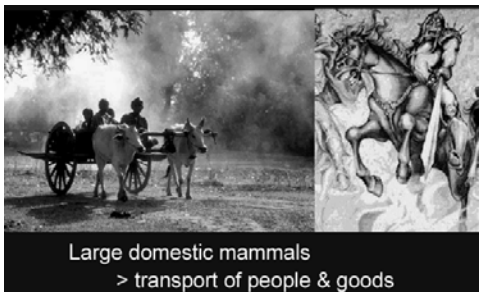
Link to Aborigines: No evidence of large-scale crop domestication.

Biogeography, Agriculture, and Human Society



Link to Aborigines: No food storage, Nomadic lifestyle

Biogeography, Agriculture, and Human Society



Link to Aborigines: Dogs were the only domesticated animals. Mixed benfits.

Biogeography, Agriculture, and Human Society

Link to Aborigines: Tuberculosis, common cold, measles, smallpox, gonorrhea, syphilis brought to Australia/Tasmania. Decimated Aboriginal populations.

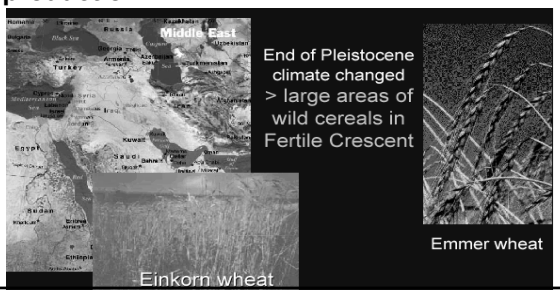
Agriculture and human ingenuity/inventiveness:

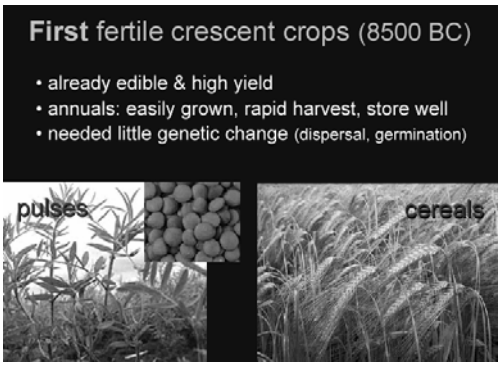
Agriculture was not invented; it evolved.

Environment, not human biology, determined where and how agriculture evolved.

Europe was lucky to be in close proximity to the 'fertile crescent'

Asia benefited from wide-scale rice production





1. **Biogeography, Agriculture, and Human Society**
2. **Human co-adaptation: the case of fire**
3. **Co-adaptation of people and environments: comparing Australia to New Guinea**

Biogeography, Agriculture, and Human Society

Aborigines: Flannery argues that Aborigines were not unable to develop agriculture. Instead, the environment in Australia made a nomadic lifestyle more appropriate. "the lack of agriculture by Australian Aborigines was a fine-tuned adaptation to a unique set of environmental problems, rather than a sign of 'primitiveness' "

Case in point: New Guinea developed agriculture; they are basically the same people as Australian Aborigines.

What one factor most likely dictated the Nomadic lifestyle in Australia, according to Flannery?

ENSO

ENSO in Australia

- **Feast or famine – not good for predictable crop harvest/storage.**
- **Lots of wasted food/leisure time during good times; but it only takes a few bad periods to decimate a population: "the size of hunter-gatherer populations is determined by the resources available at the worst of times"**

Nugget: We people have walked everywhere since time began. This is how I used to walk travelling along, following our Iwara.

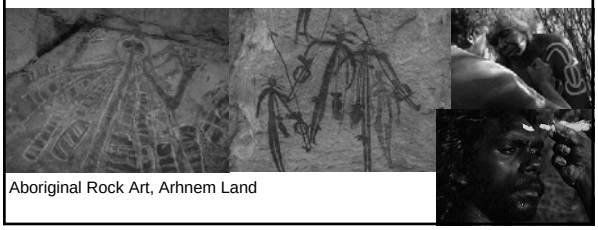
Not along roads, but far across the land by foot. It's not like travelling in a motor car. It's putting one foot in front of the other. We walked following the rainfall, and stayed where it had fallen

We drank from all the different rock holes, and lived around them for a while. After living there for a while we'd go off travelling to somewhere else. So we'd cover the entire landscape hunting and living.

Nugget Dawson
Uluru-Kata Tjuta National Park

Social/Religious reflections of Australian Environment

- **Large scale social network/cooperation: Aborigines needed each other. (examples: corroborees, stone ax trading)**
- **"Story places": religion in harmony with environment.**



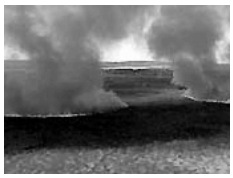
Aboriginal Rock Art, Arhnem Land

Corroborees

Songs recounted journeys, served as road maps for travel routes across Australia.

Played a critical, practical function in strengthening long-distance social networks and bonds.

Fire



Megafaunal Extinction

Flannery: *"To Australia's megafauna this was a deadly weapon.... and that's because these huge creatures were built for supreme energy efficiency, they were slow moving and despite their enormous heads they had tiny brains, but worst of all they'd evolved for millions of years in an ecosystem where nothing like humans had ever existed and that made them naive, they had no fear of human hunters"*

giant flightless bird – Geniornus. Egg shells – 60,000 yrs ago – none found 20,000 yrs ago during ice age.

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Like desert raisins, bush tomatoes, sweet nectar.

Co-adaptation and co-existence

Flannery: "After having changed everything, these people had set a new pattern for living with the special conditions of Australia. They'd established a remarkable ecological stability - there's little evidence of extinctions in the land, for tens of thousands of years.

Comparing humans and environments in Australia with New Guinea.

-More fertile New Guinea highlands allowed agriculture, high human densities.

-More sophisticated housing, tools, political structures (chiefdoms instead of tribes). "payback system"

Types of Societies*

	Band	Tribe	Chiefdom	State
Size				
Subsistence				
Settlement				
Economy				
Government				
Social Differentiation				
Religion				
Examples				

* This table is taken from Carol Ember and Melvin Ember, The Facts of Human Societies, W.W. Norton, New York, 1998

Sophisticated culture/religion

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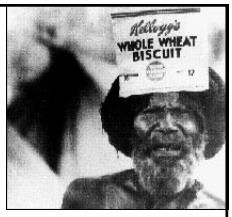
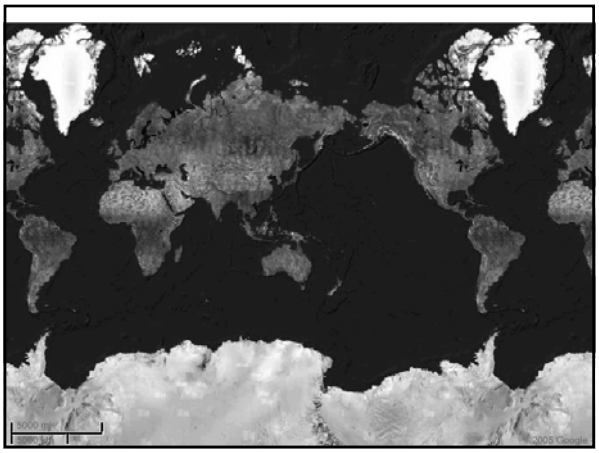
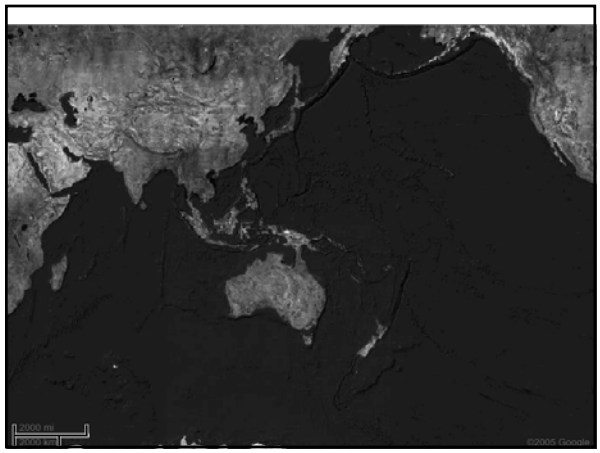
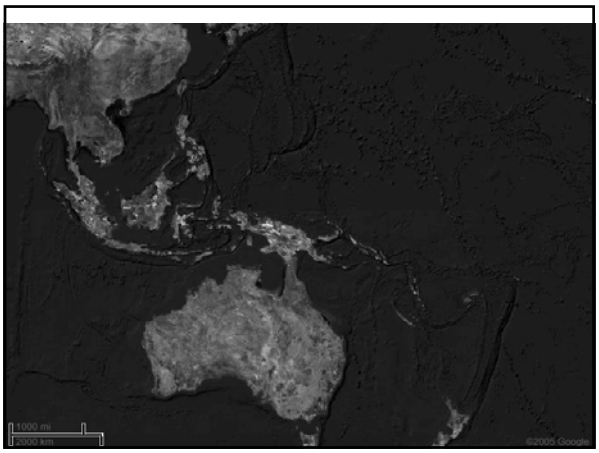
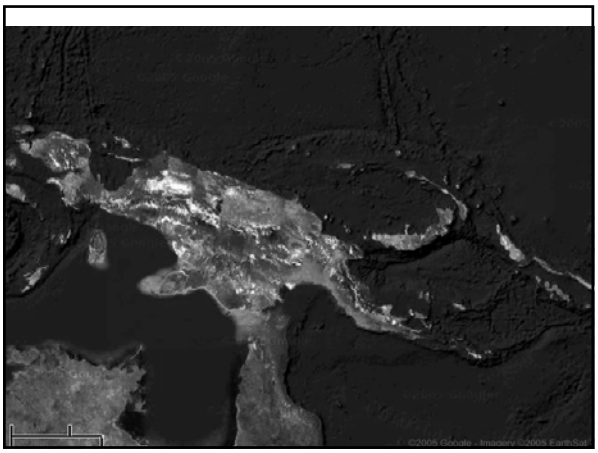
Disruption due to contact with outsiders.

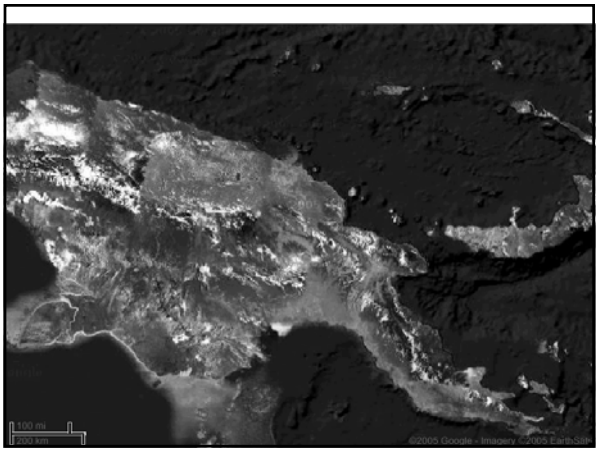


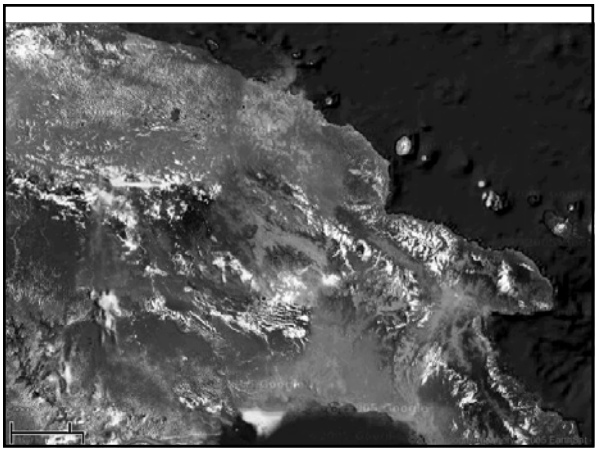


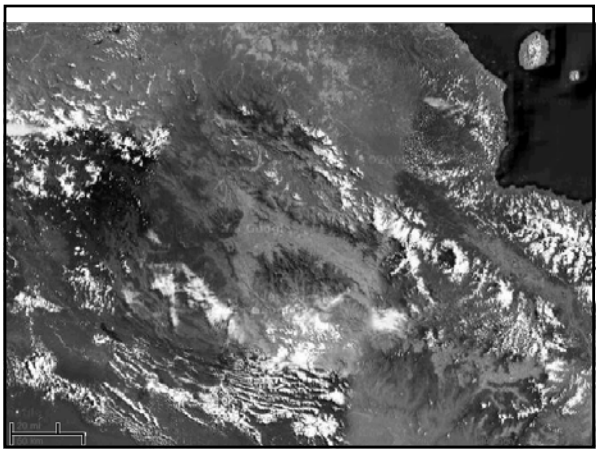


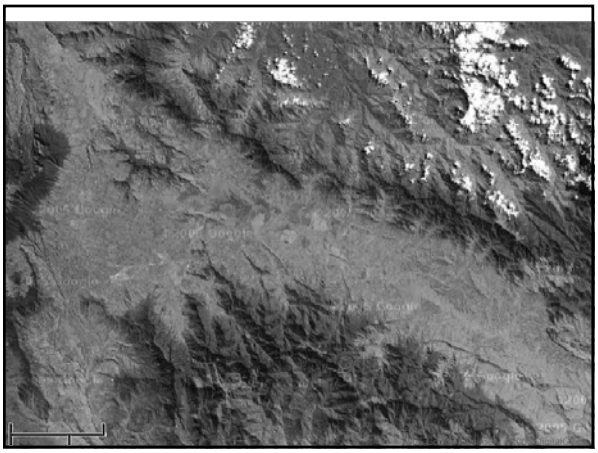


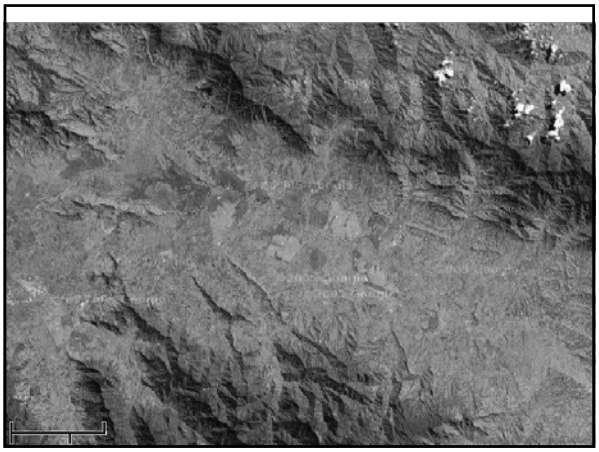












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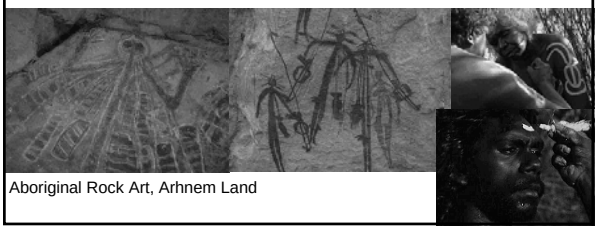

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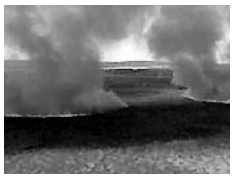

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Types of Societies*

	Band	Tribe	Chiefdom	State
Membership				
Numbers of People	Dozens	Hundreds	Thousands	Over 50,000
Settlement pattern	Nomadic	Fixed: 1 village	Fixed: 1 or more villages	Fixed: Many villages and cities
Basis of Relationships	Kin	Kin-based clans	Class and residence	Class and residence
Ethnicities and languages	1	1	1	1 or more
Government				
Decision making leadership	“egalitarian”	“egalitarian” or big-man	Centralized hereditary	Centralized
Bureaucracy	None	None	None or 1 or 2 levels	Many levels
Monopoly of force and information	No	No	Yes	Yes
Conflict resolution	Informal	Informal	Centralized	Laws, judges
Hierarchy of settlement	No	No	No-> paramount village	Capital
Religion				
Justifies kleptocracy	No	No	Yes	Yes -> No
Economy				
Food production	No	No -> yes	Yes -> intensive	Intensive
Division of labor	No	No	No -> Yes	Yes
Exchanges	Reciprocal	Reciprocal	Redistributive (“tribute”)	Redistributive (“Taxes”)
Control of land	Band	Clan	Chief	Various
Society				
Stratified	No	No	Yes, by kin	Yes, not by kin
Slavery	No	No	Small-scale	Large-scale
Luxury goods for elite	No	No	Yes	Yes
Public Architecture	No	No	No ->yes	Yes
Indigenous literacy	No	No	No	often

* This table is taken from Jared Diamond’s book Guns Germs and Steel: The Fates of Human Societies W.W. Norton, New York, 1999

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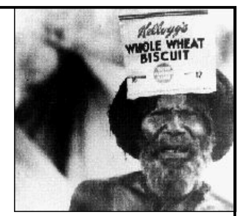
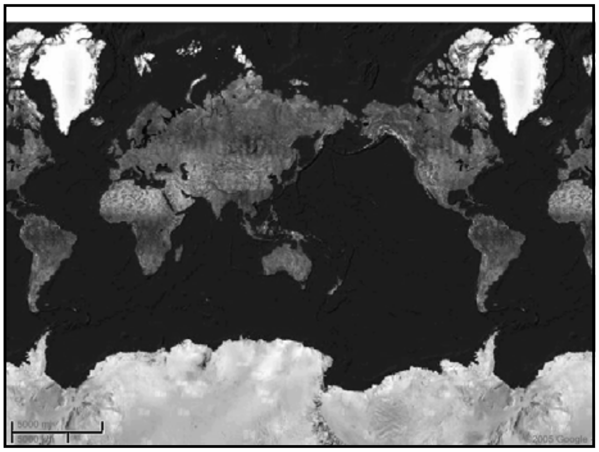
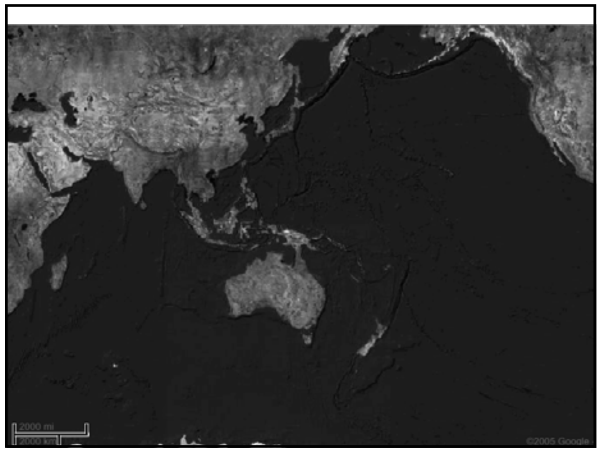
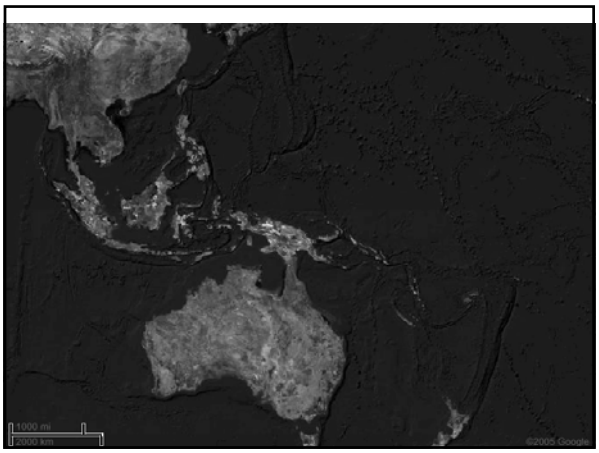
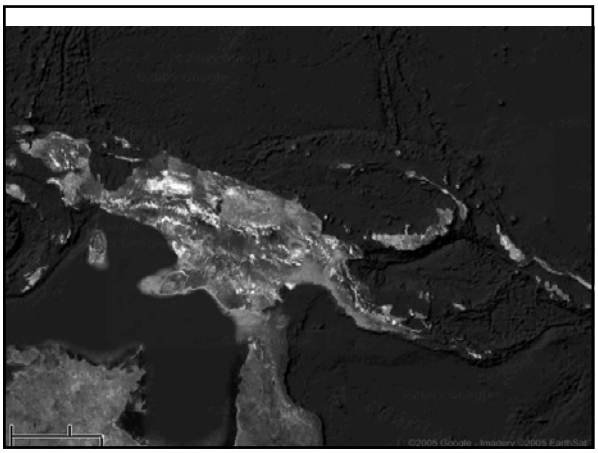
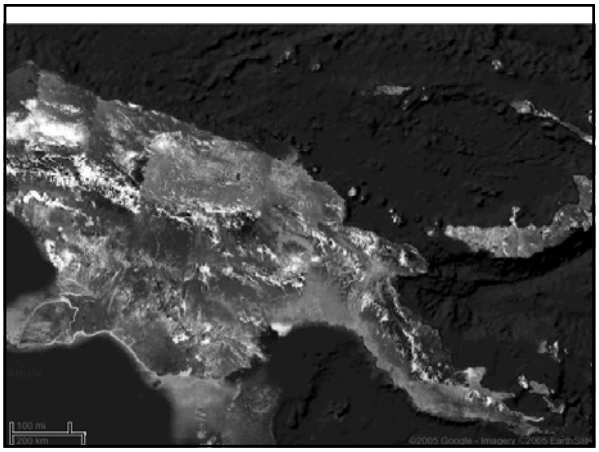


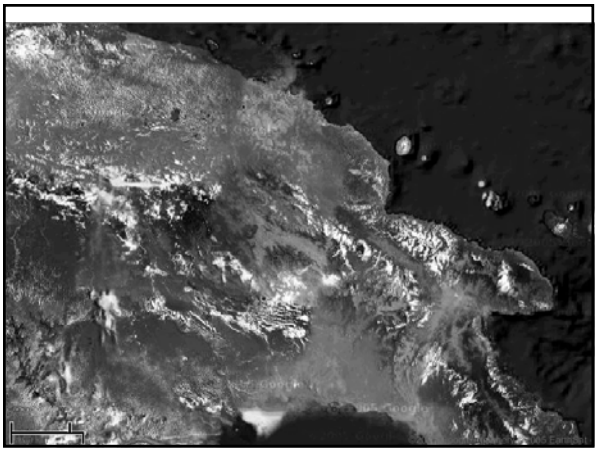


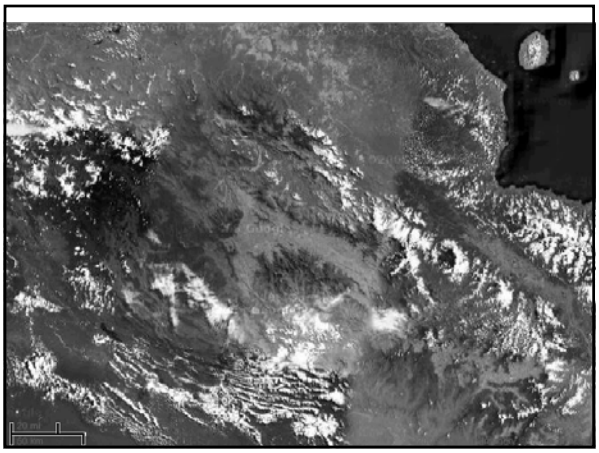


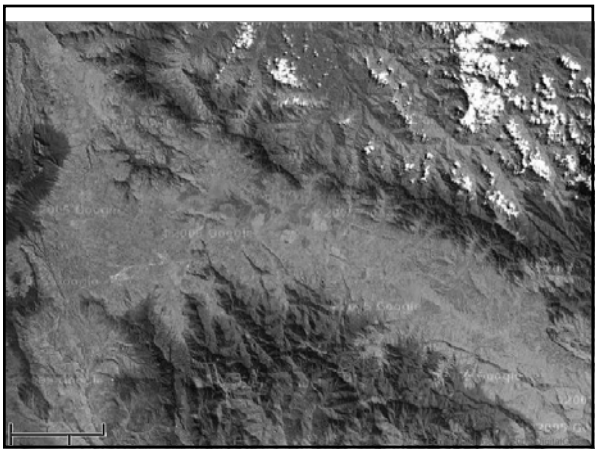


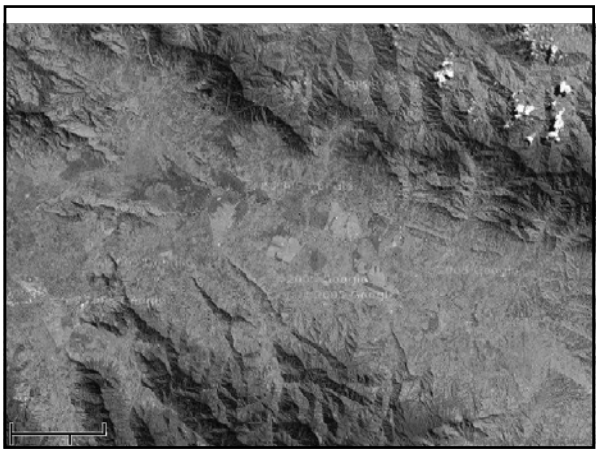


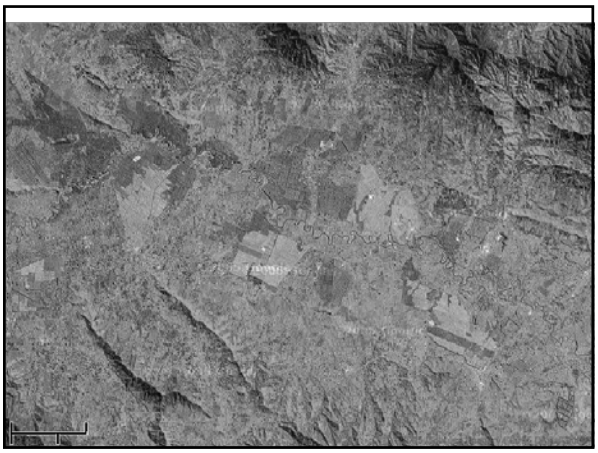












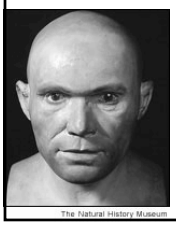
The last wave: Arrival of the Europeans

Outline

1. **Guns, Germs, Steel revisited, or why European plants and animals were so 'successful' in Australasia**
2. **"Rejected transplant": cultural maladaptation to the environment**
3. **Adaptating Culture to Biological Reality**

1. Guns, Germs, Steel revisited, or why European plants and animals were so 'successful' in Australasia

- Ice age retreat selected for those species that could disperse fastest, and monopolize resources. – a weedy sweepstakes.



- Plant and animal domestication opened new avenues for resource exploitation – good for Europeans settlers in Australasia during 'good times', but a short-sighted way of life.

2. "Rejected transplant": cultural maladaptation to the environment

Evidence of 'cluelessness':

1770 - "Like plantations in a gentleman's park' – early observations of Australia were very superficial and took the short view.

1789 – "in the whole world there is not a worse country" – Robert Ross.

Modern customs: Christmas, Easter bunnies.

2. "Rejected transplant": cultural maladaptation to the environment

"Acclimitasation Societies" – sought to remake the Australasian landscape into a version of Britain.

"…the English nightingale was to sing in English elms…"

The red deer in New Zealand – introduced to provide sport hunting. A huge pest now.

- overgrazes grasslands, decimates forest understory

2. "Rejected transplant": cultural maladaptation to the environment

Technological follies:

- **unsustainable mechanized Farming.**

- irrigation schemes

2. "Rejected transplant": cultural maladaptation to the environment

Unbounded optimism:

"There is every reasonable probability that in 1988 Australia will be… peopled by 50 millions of English-speaking men, who, sprung from the same races as the American of the Union…"

"If the US has grown in the last century… there is no reason why… we should not grow to a population of two hundred or three hundred millions of white people in the Empire"

Leopold Emergy, Under Secretary for Colonies, 1923.

2. "Rejected transplant": cultural maladaptation to the environment

Unbounded optimism:

"desert myth", "destined one day to pulse with life" – Edwin Brady, Australia Unlimited, 1918.

- reminiscent of US dust bowl optimism: "the rain follows the plow"

2. "Rejected transplant": cultural maladaptation to the environment

Future Eating:

"the early tenants of Australia's forested land had one thing in common – a supreme faith in the inexhaustibility of the timber resources of the country." – Leonard Webb, botanist.

Outline

1. **Guns, Germs, Steel revisited, or why European plants and animals were so 'successful' in Australasia**
2. **"Rejected transplant": cultural maladaptation to the environment**
3. **Adaptating Culture to Biological Reality**

3. Adaptating Culture to Biological Reality

Flannery's key recommendations (Australia):

-Develop a population policy for Australia based on environmental sustainability. Target population to perhaps 6-12 million (current population = 20.1 million)

-Mimic Aboriginal firestick farming practices with modern technology, to prevent wholesale destruction by huge bushfires. (the 'fractal fringe', martha's vineyard)

-Initiate sustainable development and replace European style farming with farming of native species like the emu, kangaroo and crocodile.

3. Adaptating Culture to Biological Reality

Is it that simple? Plenty of critics of Flannery:

-Firestick farming:

"Aboriginal land management varied/varies from region to region, for example between northern and central Australia, and so you cannot generalise." - Jeremy Russell-Smith, Bush Fire Council, Northern Territory

3. Adaptating Culture to Biological Reality

Is it that simple? Plenty of critics of Flannery:

-Firestick farming:

"This is certainly a beneficial idea, but one must ask whether it's the most important thing to do with scarce conservation resources. I'd be investing effort in working out how to control cats and foxes, and how to bring grazing pressure down to a sustainable level." – Steve Morton, University of Melbourne. (arid-zone ecologist)

3. Adaptating Culture to Biological Reality

Is it that simple? Plenty of critics of Flannery:

-Population:

"We export food and other primary resources to many other countries. It is by no means certain that controlling the Australian population will necessarily protect and preserve our environment because habitats may continue to be destroyed and farmland abused to balance our trade. By simply focusing on Australian population levels the issues becomes trivialised and more importantly can be used for mischievous political purposes such as focusing on the ethnic or racial composition of immigrants - policies that have no place in the civilised world." – David Bowman, Senior Research Fellow, Northern Territory University.

3. Adaptating Culture to Biological Reality

Is it that simple? Plenty of critics of Flannery:

-Native animal farming:

"Care must be take to ensure that economic imperatives to maximise short-term profits don't result in the 'tail wagging the dog' leading to the pillaging of wildlife stocks." – David Bowman

Canada geese?

Concluding words of wisdom:

"When it suits them, men may take control and play fine tricks and hustle nature. Yet we may believe that Australia, quietly and imperceptibly… is experimenting on the men… She will be satisfied at long last, and when she is satisfied an Australian nation will in truth exist"

- Sir Keith Hancock, "Australia", 1930