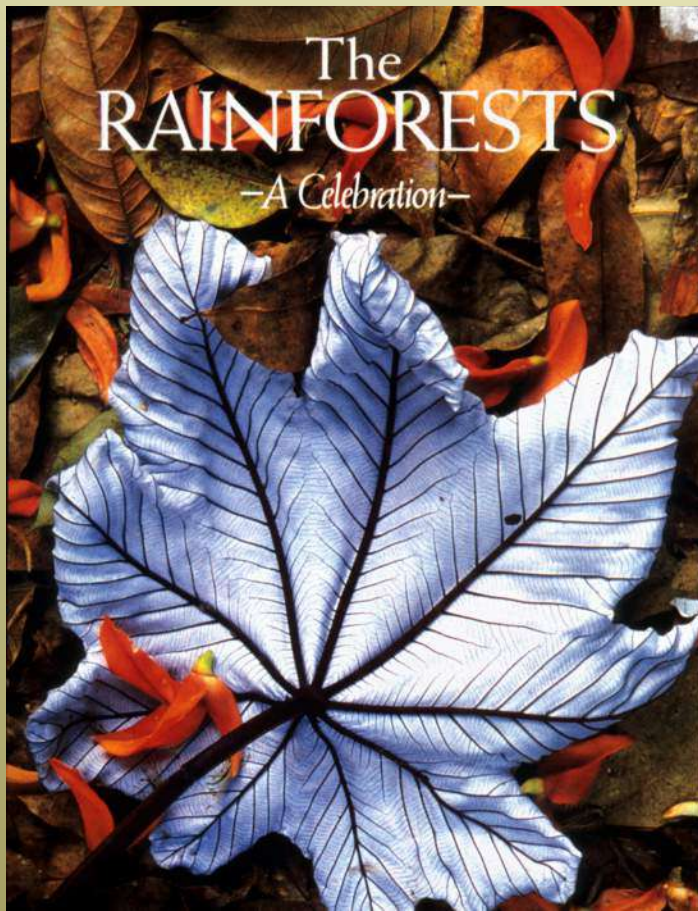
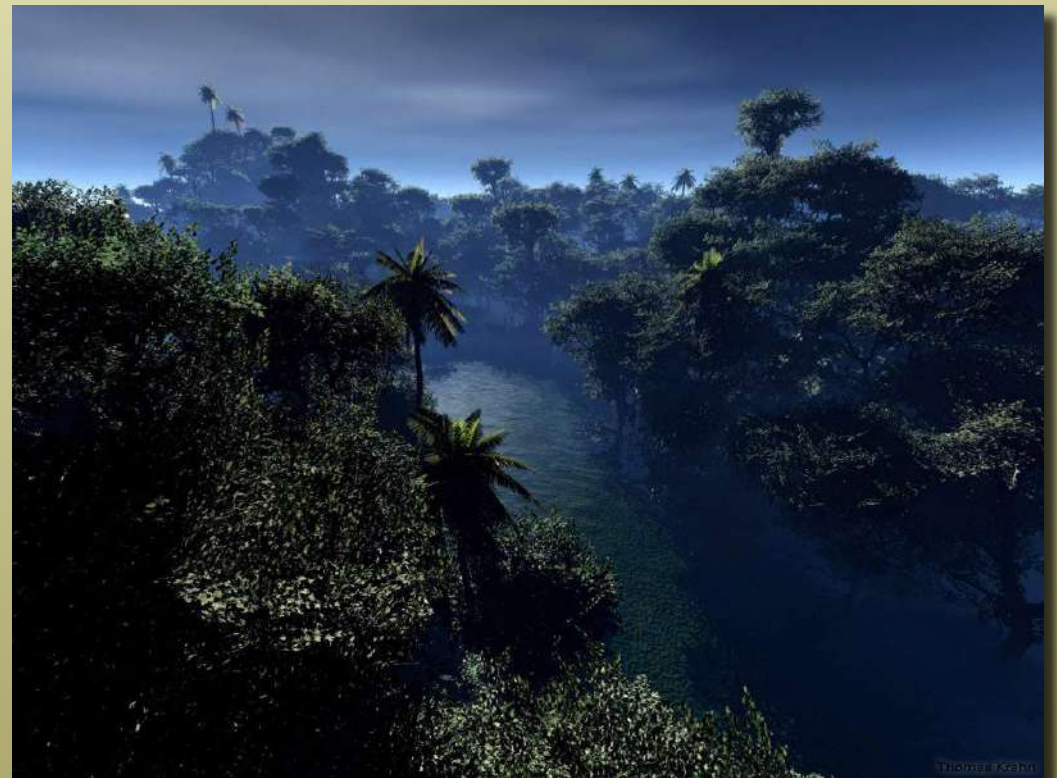


# Tropical Rainforest Biome

*"The land is one great, wild, untidy luxuriant hothouse, made by Nature for herself. . . How great would be the desire in every admirer of Nature to behold, if such were possible, the scenery of another planet! . . . Yet to every person it may truly be said, that the glories of another world are opened to him"*

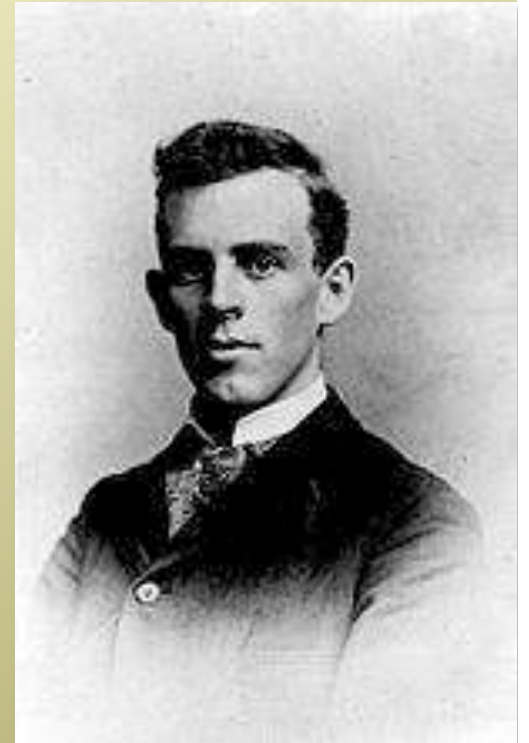


Charles Darwin in *The Voyage of the Beagle*



# Tropical Rainforest Biome

*"Never to have seen anything but the temperate zone  
is to have lived on the fringe of the world"*



David Fairchild

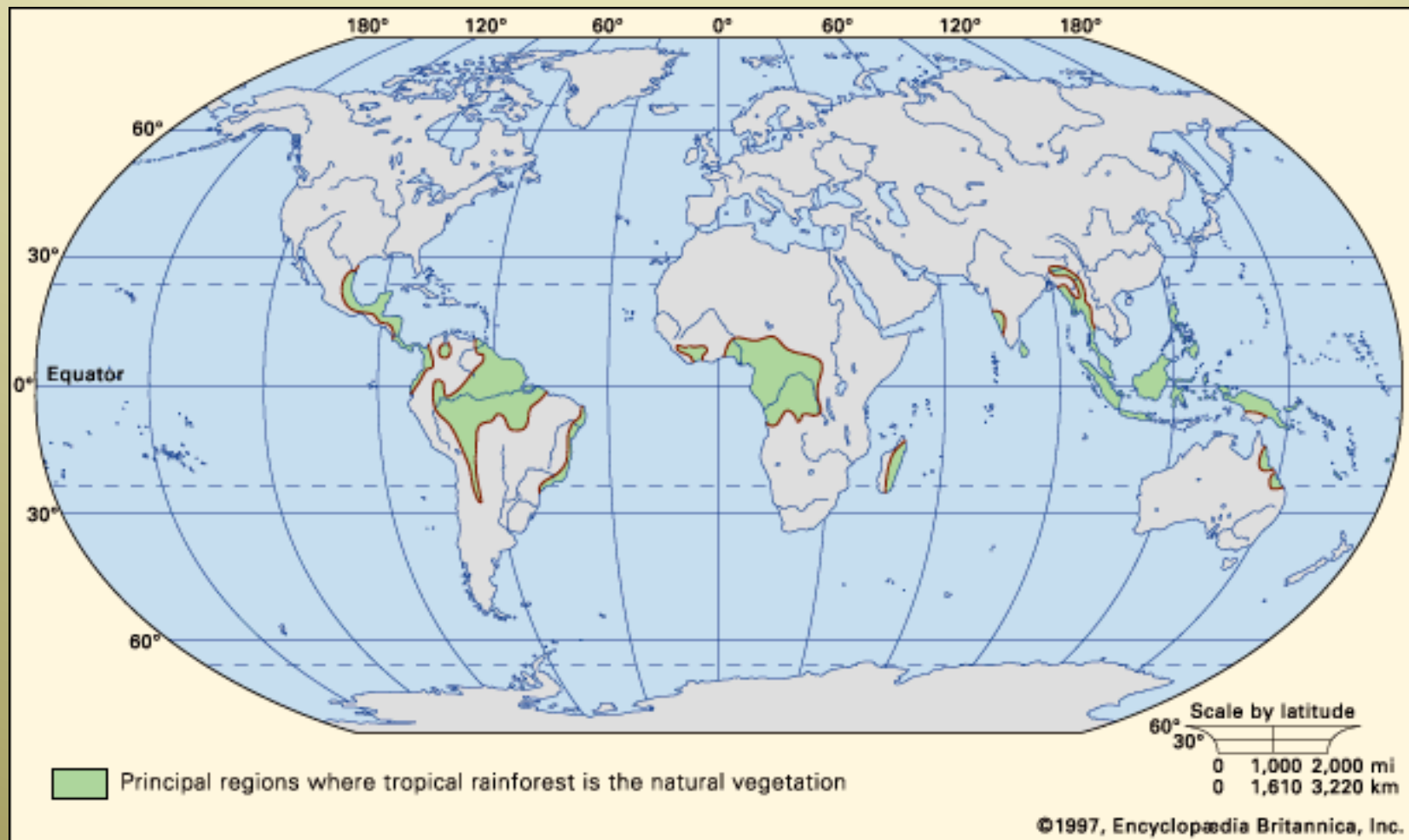
## Tropical Rainforest Biome

- equatorial lowlands and rainbelt; very short dry season
- multi-layered, evergreen canopy, high species diversity
- convergent adaptations around world, but different floras



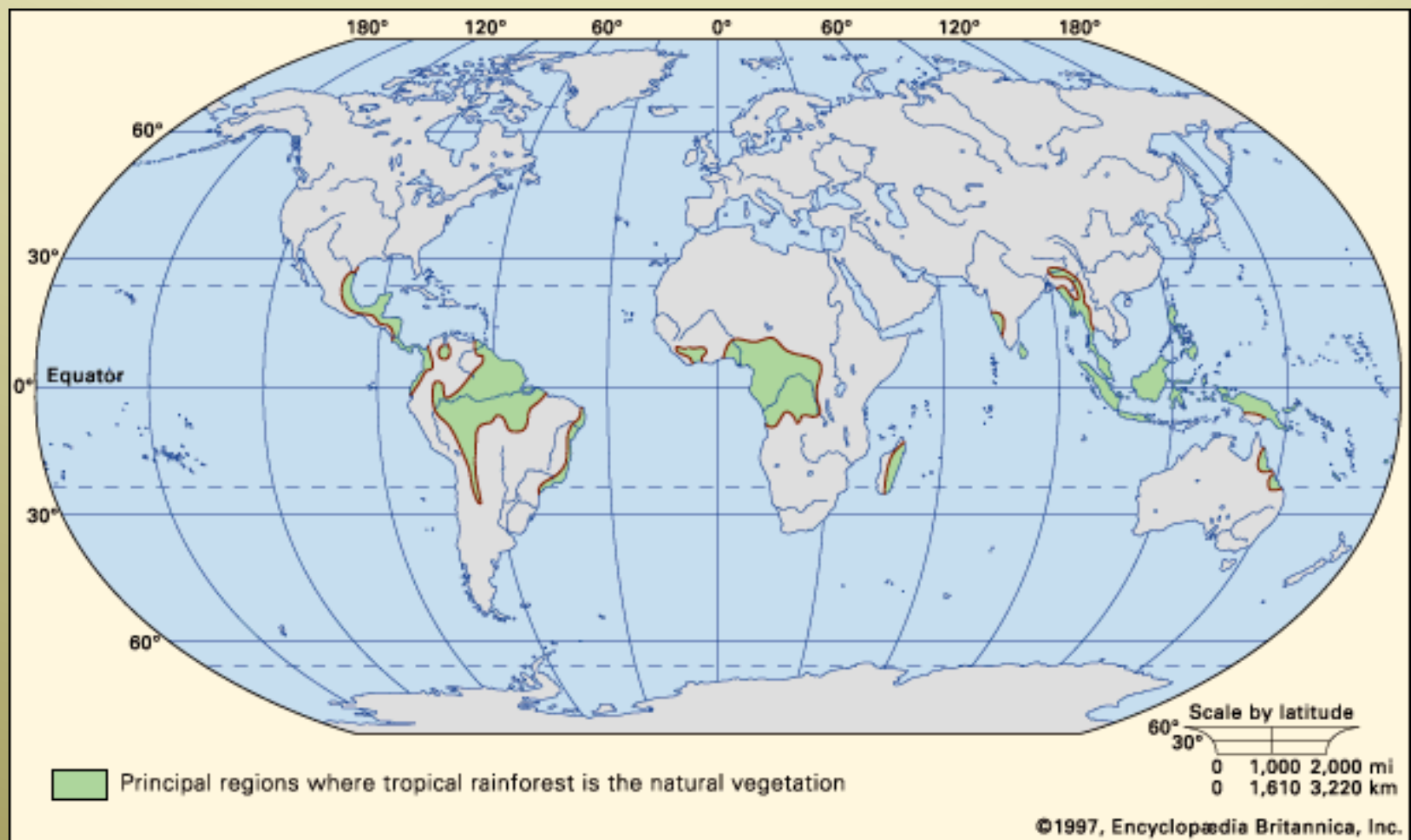
# Tropical Rainforest Biome

**Location:** 1. Equator to 10° or 25° N & S latitude and 0 - 1,000m elevation in Americas, Africa, SE Asia



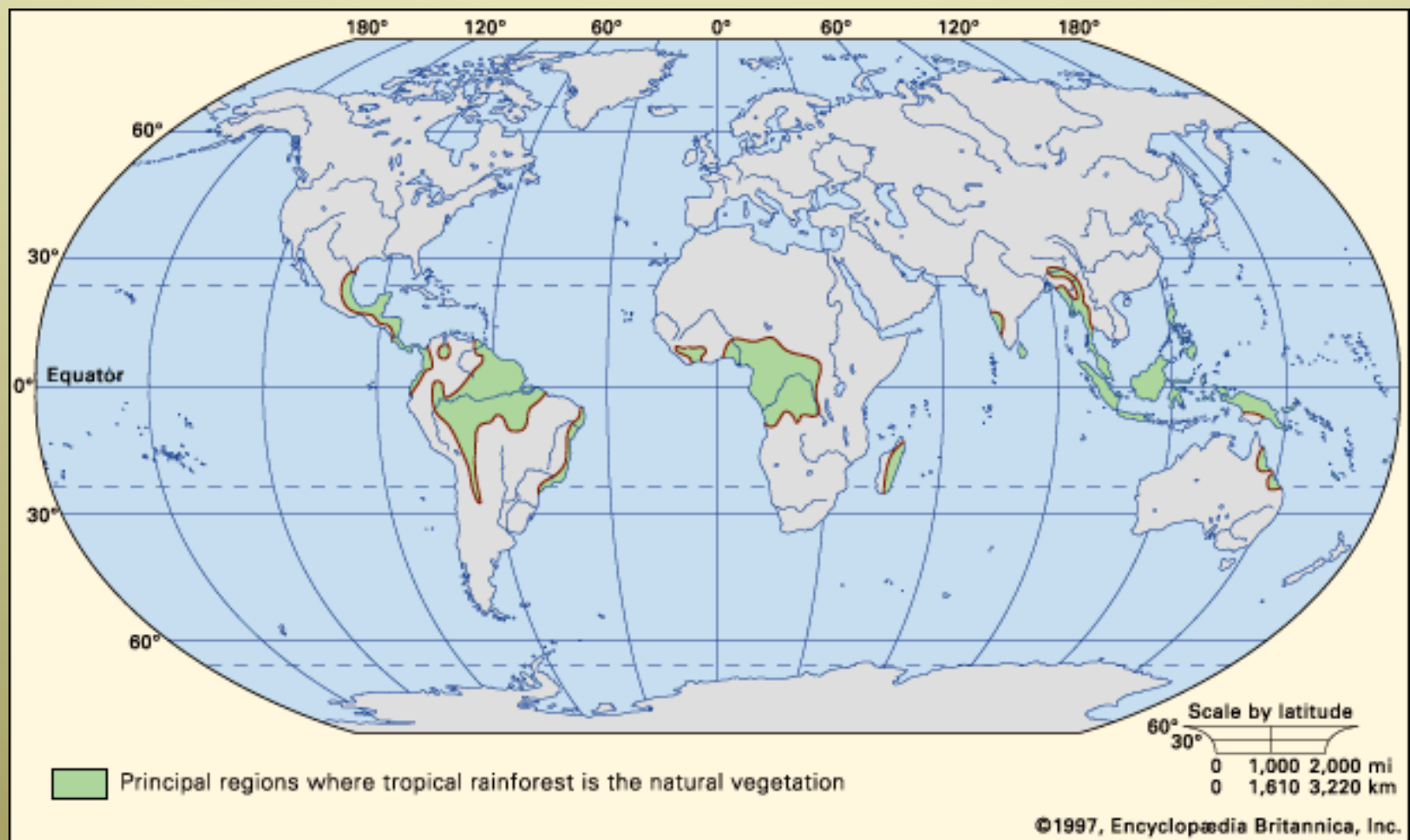
# Tropical Rainforest Biome

**Location:** 2. Along coasts windward to the trades — E. Brazil, Madagascar, NE Australia



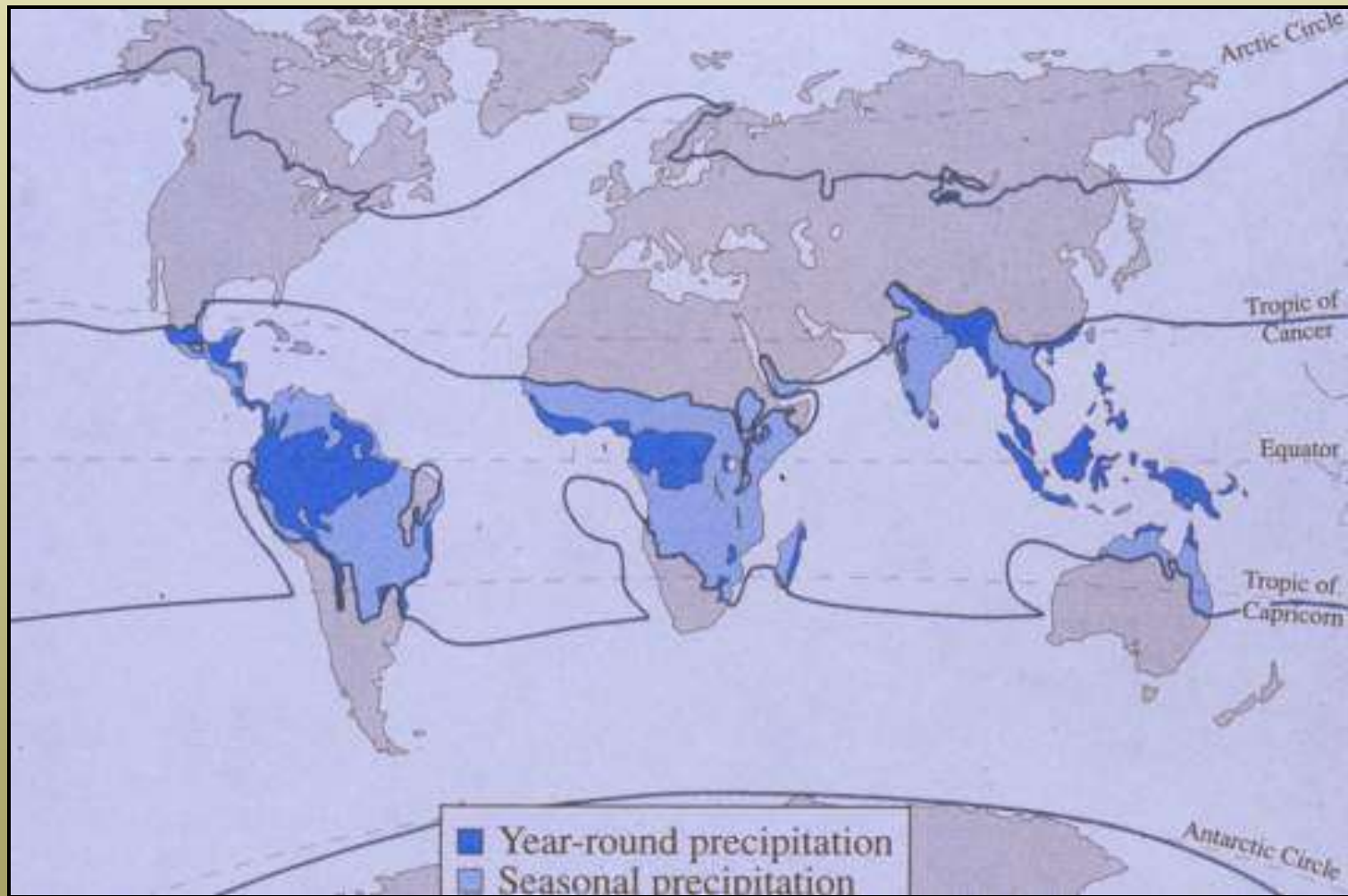
# Tropical Rainforest Biome

**Location:** 3. East coasts with orographic precipitation —  
E. Panama and Costa Rica, E. Puerto Rico



## Tropical Rainforest Biome

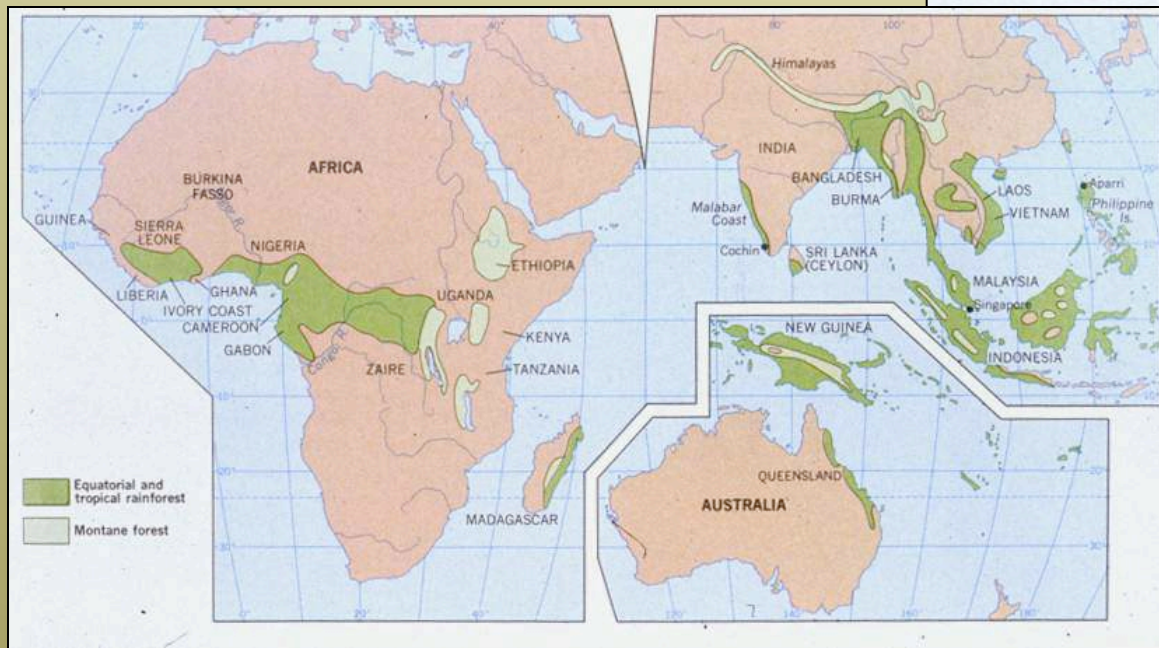
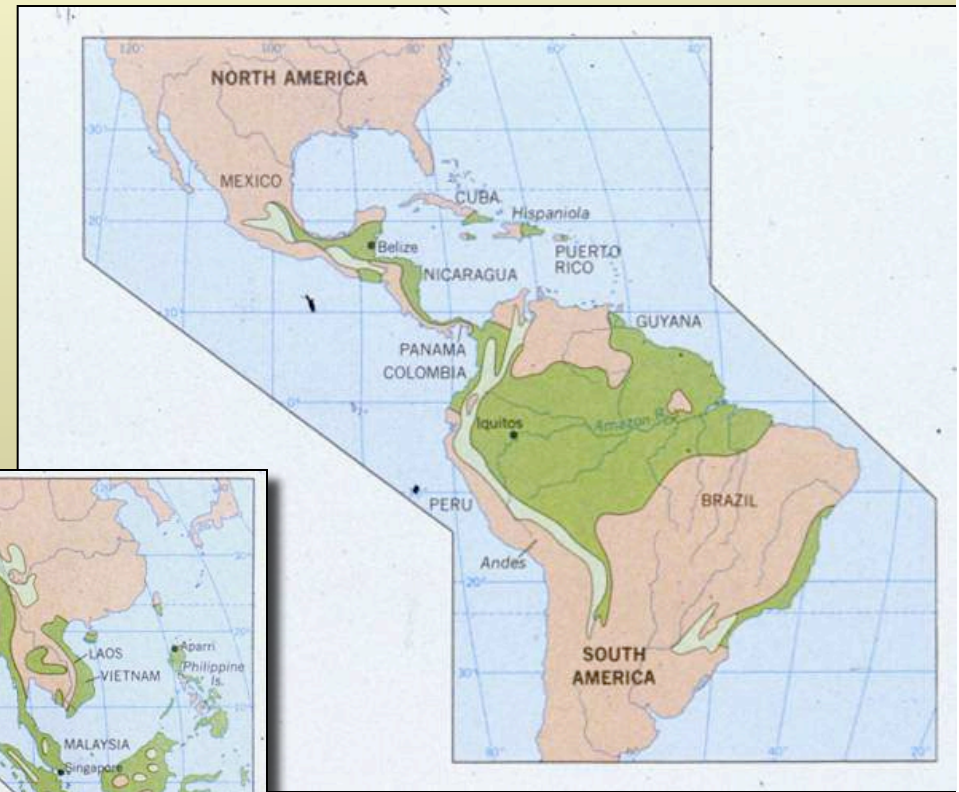
**Location:** Seasonally dry tropical forests adjacent at higher latitudes or on leeward side of montane regions



# Tropical Rainforest Biome

Three floristically diverse regions:

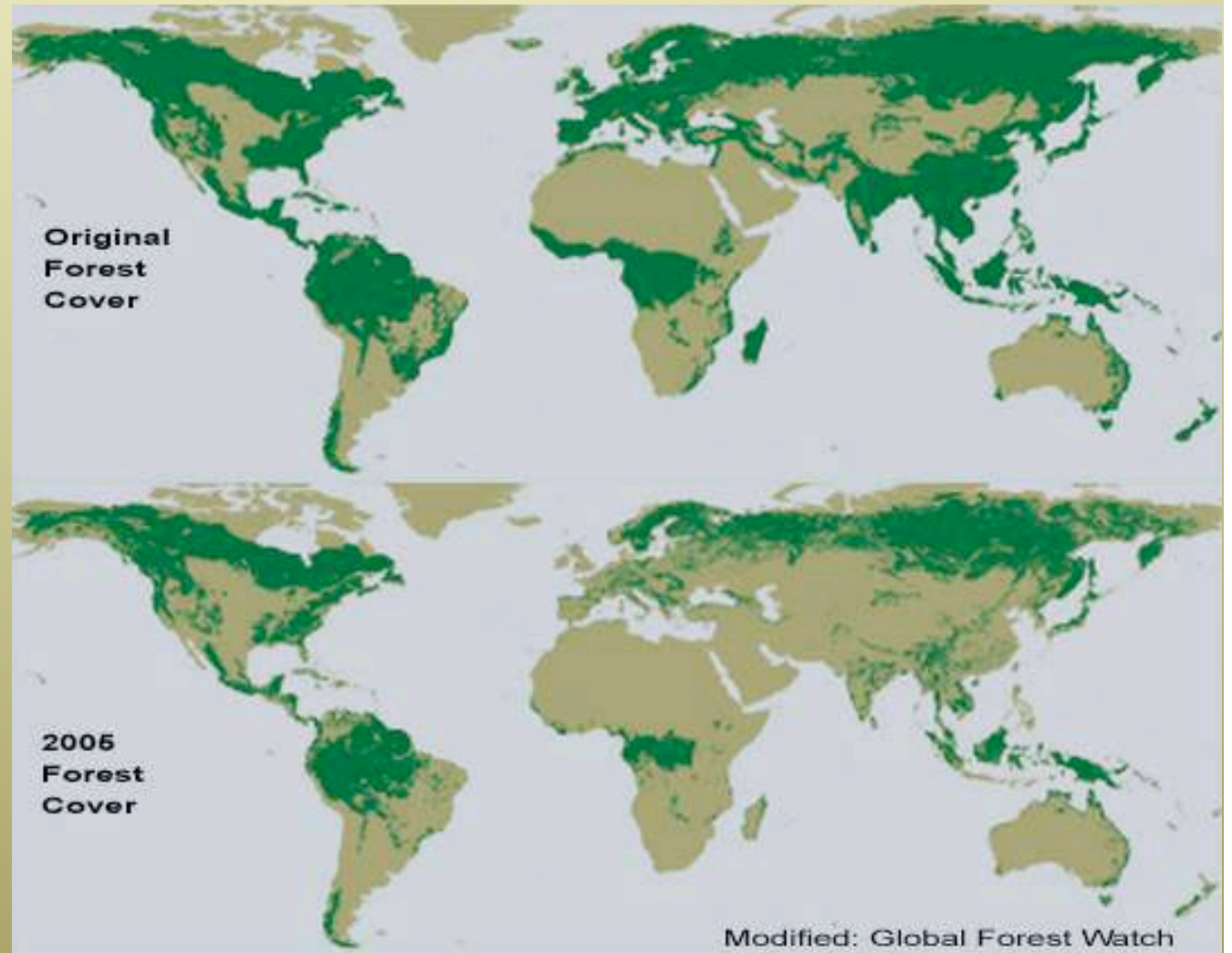
1. American: 50% of area
2. African: 20%
3. S.E. Asian - Pacific: 30%





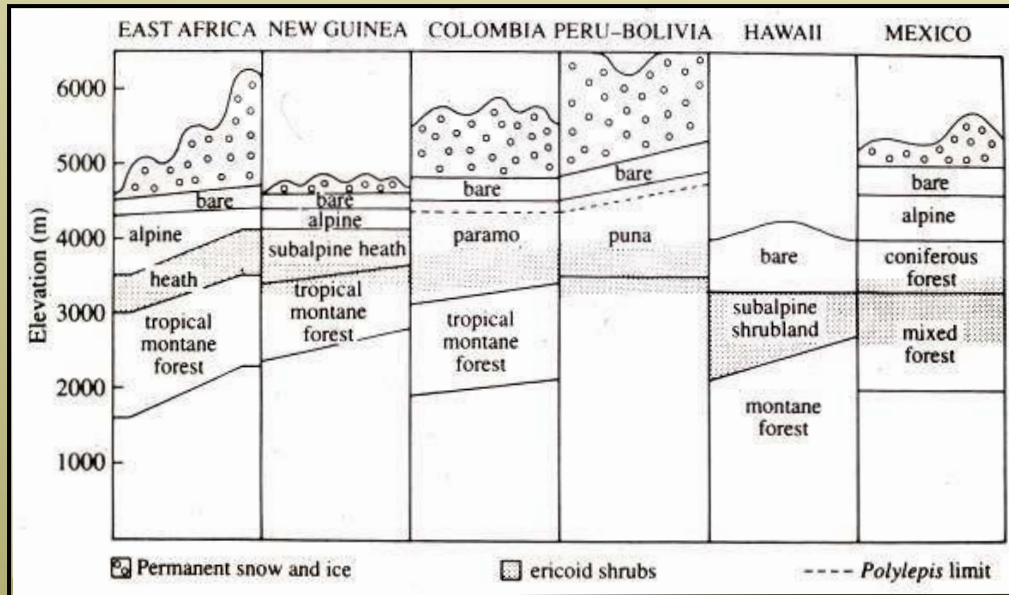
# Tropical Rainforest Biome

Fragmentation of rainforests  
— especially African and  
Asian — ongoing



# Tropical Rainforest Biome

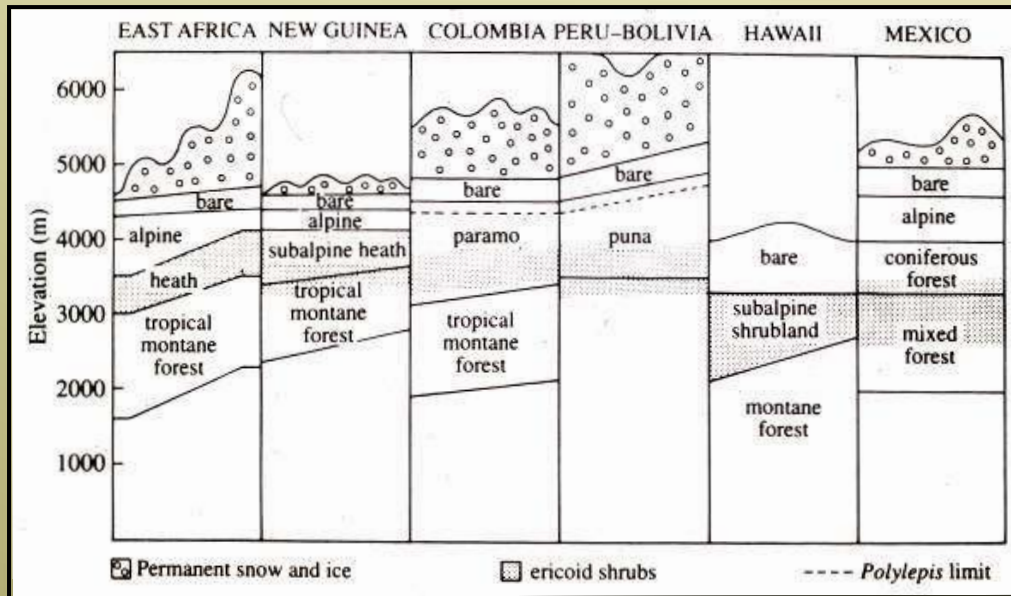
Relationships to other tropical forest systems — elevation gradient:



Tropical montane or cloud forest

# Tropical Rainforest Biome

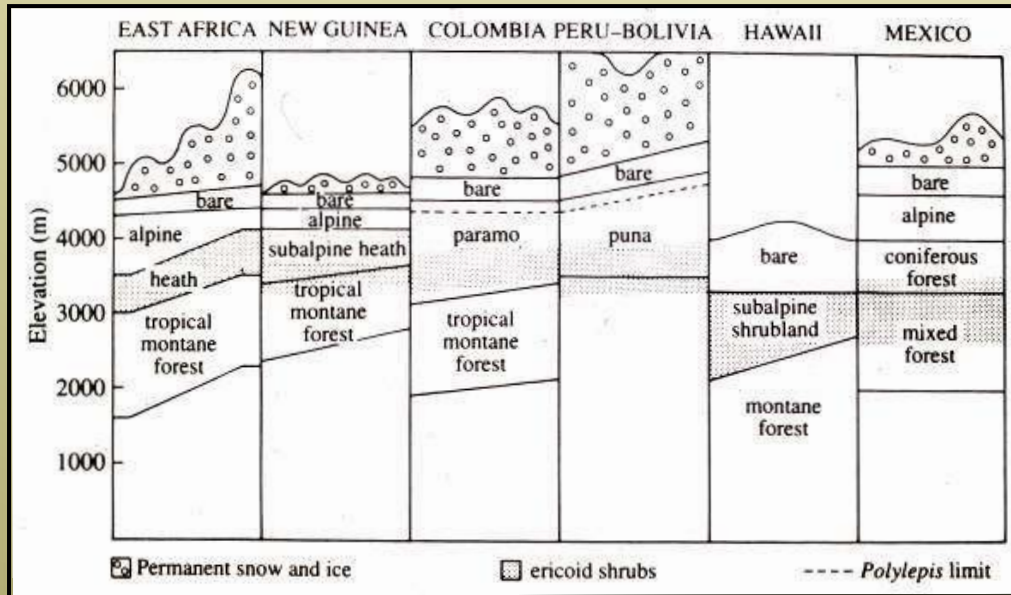
Relationships to other tropical forest systems — elevation gradient:



Elfin forest

# Tropical Rainforest Biome

Relationships to other tropical forest systems — elevation gradient:



Paramo

Photo: Mauricio Diazgranados

# Tropical Rainforest Biome

Relationships to other tropical forest systems — ecological gradient:

Mangrove and beach forests



# Tropical Rainforest Biome

Relationships to other tropical forest systems — ecological gradient:

Seasonally flooded swamp forests

*Várzea*: flooded by muddy water tributaries of Amazon

Rio Beni, Bolivia



# Tropical Rainforest Biome

Relationships to other tropical forest systems — ecological gradient:

Seasonally flooded swamp forests

*Várzea*: flooded by muddy water tributaries of Amazon

flooded vs. dry



## Tropical Rainforest Biome

Relationships to other tropical forest systems — ecological gradient:

Seasonally flooded swamp forests

**Igapó:** flooded by nutrient poor waters of sandy soils (leached tannin stained)



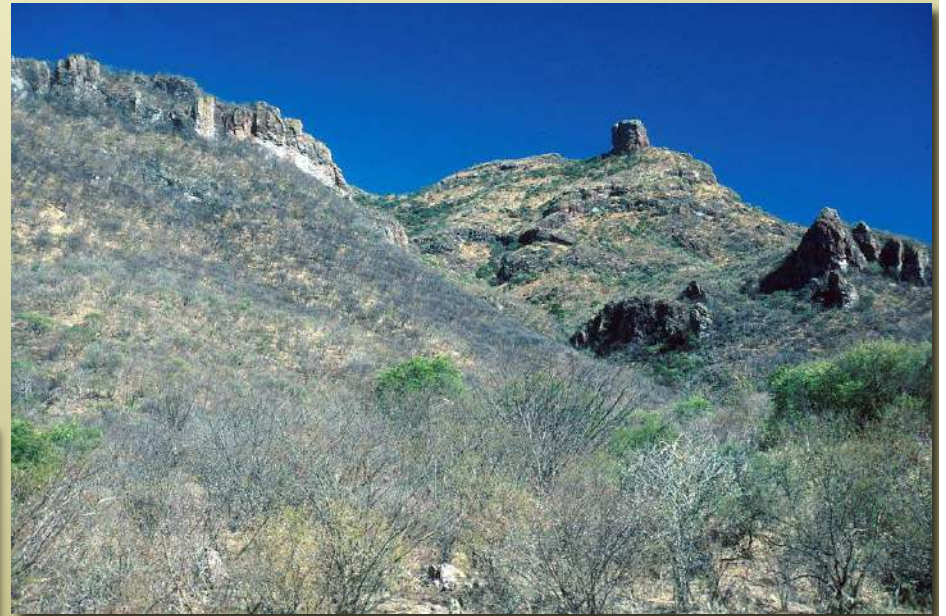
Rio Negro, Amazonas



# Tropical Rainforest Biome

Relationships to other tropical forest systems — latitudinal gradient:

Subtropical deciduous forests (& monsoon, tropical deciduous, thorn forest)



Alamos, Mexico  
Summer green, winter dry



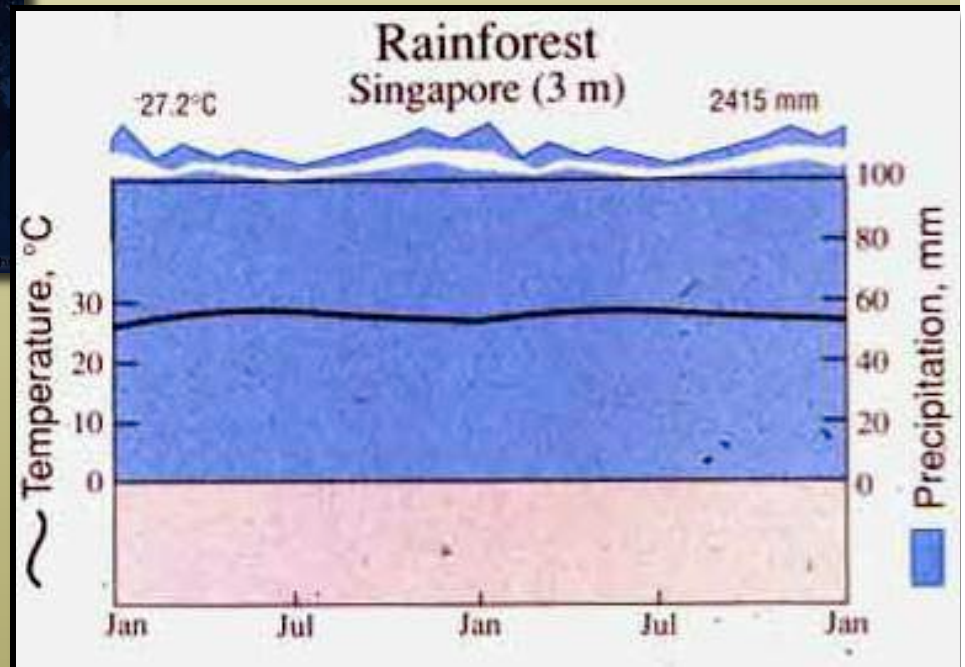
# Tropical Rainforest Biome



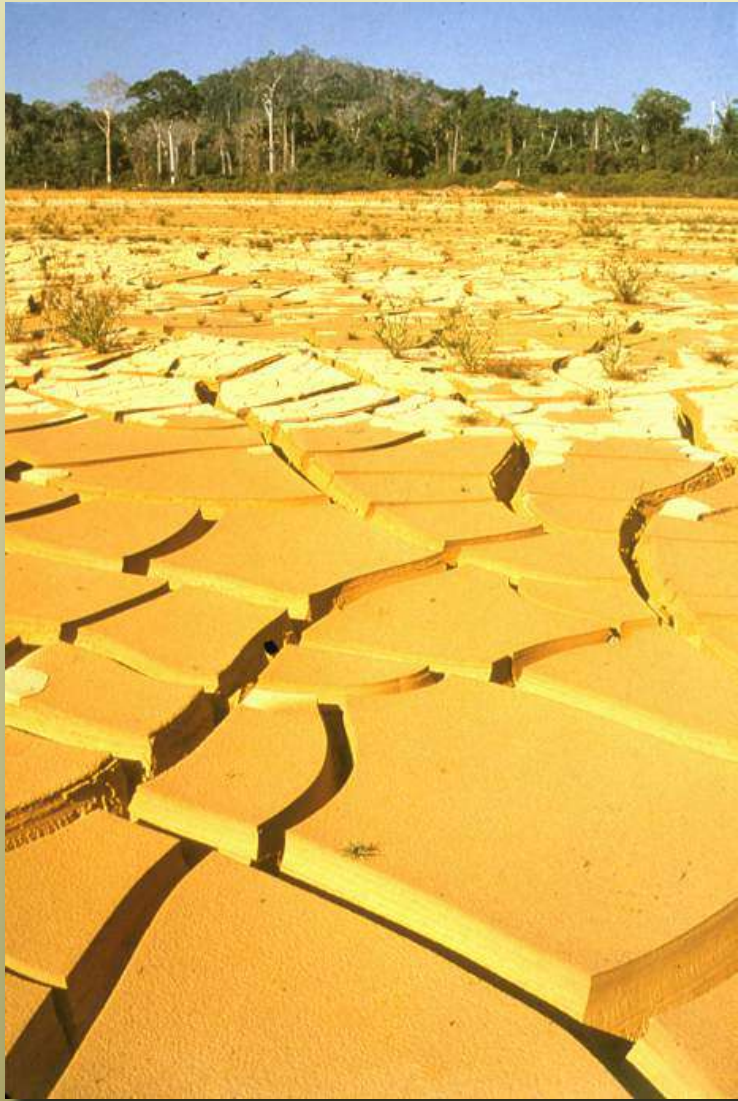
## Climate

- diurnal patterns (not seasonal)
- 25° C mean annual temperature

- daily convectonal precipitation
- 2 - 4 meters + rain



# Tropical Rainforest Biome



Brazil - after deforestation

## Soil

- warm soil and water surplus promote rock decomposition
- reddish laterite soil
- well leached, no litter



Hawaiian (5my) richer volcanic soil

# Tropical Rainforest Biome



Panama slash burn agriculture

Brazil cattle grazing following limited slash burn agriculture

## Soil

- soil incapable of holding nutrient base cations
- nutrients held in biomass
- slash-burn agriculture depletes nutrients in biomass and soil



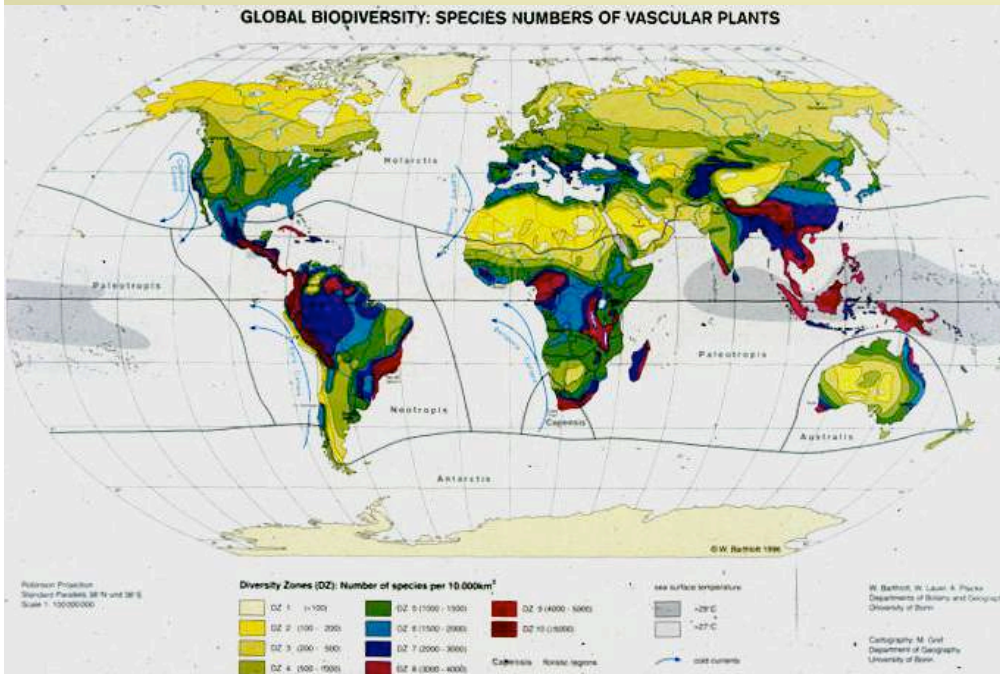
# Tropical Rainforest Biome

- Vegetation**
- warm & wet climate allows for **broadleaf evergreen forest** to dominate
  - net productivity is highest of terrestrial biomes
  - highest diversity (species number) of any biome



# Tropical Rainforest Biome

**Diversity** – 2% of earth surface, 50% of total species diversity



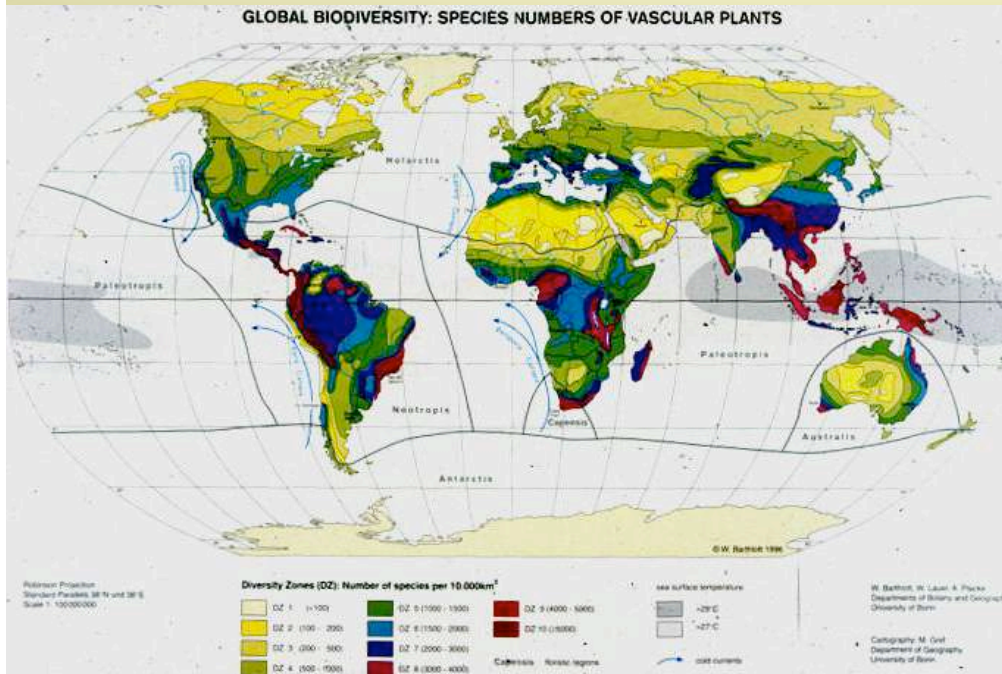
- 100,000 +/- species of flowering plants (40% of world's angiosperm flora)
- many undescribed

Al Gentry (UW grad) holds  
undescribed **genus** of liana



# Tropical Rainforest Biome

**Diversity** – 2% of earth surface, 50% of total species diversity



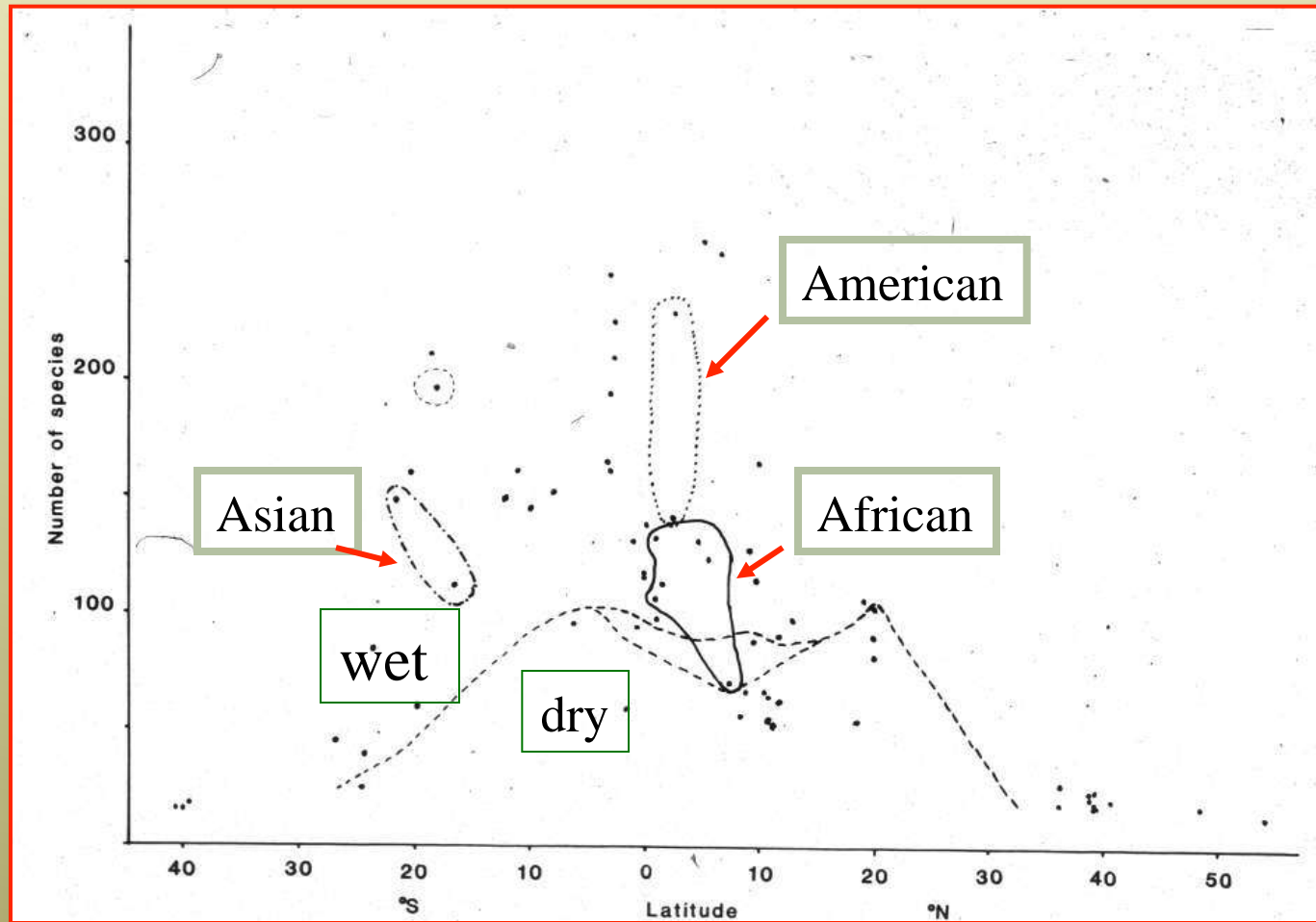
- species diversity comes from the **R**apid **A**ssessment **P**rogram of Conservation International



- two leaders were Ted Parker (ornithologist) and Al Gentry (botanist)
- knew by sight (or sound) more tropical American birds and plants, respectively, than anyone else to date

# Tropical Rainforest Biome

Why this diversity? • correlation with low latitude and rainfall



Tree species diversity in 1 hectare wet and dry forests (Gentry)



# Tropical Rainforest Biome

- Why this diversity?
- stable ecologically?
  - climatic change, allopatric speciation?
  - coevolution with animals?



*Virola* (nutmeg family)  
Bird dispersed fruits

## Bat pollinated flowers

*Parkia* (Fabaceae)



*Lecythis* (Lecythidaceae)

*Tacca* (Taccaceae)



# Tropical Rainforest Biome

## Where is the diversity?

- in the tree strata primarily
- 40 - 100 woody species per hectare

<i>Amazon</i>	<i>Wisconsin</i>
60,000 spp.	2,500 spp.
6,000 trees	50 trees



# Tropical Rainforest Biome

## Floristic dissimilarity of 3 regions

- palms (Arecaceae) basically lacking in Africa (but not Madagascar) and diverse in Malaysia and South America



Madagascar



Malaysia

# Tropical Rainforest Biome

## Floristic dissimilarity of 3 regions

- dipterocarps (Dipterocarpaceae) in SE Asia, lacking elsewhere



Does it suggest only ancient floristic linkage of tropical biomes?



Dipterocarp forest in Borneo

# Tropical Rainforest Biome

## Floristic nature of 3 regions

Similar families of trees involved in each floristic region, but quite different genera and species



Gentry tropical forest study sites

**Table 2.2** Characteristic families and genera containing dominant, abundant, conspicuous or subendemic woody plants in the rain forests of the world, with associated epiphytes and secondary forest trees (after Longman and Jenik, 1987; Mabberley, 1992)

<b>Neotropics</b>	
→ Leguminosae	<i>Andira, Apuleia, Dalbergia, Dinizia, Hymenolobium, Mora</i>
→ Sapotaceae	<i>Manilkara, Pradosia</i>
→ Meliaceae	<i>Cedrela, Swietenia</i>
→ Euphorbiaceae	<i>Hevea</i>
→ Myristicaceae	<i>Virola</i>
→ Moraceae	<i>Cecropia, Ficus</i>
→ Lecythidaceae	<i>Bertholletia</i>
→ Epiphytes	ferns, Orchidaceae, Bromeliaceae, Cactaceae
→ Secondary	<i>Cecropia, Miconia, Vismia</i>
<b>Africa</b>	
→ Leguminosae	<i>Albizia, Brachystegia, Cynometra, Gilbertiodendron</i>
→ Sapotaceae	<i>Afrosorsalisia, Chrysophyllum</i>
→ Meliaceae	<i>Entandrophragma, Khaya</i>
→ Euphorbiaceae	<i>Macaranga, Uapaca</i>
→ Moraceae	<i>Chlorophora, Ficus, Musanga</i>
→ Sterculiaceae	<i>Cola, Triplochiton</i>
→ Ulmaceae	<i>Celtis</i>
→ Epiphytes	ferns, Orchidaceae
→ Secondary	<i>Harungana, Macaranga, Musanga</i>
<b>Indo-Malesia</b>	
→ Dipterocarpaceae	<i>Dryobalanops, Hopea, Shorea</i>
→ Leguminosae	<i>Koompassia</i>
→ Meliaceae	<i>Aglaia, Dysoxylum</i>
→ Moraceae	<i>Artocarpus, Ficus</i>
→ Anacardiaceae	<i>Mangifera</i>
→ Dilleniaceae	<i>Dillenia</i>
→ Thymelaeaceae	<i>Gonystylus</i>
→ Epiphytes	ferns, Orchidaceae, Asclepiadaceae, Rubiaceae
→ Secondary	<i>Glochidion, Macaranga, Mallotus, Melastoma</i>

(Source: K. A. Longman and J. Jenik, *Tropical Forest and its Environment*, 2nd edn; published by Longman, 1987.)

# Tropical Rainforest Biome

## Structure of the vegetation: **Trees**

- tall trees form continuous canopy; therefore dense shade below
- pervasive problem of extreme light at canopy vs. low light *quantity* within forest



Dense canopy in Borneo



Dense canopy in Costa Rica

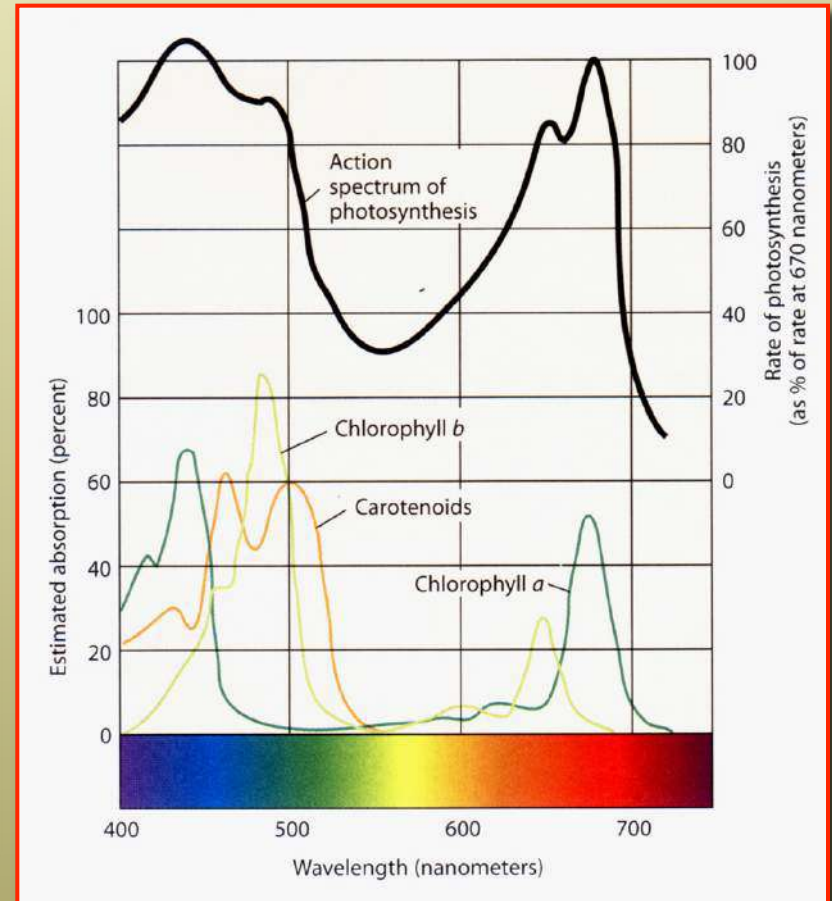
# Tropical Rainforest Biome

## Structure of the vegetation: **Trees**

. . . and low light *quality* within forest



Dense canopy in Borneo



# Tropical Rainforest Biome

## Structure of the vegetation: **Trees**

- struggle for light has generated similar life forms and physiological adaptations in unrelated species



Dense canopy in Borneo

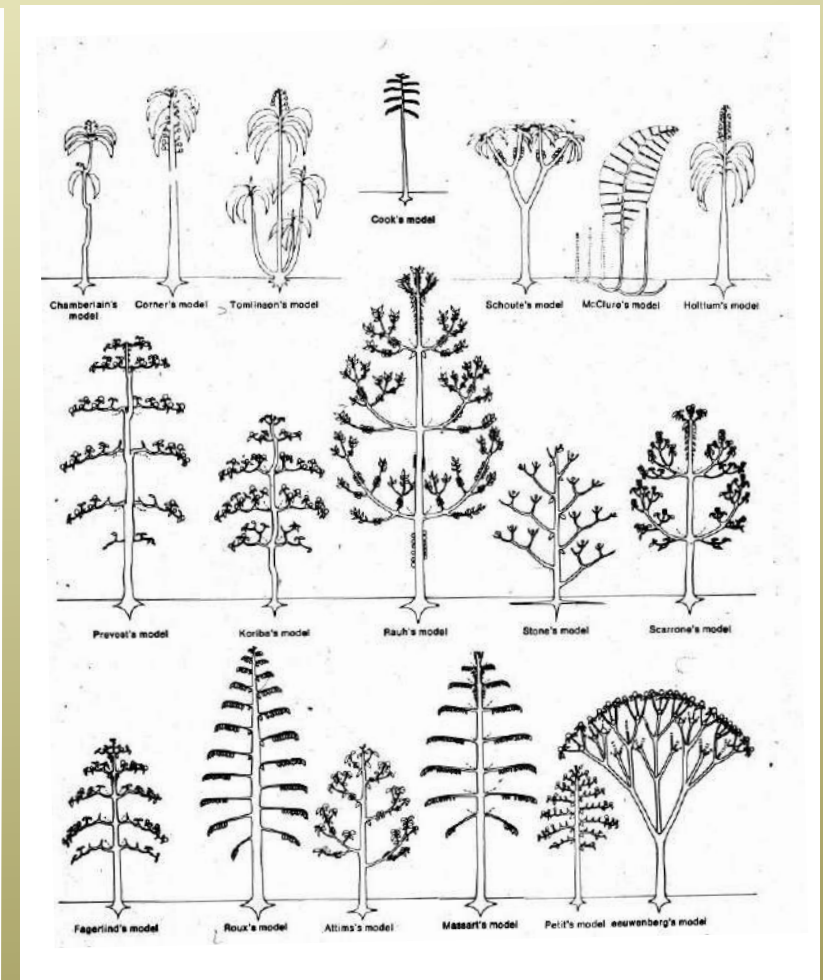
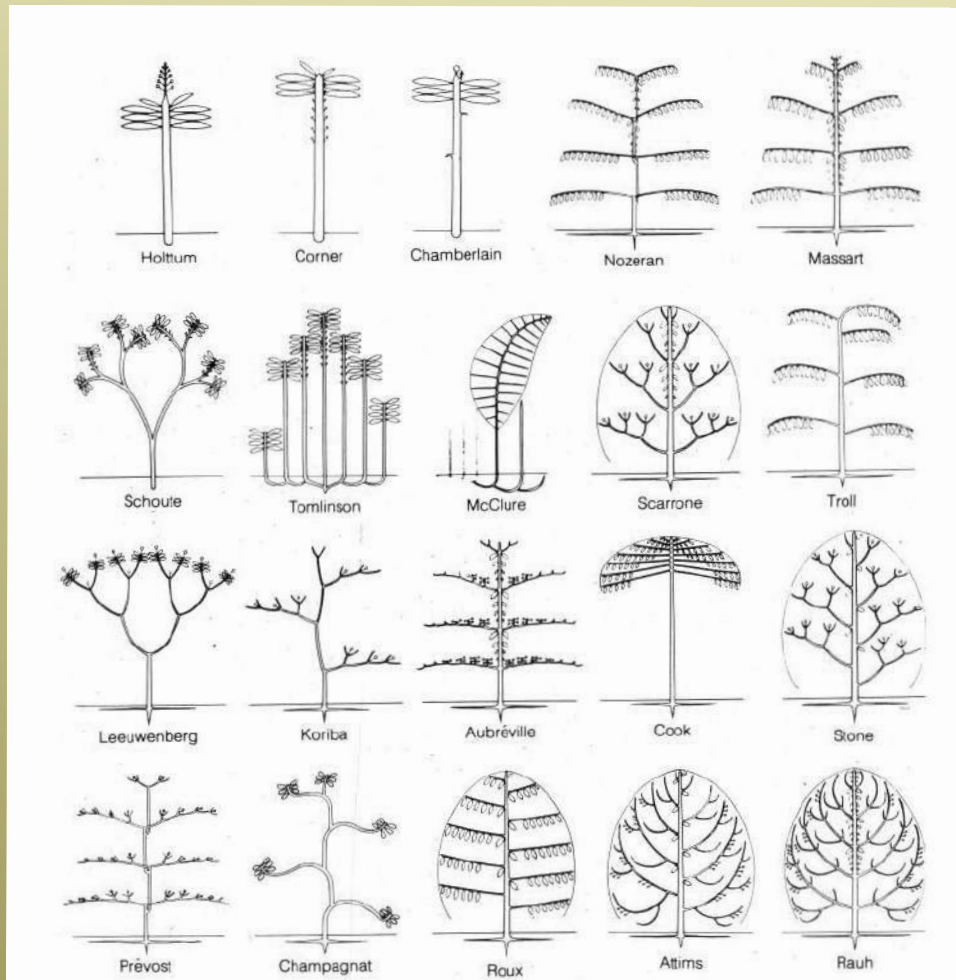




# Tropical Rainforest Biome

## Structure of the vegetation: Trees

- tropical trees show characteristic shape and branching (convergence)



## Tropical Rainforest Biome

### Structure of the vegetation: **Trees - 3 strata**

- emergent crowns discontinuous; 40 m (130 ft) tall



American tropics



Asian tropics

# Tropical Rainforest Biome

## Structure of the vegetation: **Trees - 3 strata**

- buttress or plank roots for shallowly rooted trees - convergent evolution



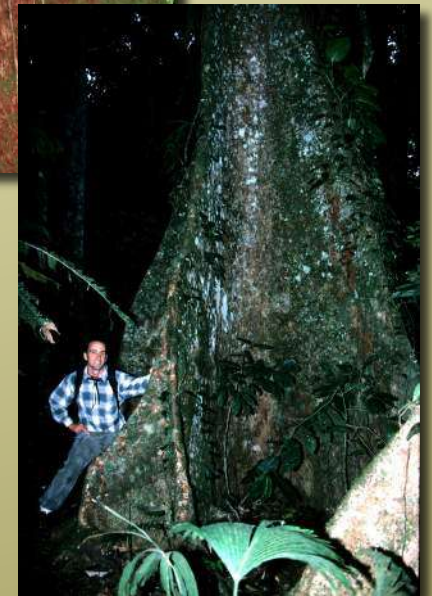
*Swietenia* - mahogany (Costa Rica)



*Stockwellia*  
(Australia)



dipterocarp (Borneo)

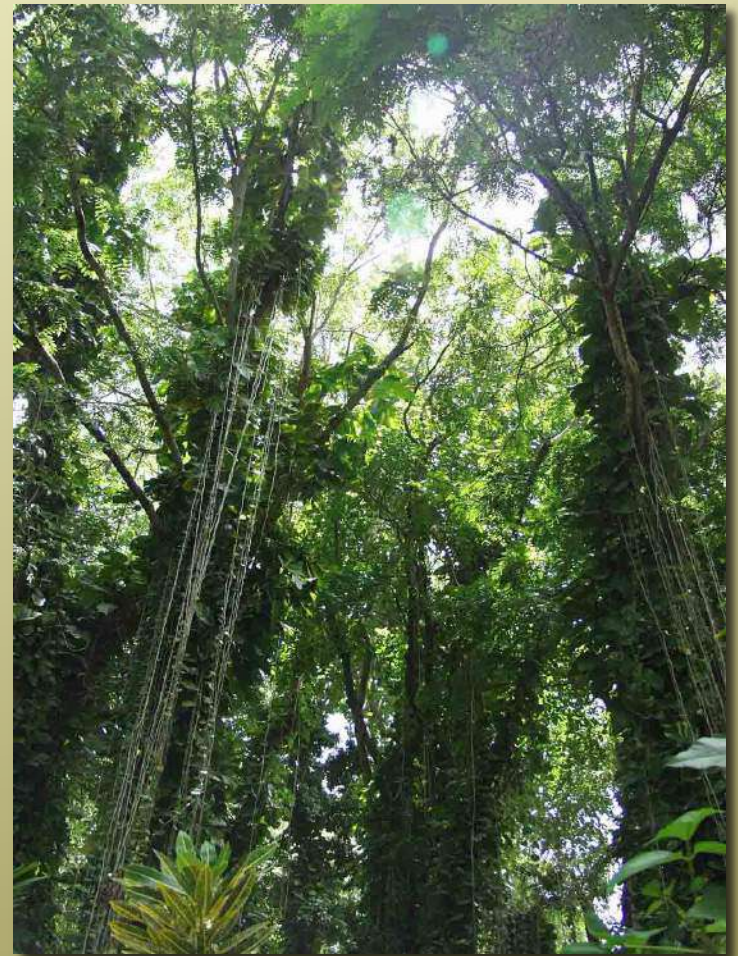


*Gyranthera* (Venezuela)

# Tropical Rainforest Biome

Structure of the vegetation: **Trees - 3 strata**

- continuous canopy at 15-30 m (50-100 ft)



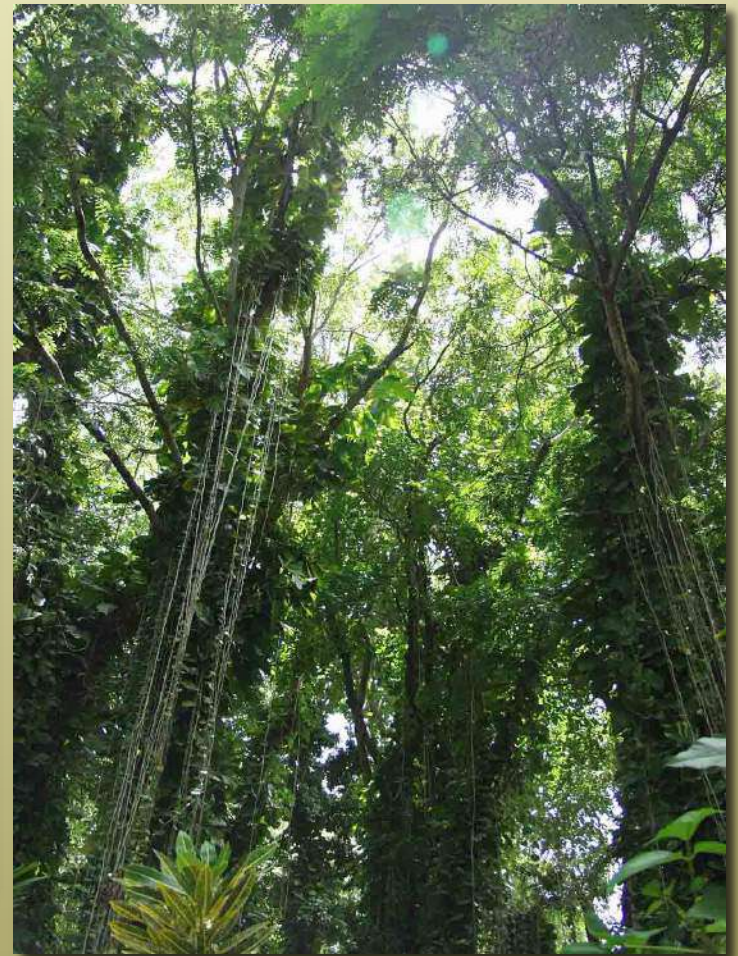
# Tropical Rainforest Biome

Structure of the vegetation: **Trees - 3 strata**

- continuous canopy at 15-30 m (50-100 ft)



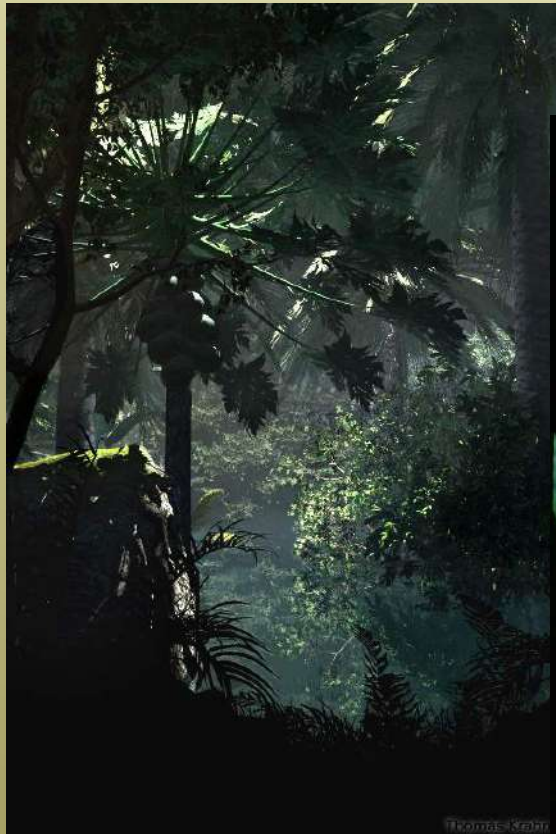
Canopy walk in Costa Rica



# Tropical Rainforest Biome

## Structure of the vegetation: **Trees - 3 strata**

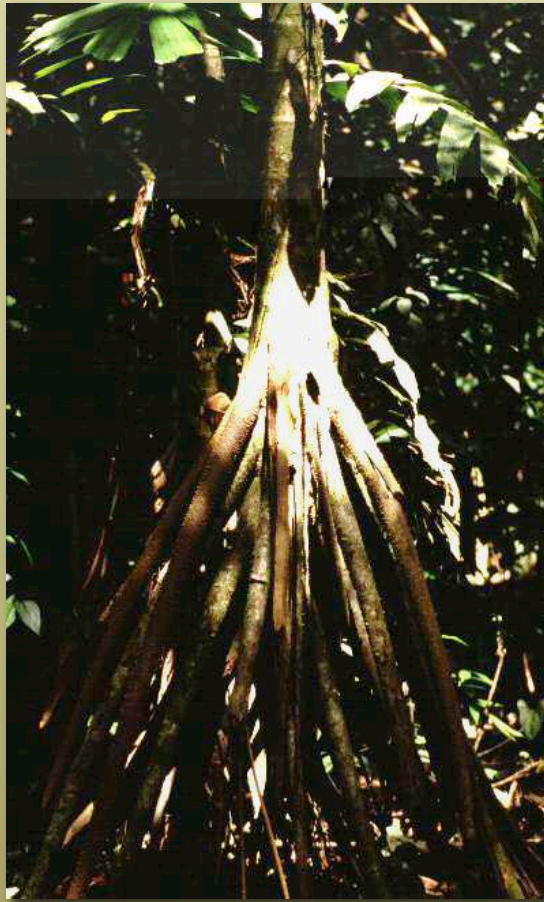
- lower zone at 5-15 m (15-50 ft); palms and palm relatives often dominate here



# Tropical Rainforest Biome

## Structure of the vegetation: **Trees - 3 strata**

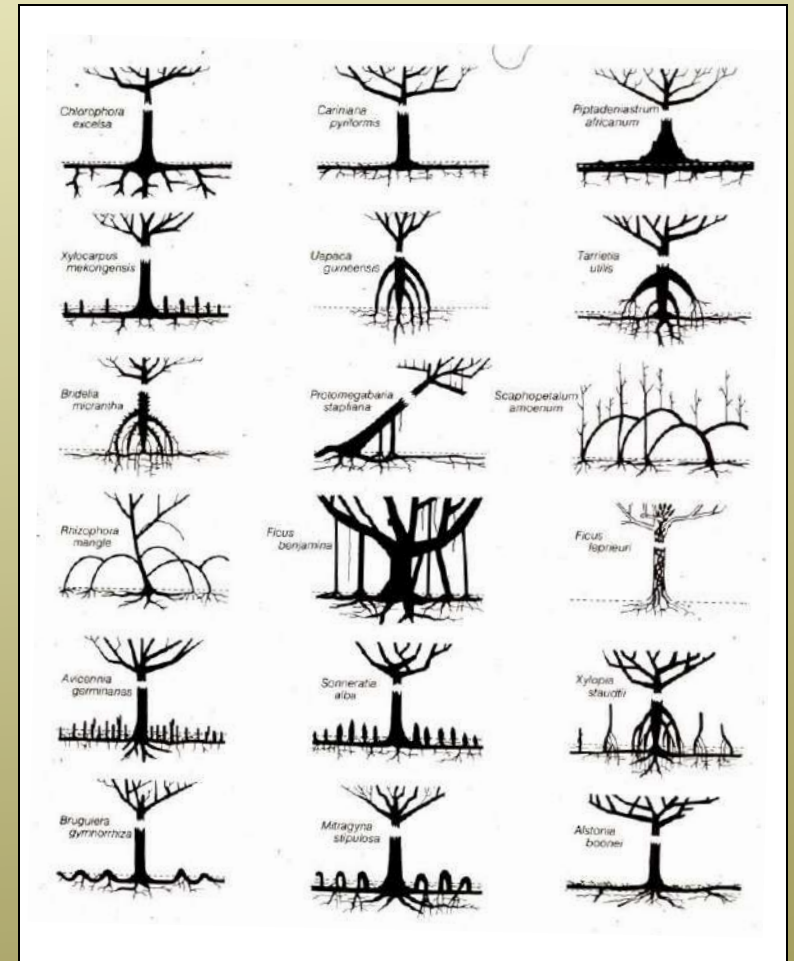
- lower zone at 5-15 m (15-50 ft); small, slender crowns, stilt roots for support - convergent



Palm - Panama



*Hornstedtia*  
(Zingiberaceae)  
Borneo



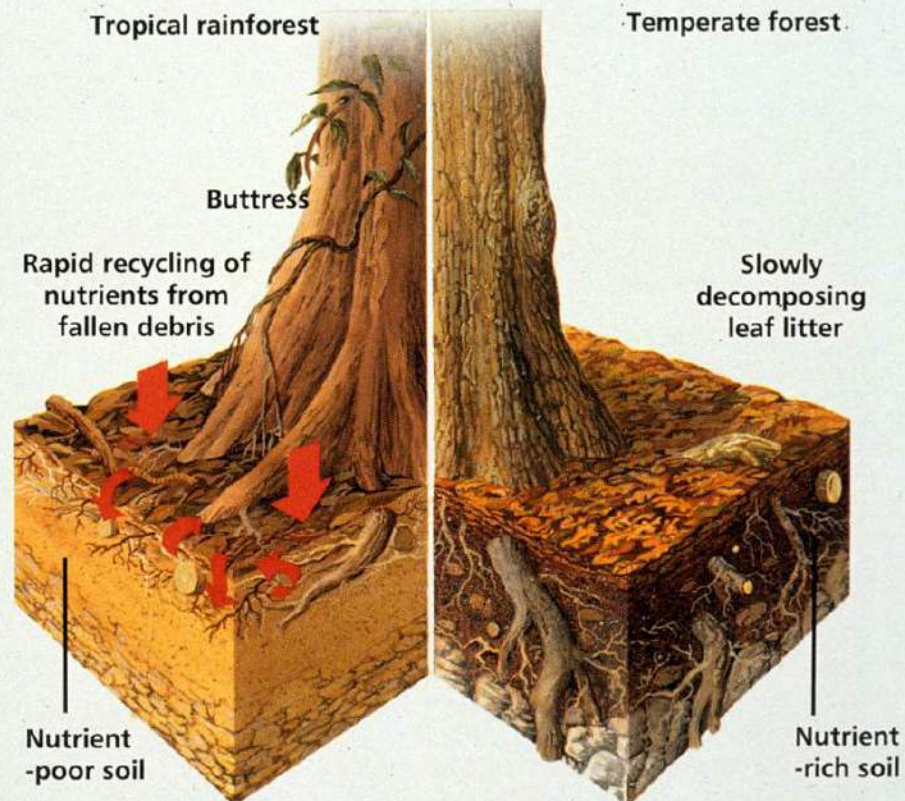
# Tropical Rainforest Biome

## Structure of the vegetation: **Tree roots**

- shallow feeder roots efficient in taking up nutrients
- often mycorrhizal

### FOREST SOIL SYSTEMS

*Rainforest soil is generally poorer than that of a temperate forest. Heavy rainfall leaches soil nutrients beyond the reach of roots. But fallen leaves decompose rapidly, and trees spread their roots just under the litter to reabsorb as many nutrients as possible. Buttresses give these shallow-rooted trees extra support.*





# Tropical Rainforest Biome

## Structure of the vegetation: **Tree roots**

- shallow feeder roots efficient in taking up nutrients
- often mycorrhizal
- fungi/bacteria recycle nutrients quickly for roots



# Tropical Rainforest Biome

## Structure of the vegetation: **Leaves**

- canopy leaves exposed to recurrent dry periods - evergreen, thick cuticle, leathery



*Ficus* - fig (Moraceae)

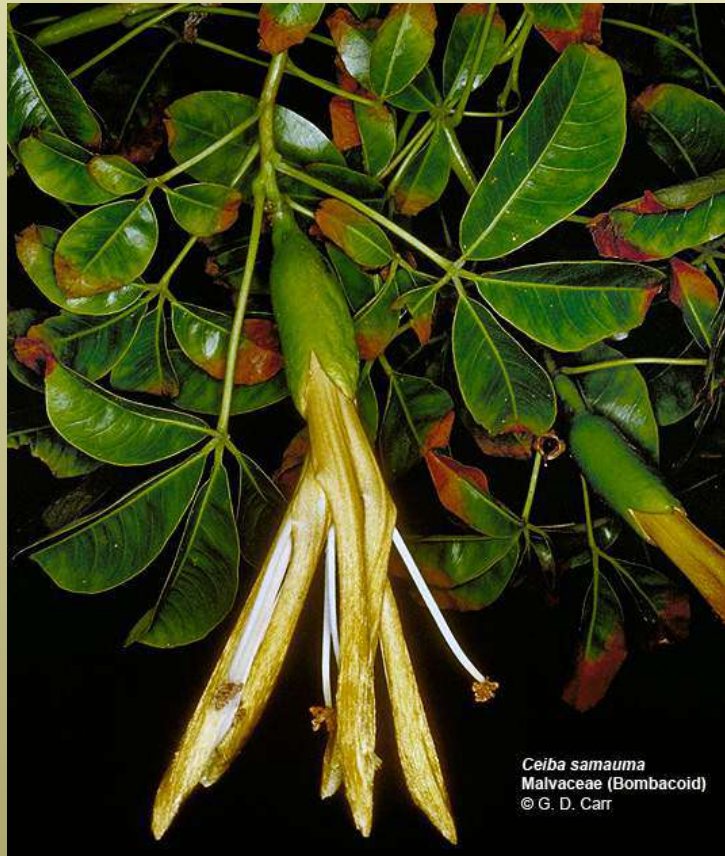


*Syzygium* (Australia)

# Tropical Rainforest Biome

## Structure of the vegetation: Leaves

- compound leaves common



*Ceiba samauma*  
Malvaceae (Bombacoid)  
© G. D. Carr

*Ceiba* - kapoc (Malvaceae)

- new leaves with anthocyanin flush to prevent photo-oxidation



*Sterculia* - (Malvaceae)

# Tropical Rainforest Biome

## Structure of the vegetation: **Leaves**

- interior forest more stable (dark and humid)
- drip tip leaves common



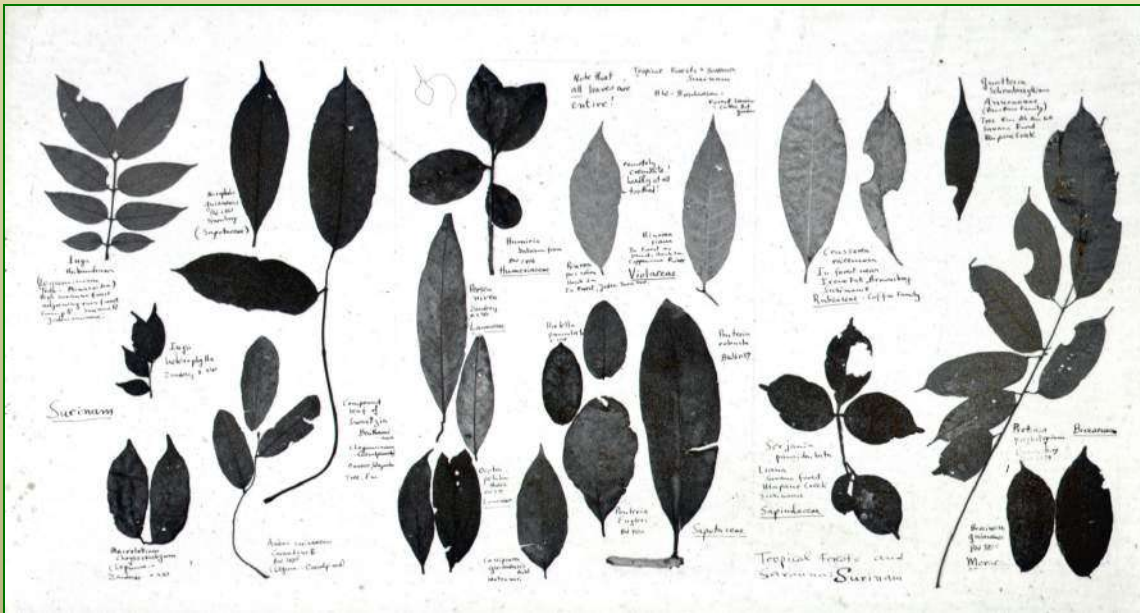
*Ficus* - fig



# Tropical Rainforest Biome

## Structure of the vegetation: Leaves

- Ghana undergrowth study with 90% drip tips



- *Nepenthes* (Asian pitcher plant) drip tip converted into carnivorous trapping structure



# Tropical Rainforest Biome

## Structure of the vegetation: **Herbs**

- 70-90% of species are trees
- low light levels discourage herbs
- some common families



Gesneriaceae - African  
violet family



Melastomataceae -  
melastome family



## Tropical Rainforest Biome

### Structure of the vegetation: **Herbs**

- 70-90% of species are trees
- low light levels discourage herbs
- other common families



Begoniaceae -  
begonia family

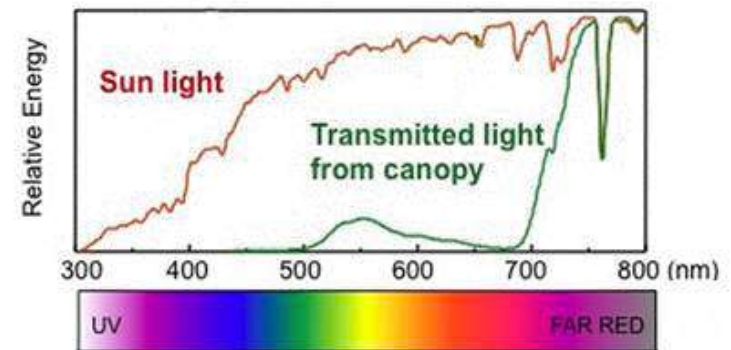


Commeliniaceae -  
spiderwort family

# Tropical Rainforest Biome

## Structure of the vegetation: **Herbs**

- velvety, variegated, or metallic shimmer leaves
- adaptive in low light conditions



**Figure 1.** Comparison of full sunlight spectrum to that beneath a canopy of trees.



# Tropical Rainforest Biome

## Structure of the vegetation: **Herbs**

- **coarse herbs** common in riparian (river edge) or gap habitats
- order Zingiberales (banana families: heliconias, gingers, etc.)



*Heliconia* (Heliconiaceae)



*Costus* (Costaceae)

# Tropical Rainforest Biome

## Structure of the vegetation: **Herbs**

- **mycorrhizal parasites** common
- adaptation to low nutrients (mycorrhizal) and low light (non-photosynthetic)



*Voyria* (Gentianaceae)



*Triuris* (Triuridaceae)

# Tropical Rainforest Biome

## Structure of the vegetation: **Herbs**

- **parasites** common
- adaptation to low nutrients (parasitize plants) and low light (non-photosynthetic)



*Rafflesia* (Rafflesiaceae)



*Heliosis* (Balanophoraceae)

# Tropical Rainforest Biome

## Structure of the vegetation: **Herbs**

- **fungi** common
- non-photosynthetic



Stinkhorn



Bracket fungus

## Tropical Rainforest Biome

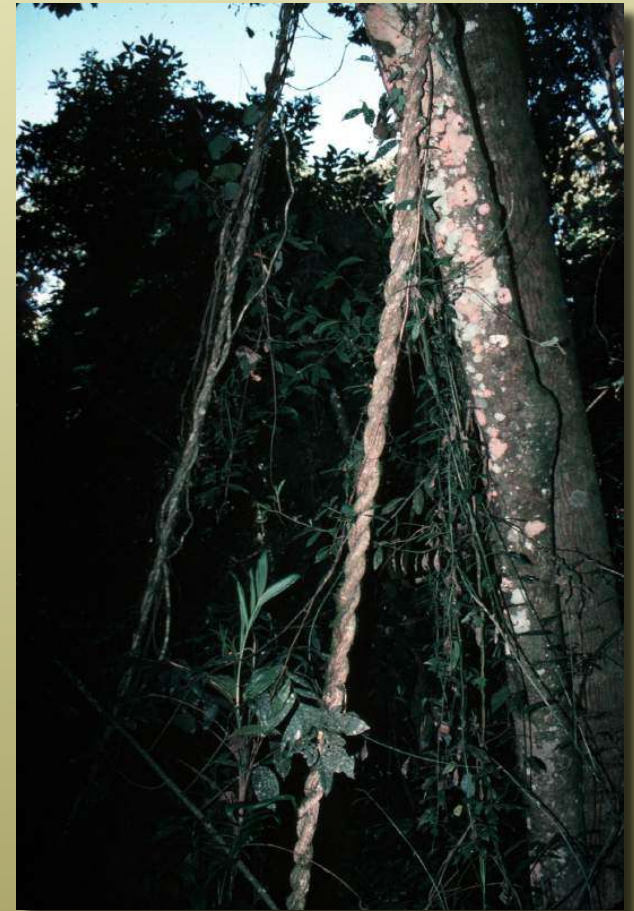
Structure of the vegetation: **Lianas** — a cost effective method in struggle for light

- exploit tree as support for rapidly growing flexible stem and branch in canopy



*Combretum* (Combretaceae)

*Ficus* - fig (Moraceae)



## Tropical Rainforest Biome

Structure of the vegetation: **Lianas** — a cost effective method in struggle for light

- 90% of all lianas confined to wet tropical rainforests - why?
- rope-like (20cm, 8in) but with pliable secondary thickenings



*Ficus* - fig (Moraceae)

# Tropical Rainforest Biome

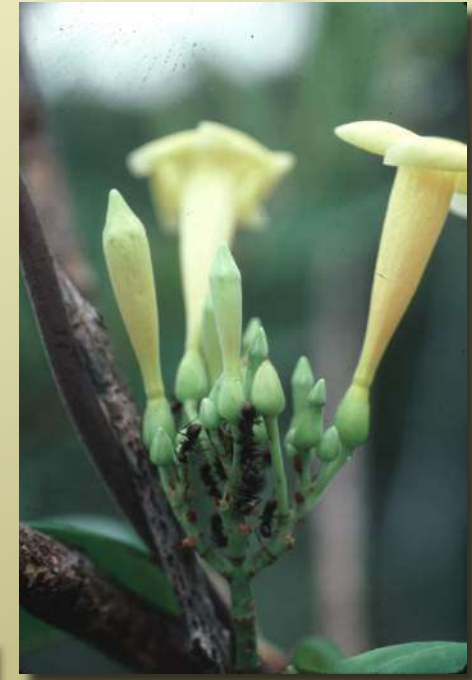
## Structure of the vegetation: **Lianas**

- other common liana families



*Bignoniaceae -  
catalpa family*

*Apocynaceae -  
dogbane family*



*Cucurbitaceae -  
gourd family*



*Gurania* and other  
cucurbit flowers are  
sole source of nectar  
for adult heliconid  
butterflies

# Tropical Rainforest Biome

## Structure of the vegetation: **Lianas**

- other common liana families



*Passifloraceae - passion  
flower family*

*Passiflora* leaves are sole  
source of food for heliconid  
butterfly larvae





## Tropical Rainforest Biome

Structure of the vegetation: **Epiphytes** — a cost effective method in struggle for light

- germination in top most branches of host tree
- host solely as means of physical support



Epiphytes in Costa Rica canopy walk

- flowering plants, ferns, mosses, liverworts, lichens, algae (**epiphylls**)



## Tropical Rainforest Biome

Structure of the vegetation: **Epiphytes** — a cost effective method in struggle for light

- the study and collection of epiphytes one of the most challenging in science



Alec Barrow - Barro Colorado Island

Scott Mori - NY Bot Gard in Guyana

## Tropical Rainforest Biome

Structure of the vegetation: **Epiphytes** — a cost effective method in struggle for light

- dominant angiosperm epiphytes:

Orchidaceae - orchids



Cactaceae - cacti



## Tropical Rainforest Biome

Structure of the vegetation: **Epiphytes** — a cost effective method in struggle for light

- dominant angiosperm epiphytes:



Piperaceae - peperomias



Araceae - aroids

## Tropical Rainforest Biome

Structure of the vegetation: **Epiphytes** — a cost effective method in struggle for light

- dominant angiosperm epiphytes:



Gesneriaceae -  
African violets



Bromeliaceae - pineapples

## Tropical Rainforest Biome

Structure of the vegetation: **Epiphytes** — adaptations to epiphytic condition — *the problem of obtaining and storing water*



**water tanks** (water storage)  
- Bromeliaceae

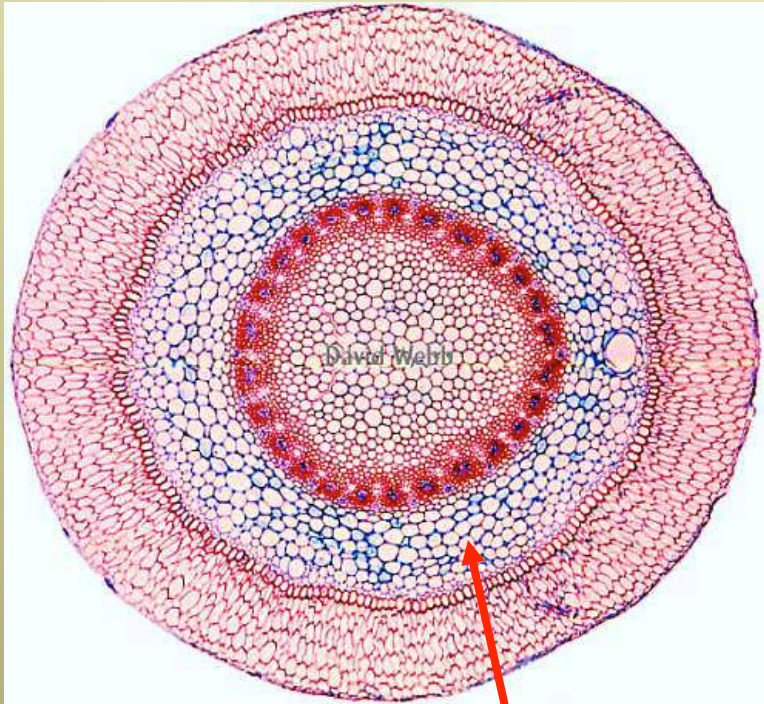


**Scales** (water & nutrient uptake)  
- Bromeliaceae



## Tropical Rainforest Biome

Structure of the vegetation: **Epiphytes** — adaptations to epiphytic condition — *the problem of obtaining and storing water*



**leaf tubers** (water storage) - Orchidaceae

Orchid root **velamen** (water storage)

# Tropical Rainforest Biome

Structure of the vegetation: **Epiphytes** — adaptations to epiphytic condition — *the problem of obtaining and storing water*



**Succulence & CAM**  
photosynthesis - Cactaceae



**“trash baskets” & aerial roots** - staghorn ferns (above) and Araceae (right)





## Tropical Rainforest Biome

Structure of the vegetation: **Stranglers** — a cost effective method in struggle for light

- start as epiphytes and grow roots down host tree



*Ficus* (strangler fig - Moraceae)

## Tropical Rainforest Biome

Structure of the vegetation: **Stranglers** — a cost effective method in struggle for light

- start as epiphytes and grow roots down host tree
- shoot elongates and roots thicken, coalesce



*Ficus* (strangler fig - Moraceae)



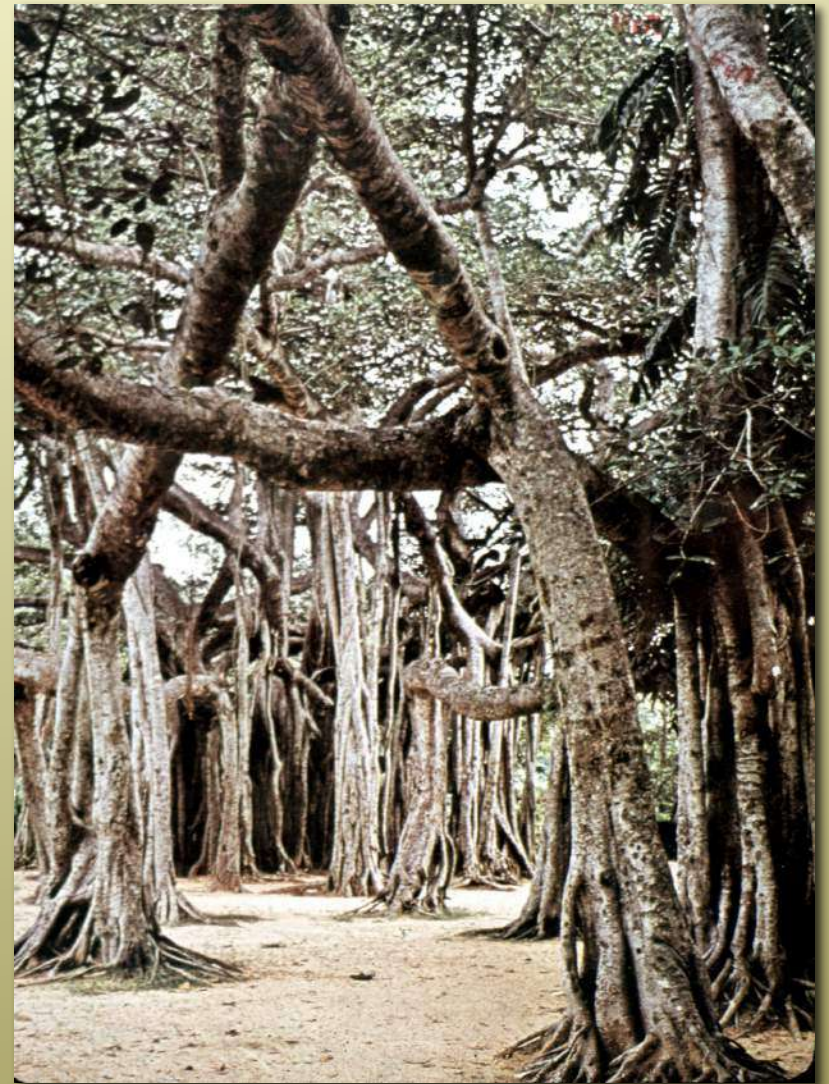
## Tropical Rainforest Biome

Structure of the vegetation: **Stranglers** — a cost effective method in struggle for light

- strangulation of host via “root” stem



*Ficus* (strangler fig - Moraceae)



## Tropical Rainforest Biome

Structure of the vegetation: **Stranglers** — a cost effective method in struggle for light

- other stranglers



*Clusia*  
(Clusiaceae)



## Tropical Rainforest Biome

Structure of the vegetation: **Stranglers** — a cost effective method in struggle for light

- other stranglers



*Metrosideros robusta* -  
Northern rata (Myrtaceae)

# Tropical Rainforest Biome

## Structure of the vegetation: **Hemi-epiphytes**

- germinate on ground, grow up as lianas (root climbers)
- bottom dies, becomes epiphytes
- “walk” through forest looking for light



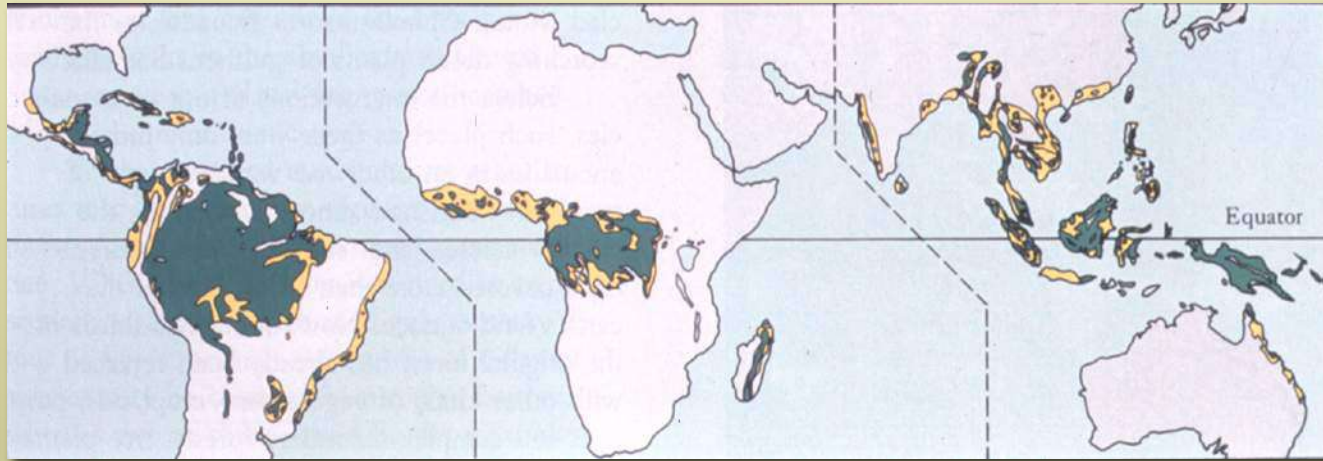
*Anthurium & Philodendron* (aroid - Araceae)



*Philodendron* (aroid -  
Araceae)

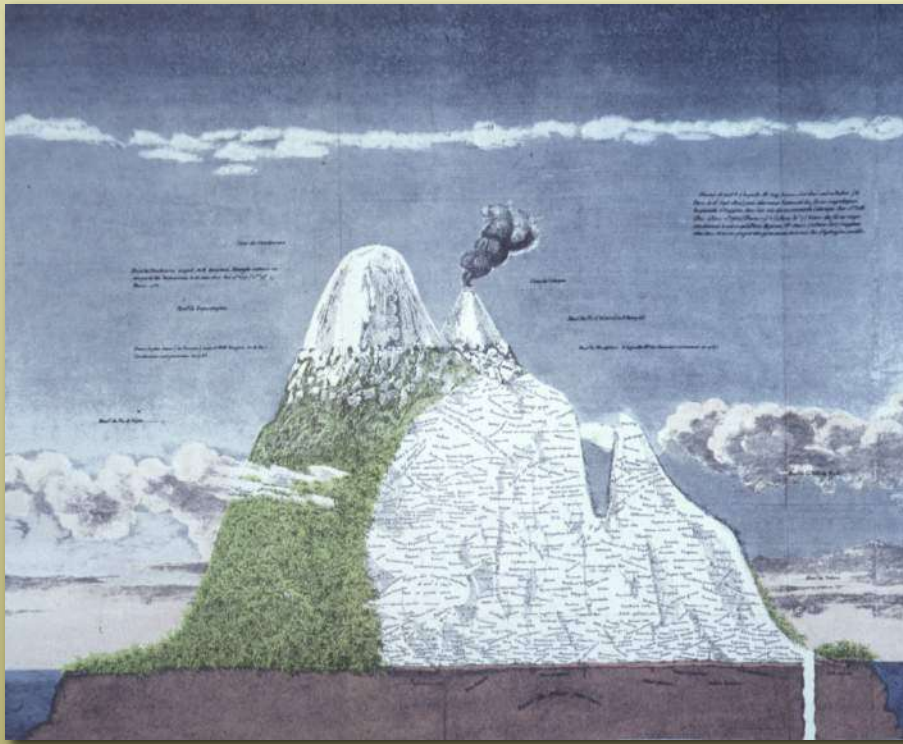
## Cloud Forest or Tropical Montane Biome

- Form when moisture laden winds encounter mountains



## Cloud Forest or Tropical Montane Biome

- Form when moisture laden winds encounter mountains
- Elevation and humidity related - not precise location



Panamanian cloud forests lower

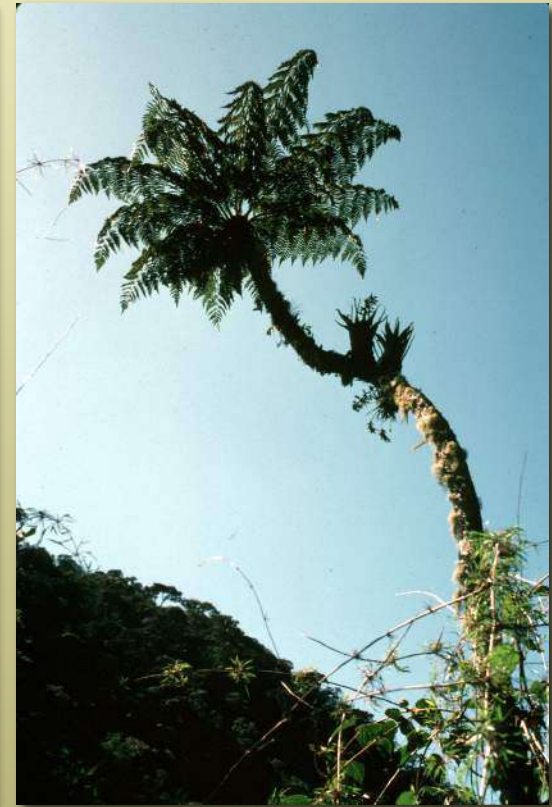
Andean cloud forests higher





## Cloud Forest or Tropical Montane Biome

- epiphytes most abundant here
- trees smaller, lianas rare



## Cloud Forest or Tropical Montane Biome

- characteristic groups of cloud forests



- tree ferns

*Cyathea*



## Cloud Forest or Tropical Montane Biome

- characteristic groups of cloud forests



*Hymenophyllum* - filmy fern

- filmy ferns  
(Hymenophyllaceae)
- club mosses, spike mosses, true mosses



*Selaginella* - spike moss

## Cloud Forest or Tropical Montane Biome

- characteristic groups of cloud forests



- *Gunnera*  
(Gunneraceae)

- Rubiaceae (coffee family)



- Ericaceae (blueberry family)



## Above Tropical Montane Forests



Elfin forest - Costa Rica

Ruwenzoris



Costa Rica  
- Cerro de  
la Muerte



Tropical subalpine, paramo

## Above Tropical Montane Forests



Sierra Nevada del Cocuy  
National Park, Colombia  
[4,638 m]

*Lupinus alopecuroides*  
growing with *Senecio*  
*niveoaureus* in a superparamo

Photo: Mauricio Diazgranados

# Reproductive Strategies in Tropical Forests

## Pollination biology

- outcrossing mechanisms in trees, usually animal-mediated
- e.g., dioecy - separate male and female plants

## Level of dioecy

Costa Rica

20% tall trees

12% small trees

Sarawak

26% trees

Nigeria

40% trees



dioecious *Clusia*

# Reproductive Strategies in Tropical Forests

## Pollination biology

- wind pollination rare in mature rain forests
- common in early seral stages (light gaps, cut-over forests)

- wind pollination dropped from 38% to 8% in two years after light gap formed in Costa Rica



Wind pollinated *Cecropia*



# Reproductive Strategies in Tropical Forests

## Pollination biology

- animal pollination involves bats, birds, bees, moths, beetles



Carrion insect/bat pollinated  
*Aristolochia*



Hummingbird pollinated  
*Fuchsia*

# Reproductive Strategies in Tropical Forests

## Pollination biology

- animal pollination involves bats, birds, bees, moths, beetles



many bat-pollinated trees are **cauliflorous** - flowers on stem



or with pendant flowers (*Parkia* - Fabaceae)

# Reproductive Strategies in Tropical Forests

## Seed or fruit dispersal

- fleshy fruits dominate (90% +)
- wind dispersal (5-10%)
- water dispersal (1-2%)



bat-dispersed figs



frugivorous  
birds



primate dispersed durian

# Major Animal Radiations in Tropical Forests



## Major Animal Radiations in Tropical Forests



# Major Animal Radiations in Tropical Forests



## Major Animal Radiations in Tropical Forests

