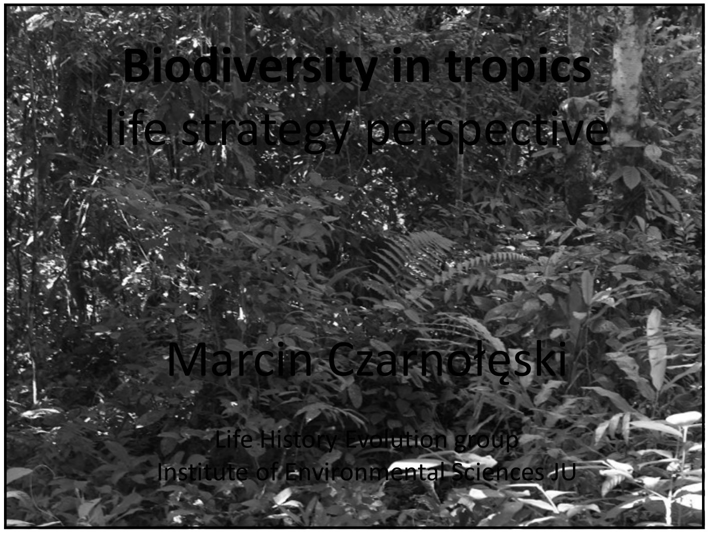
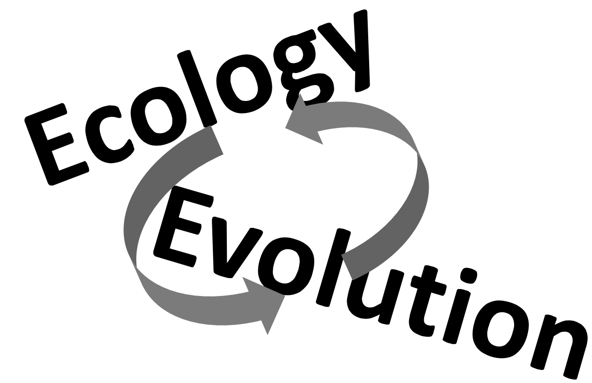
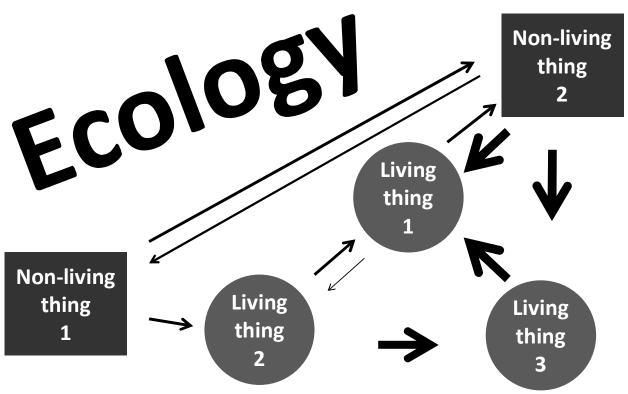


Fuller understanding requires EcoEvo



General framework



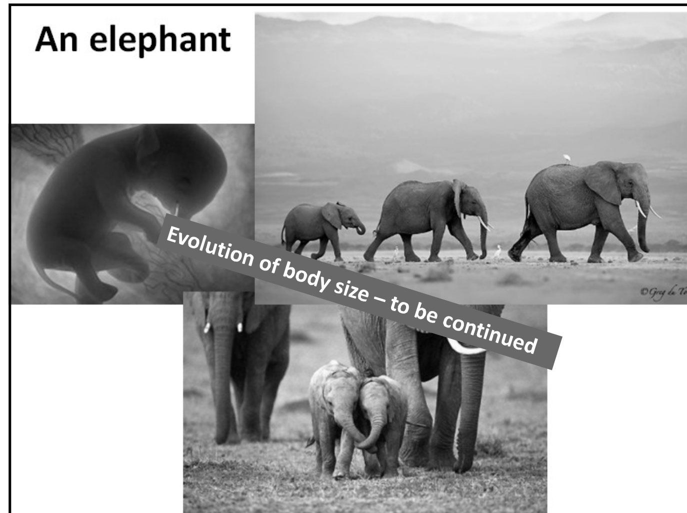
General framework

What can evolve?
Phylogenetic history
Mutations
Migrations
Perfection or effectiveness
Genetic drift
Trade-offs
Selection
Get benefits now, pay later
Evolution
Fitness
Adaptation
Inclusive fitness
Games

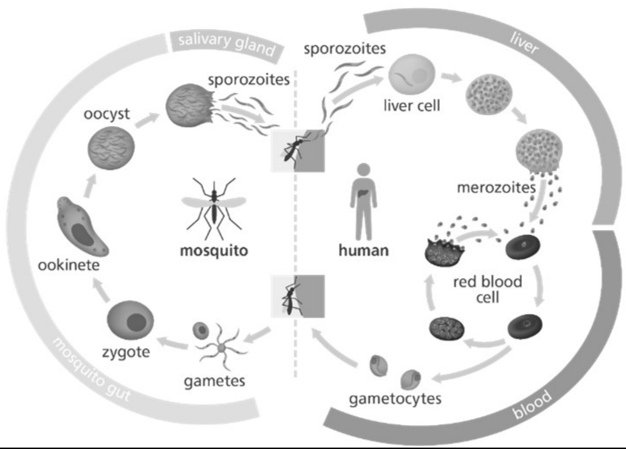
Let's change the perspective

Living things are
life strategies with dynamic life cycles that undergo evolution

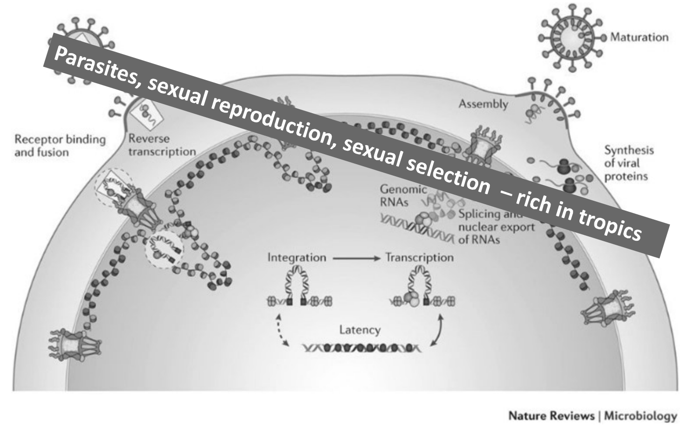
An elephant



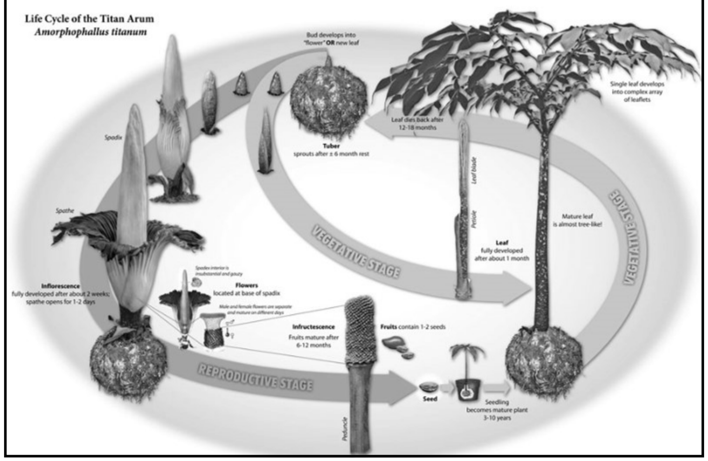
A Plaspodium



HIV



Titan arum



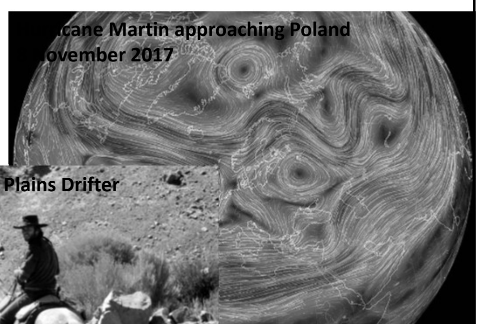
Titan arum

Carrion flowers: mimicry & flower size– to be continued

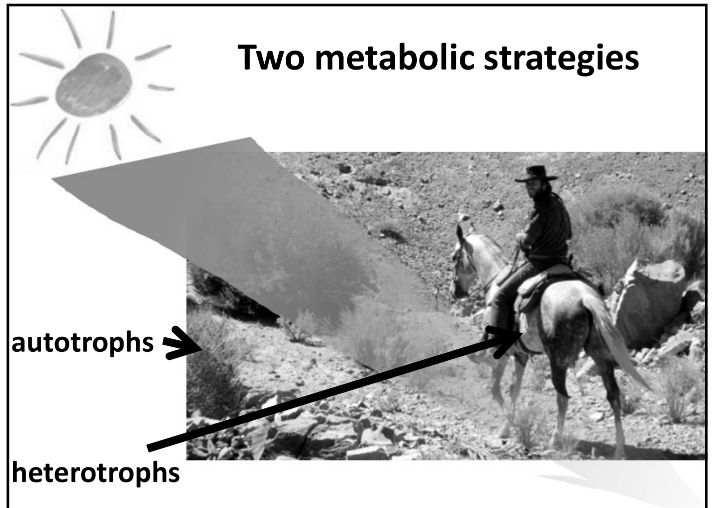
Info & anecdote

Real name - *Amorphophallus titanum.* Endemic to Sumatra. Produces the largest inflorescence in the world. Flowers every some years. Flowers smell rotten meat to attract carrion-eating beetles. The name *Titan arum* given by Sir David Attenborough who realised that English translation of the proper name for his BBS series „Private life of Plants" would be embarrassing.

Thermodynamicaly – organisms are dissipative structures



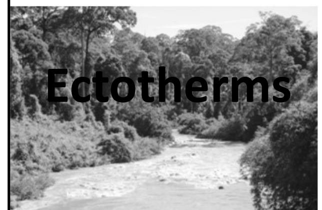
Two metabolic strategies

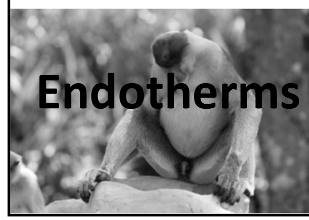


The two metabolic strategies

	Carbon	Energy
(top image)	**Nonorganic** CO_2	**Light**
(bottom image)	**Organic** sugars, lipids, proteins	**Organic** sugars, lipids, proteins

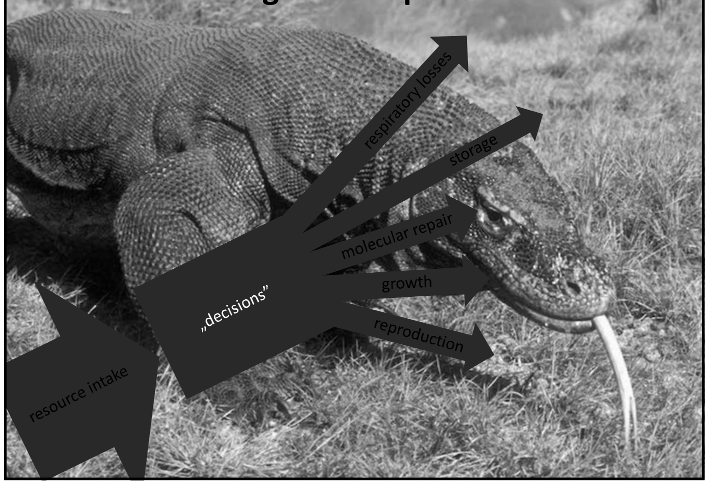
Another look at metabolic strategies



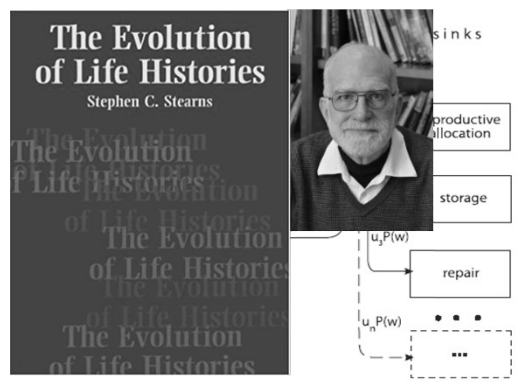


	Heat source	Thermoregulation
Ectotherms	**External** Internal	**Behavioural** Physiological
Endotherms	External **Internal**	Behavioural **Physiological**

How to manage the acquired resources?



Strategy of optimal resource allocation

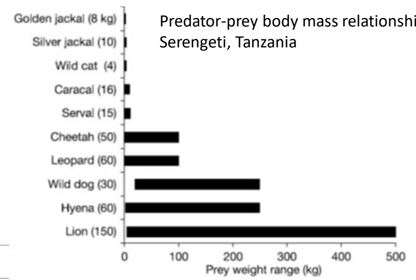


Kozłowski 2000

Body size has strong adaptive value

fertility (physiological capacity, sexual attractiveness), capacity to aquire resources, survival capacity

Predator-prey body mass relationships
Serengeti, Tanzania

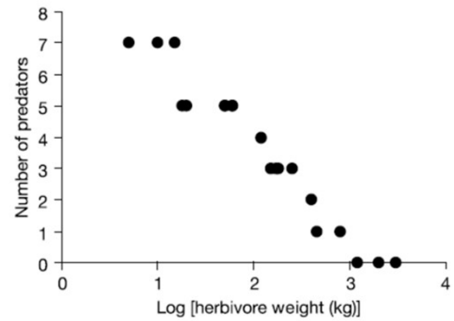


Sinclair et al 2003 Nature

Body size has strong adaptive value

fertility (physiological capacity, sexual attractiveness), capacity to aquire resources, survival capacity

The number of mammal carnivore species that prey upon the savannah ungulates of different body sizes. Serengeti, Tanzania



Sinclair et al 2003 Nature

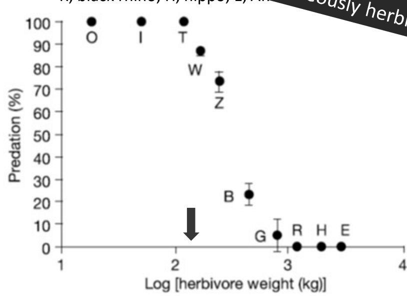
Body size has strong adaptive value

fertility (physiological capacity, sexual attractiveness), capacity to aquire resources, s... capacity

... adult mortality accounted for by predation in ten non-migratory ungulat... ecosystem. There is a threshold in body size of about 150 kg ... switches to food limitation.

Species: O, oribi; I, impala; T, topi; W, ... buffalo; G, giraffe; R, black rhino; H, hippo; E, ...

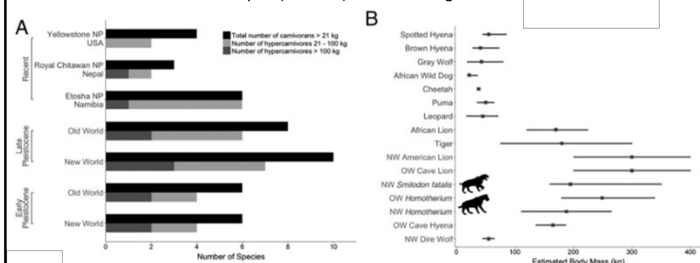
Biodiversity (here in body mass) makes both predation (top-down) and resource limitation (bottom-up) to affect simultaneously herbivore populations



Sinclair et al 2003 Nature

Large carnivores. Now and earlier

Extant tropics (savanna) are rich in large carnivores

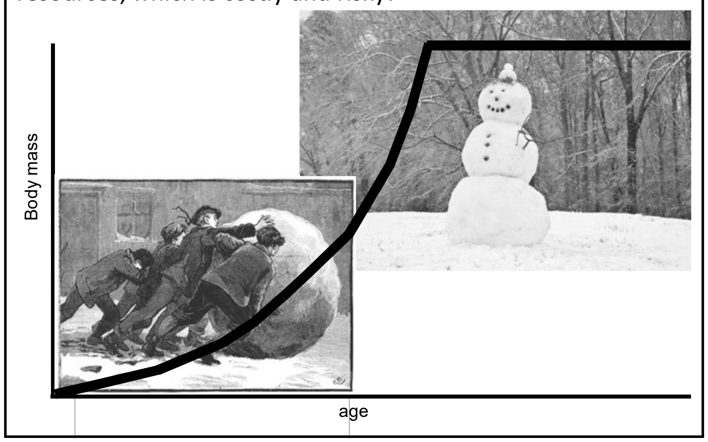


(A) Predator guild composition for four Pleistocene (red) and three extant (blue) communities. Indicated for each guild are the total number of species of carnivorans (hypercarnivores and omnivores, e.g., ursids) with masses >21 kg (black), the subset of these that are hypercarnivores (twotoned bar), and the subset of these that are hypercarnivores with masses >100 kg (dark blue or red).

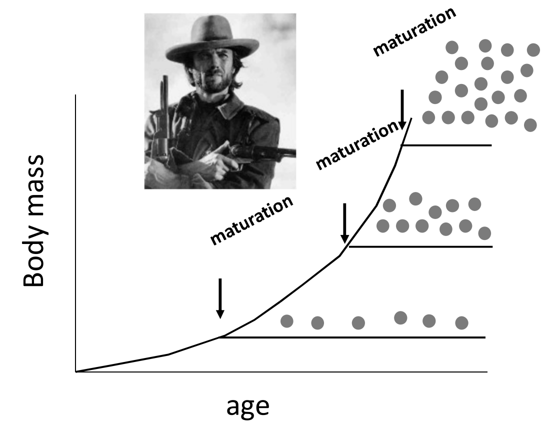
(B) Estimated body masses (mean and range) of extant (blue) and extinct (red) hypercarnivores.

Valkenburgh et al. 2016 PNAS

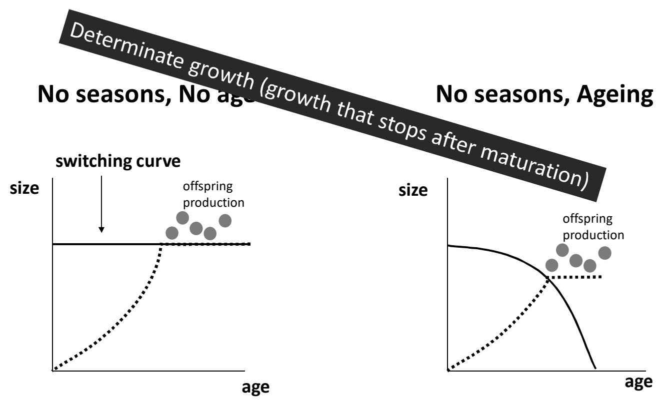
Body size has strong adaptive value, but
adult size is not „given at birth”: to grow you need time & resources, which is costly and risky!



Resources channeled to growth are an investment to the future reproduction

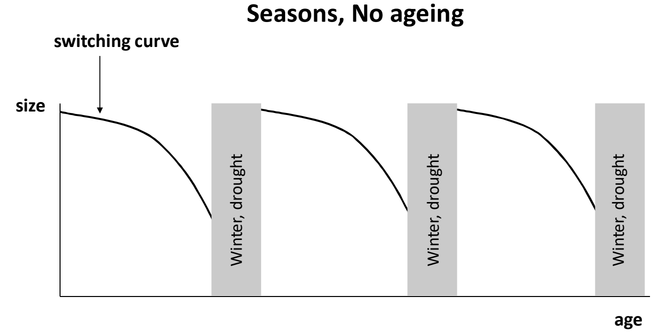


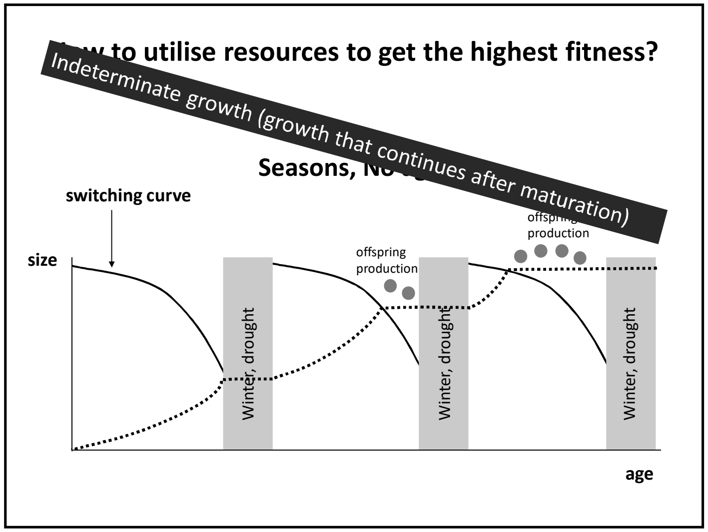
How to utilise resources to get the highest fitness?



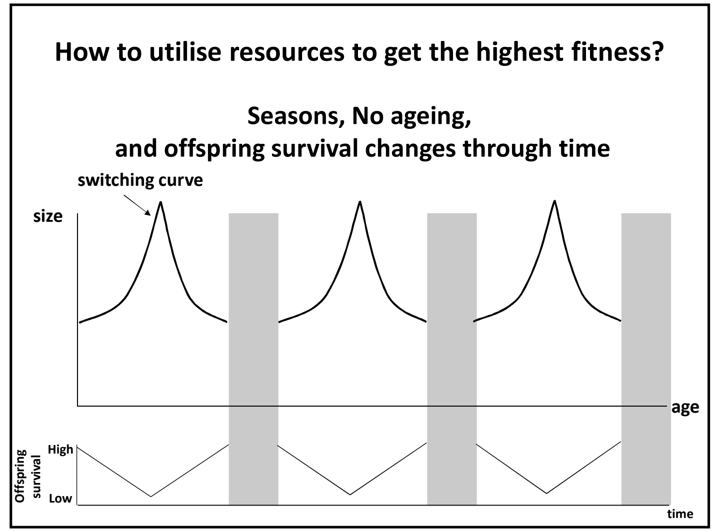
How to utilise resources to get the highest fitness?

Seasons, No ageing

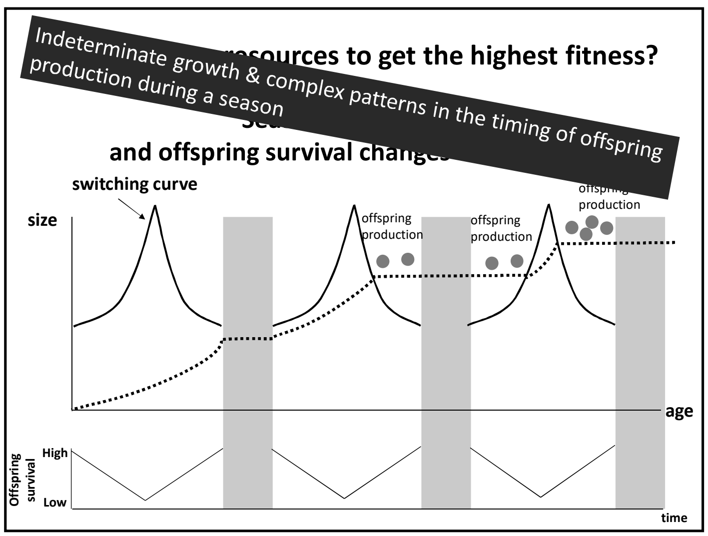




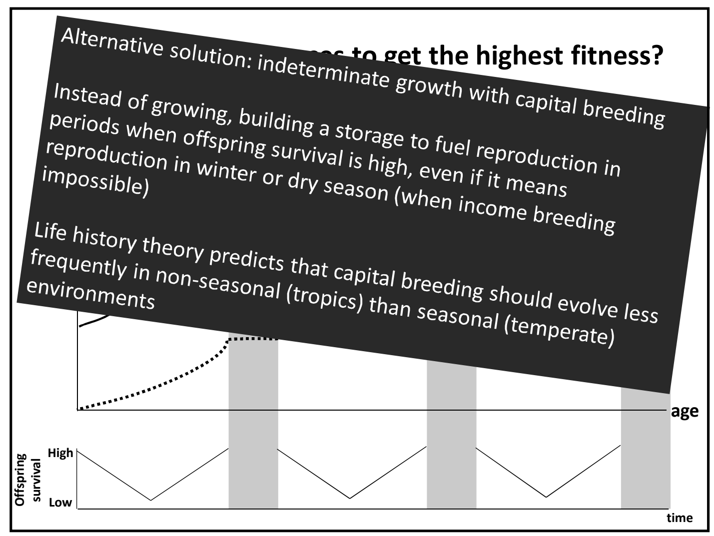
to utilise resources to get the highest fitness?
Indeterminate growth (growth that continues after maturation)
Seasons,
switching curve
size
offspring production
offspring production
Winter, drought
Winter, drought
Winter, drought
age



How to utilise resources to get the highest fitness?
Seasons, No ageing,
and offspring survival changes through time
switching curve
size
age
Offspring survival
High
Low
time

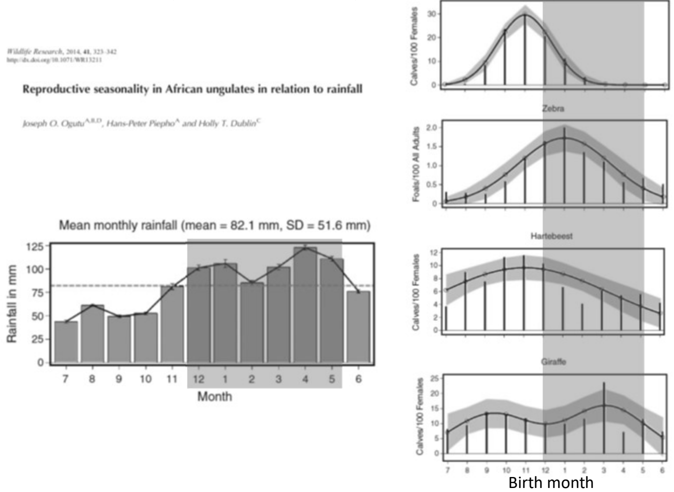


resources to get the highest fitness?
Indeterminate growth & complex patterns in the timing of offspring production during a season
and offspring survival change
switching curve
size
offspring production
offspring production
production
age
Offspring survival
High
Low
time



to get the highest fitness?
Alternative solution: indeterminate growth with capital breeding
Instead of growing, building a storage to fuel reproduction in periods when offspring survival is high, even if it means reproduction in winter or dry season (when income breeding impossible)
Life history theory predicts that capital breeding should evolve less frequently in non-seasonal (tropics) than seasonal (temperate) environments
age
Offspring survival
High
Low
time

A case study in Masai Mara (Kenya)

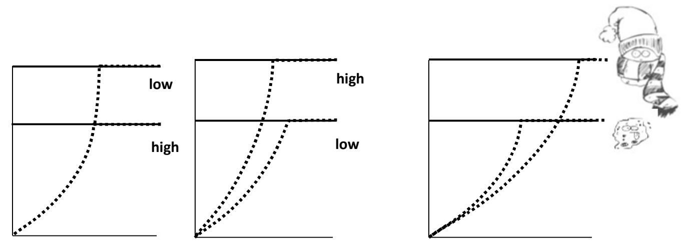


How to utilise resources to get the highest fitness?

Effects of mortality

Effects of production capacity

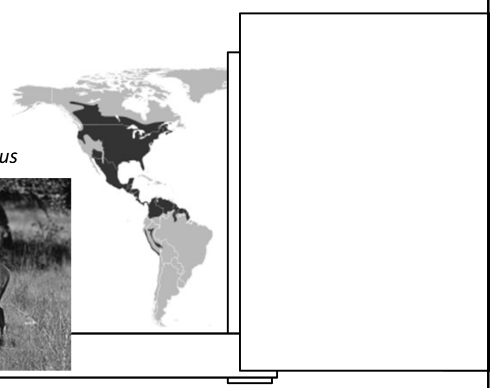
Combined effects of mortality & production (warm habitats productive but risky)



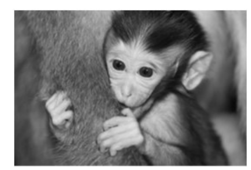
Bergmann's rule

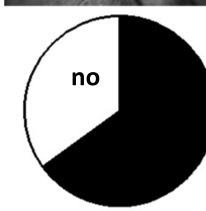
body size decreases when we approach tropics

white-tailed deer
Odocoileus virginianus



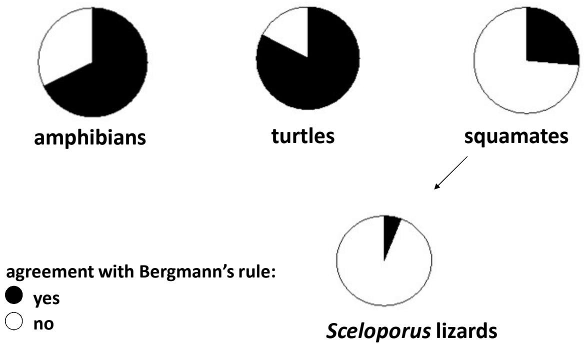
Bergmann's rule in endotherms



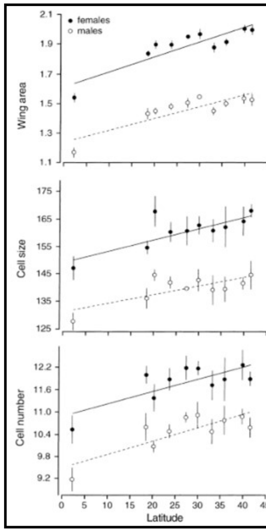


Within-species level Meiri & Dayan 2003

Bergmann's rule in ectotherms



within-species level Ashton 2002, Ashton & Feldman 2003, Sears & Angilletta 2004



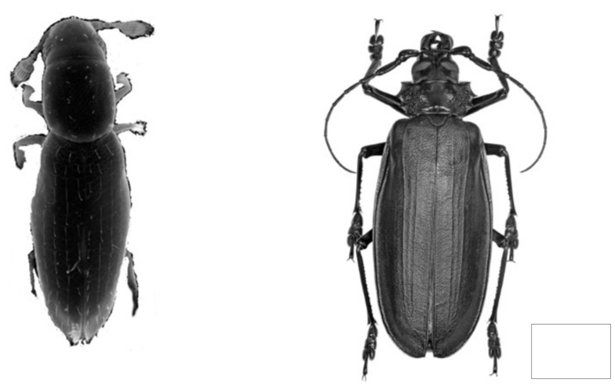
Drosophila melanogaster

Latitudinal clines in body size coupled with changes in cell size and cell number

Zwaan et al. 2000

World-record in body size of beetles both from Neotropics

Scydosella musawasensis *Titanus giganteus*



Yellow meranti Dipterocarpus (*Shorea faguetiana*) 93 m
Danum Valley Conservation Area,

The 6th tallest tree in the world, and the tallest tropical rain forest tree

Ye **horea**
fa
Da **,**
Th and
th

Interplay between temperature and precipitation
Tropics span all possible types of ecosystem

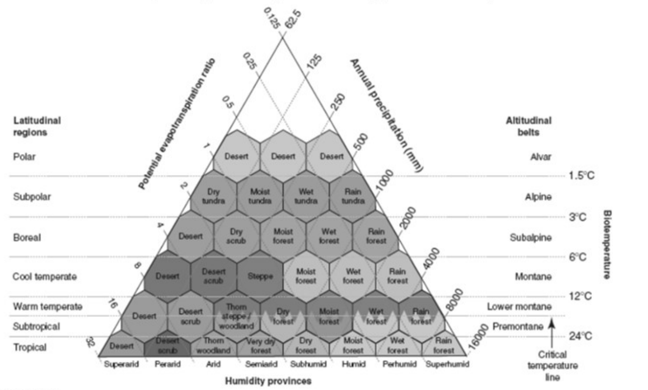


FIGURE 1-10
This is the famous Holdridge diagram that illustrates the relationship between ecosystem types as determined by latitude, elevation, and combination of precipitation and temperature.

Kricher 2011

ture and precipitation
types of ecosystem

Diagram showing the relati... ecosystem type, mean annual temperature (°C), and mean annual precipitation (centimeters). Note that tropical rain forest occurs where both climatic variables are highest.

Tropical rain forest: major life strategies

Even equatorial tropics are not invariable

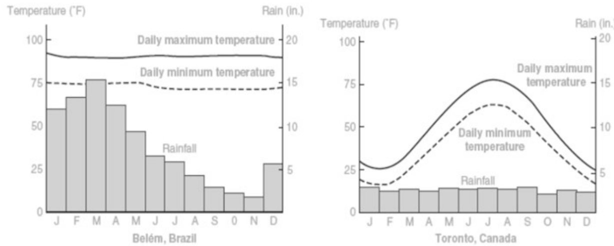


FIGURE 1-9
These graphs contrast the climate in tropical Brazil with that of temperate Canada. Note the strong seasonality of the tropics with regard to precipitation but the steady temperature that prevails in the tropics. The opposite pattern characterizes the temperate zone.

Kricher 2011

Tropical rain forest: major life strategies

Despite low seasonality, most tropical rain forest trees grow and flower in discontinuous way

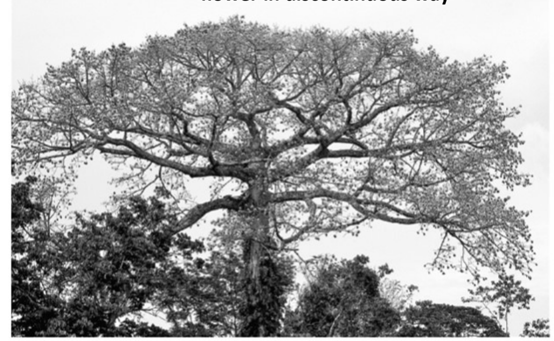


PLATE 3-11
This tree has dropped its leaves but is in full flower. Lack of leaves makes the flowering tree more obvious to pollinating animals.

Kricher 2011

Tropical rain forest: major life strategies

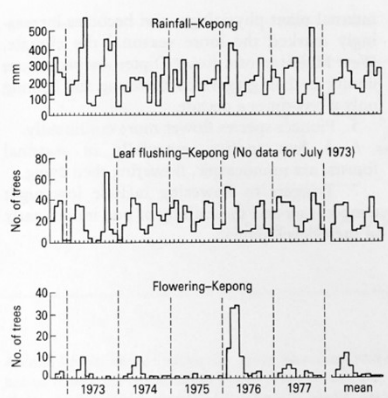
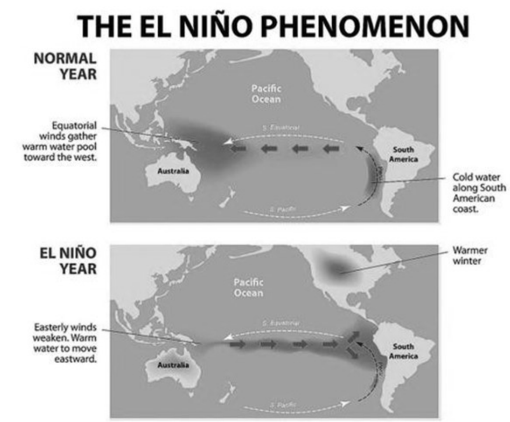


Fig. 3.40. Leaf flushing and flowering of dipterocarps, and rainfall. Kepong, Malaya. (After Ng, 1984, fig. 12.)

Seasonality in precipitation drives leaf grow and flowering in dipterocarp trees

Tropical rain forest: major life strategies

Periodic events



Tropical rain forest: major life strategies

In Malaysian dipterocarp tropical forest: mass-flowering and masting triggered by El Niño

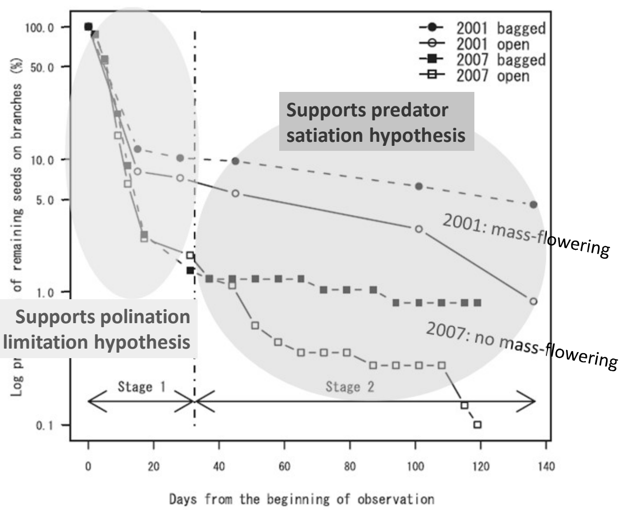
Masting increases polination success and decreases seed predation: a case study

Plant Species Biology (2009) 24, 104–108 doi: 10.1111/j.1442-1984.2009.00243.x

NOTES AND COMMENTS

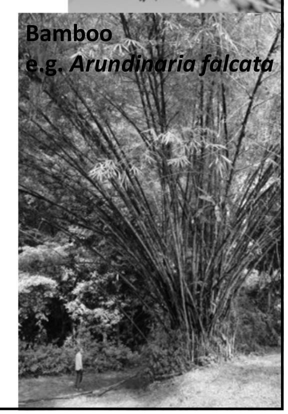
How does flowering magnitude affect seed survival in *Shorea pilosa* (Dipterocarpaceae) at the predispersal stage in Malaysia?

YUJI TOKUMOTO,* MICHINARI MATSUSHITA,* ICHIRO TAMAKI,* SHOKO SAKAI† and MICHIKO NAKAGAWA*
*Graduate School of Bioagricultural Sciences, Nagoya University, E1-1 (300), Chikusa, Nagoya 464-8601, Japan and †Research Institute for Humanity and Nature, Motoyama, Kamigamo, Kyoto 603-8047, Japan

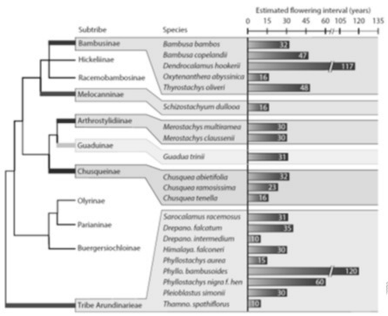


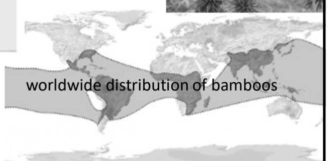
Tropical rain forest: major life strategies

Semelparity (monocarpy), a single reproduction act followed by death, occurs in many monocotyledonous tropical plants



Flooding area with offspring and mass dying of parents
many bamboos are long lived monocarps that mass-flower synchronously over long time intervals (record 130 years!!!)

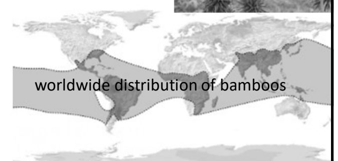




Ecology Letters, (2015) **18**: 653–659

Flooding area with offspring and mass dying of parents
many bamboos are long lived monocarps that mass-flower synchronously over long time intervals (record 130 years!!!)

wind-pollination
seed predators (rodents)
larger bamboo more seeds
satiating predators
pollination efficiency
size-dependence of seed production
increased reproductive effort
mass flowering (synchrony)
flowering at older age
escaping predator reproductive cycles
fewer resources to survive
time lags between flowering events



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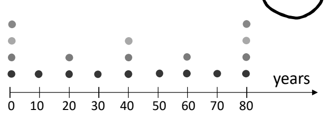


Enigmatic strategies of sympatric lobelias from the alpine zone of Mt. Kenya

Lobelia telekii - semelparous

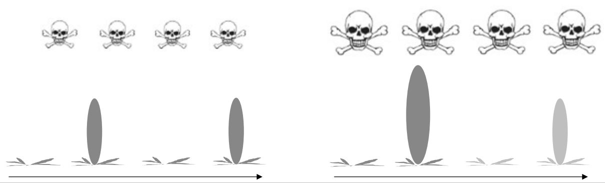
Lobelia deckenii- iteroparous

Theoretical approaches to the evolution of semelparity

- When **adult survival is low**, evolution can abandon storing resources for a future reproduction that is unlikely, and instead lead to semelparity

Survival high
Iteroparity

Survival low
Semelparity

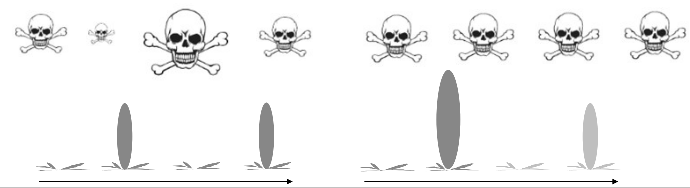


Theoretical approaches to the evolution of semelparity

- When **adult survival is low**, evolution can abandon storing resources for a future reproduction that is unlikely, and instead lead to semelparity
- When **adult survival is highly variable**, evolution can favor iteroparity, because it does not risk putting all reproductive effort into a single reproductive episode (bet-hedging/risk-spreading strategy)

Survival variable & unpredictable
Iteroparity

Survival stable & predictable
Semelparity

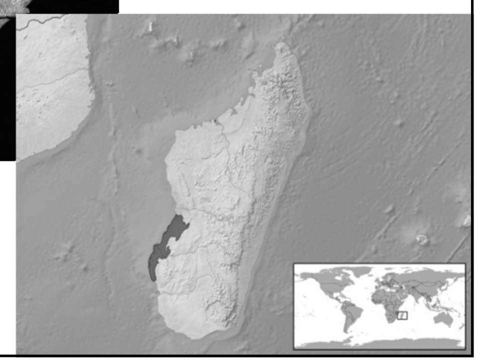


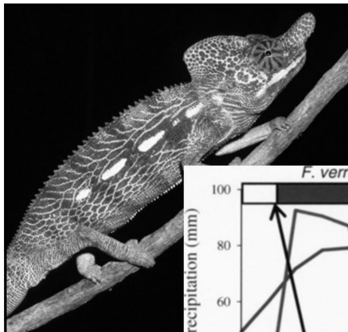
Theoretical approaches to the evolution of semelparity

- When **adult survival is low**, evolution can abandon storing resources for a future reproduction that is unlikely, and instead lead to semelparity
- When **adult survival is highly variable**, evolution can favor iteroparity, because it does not risk putting all reproductive effort into a single reproductive episode (bet-hedging/risk-spreading strategy)
- Semelparity can evolve when most of the costs of reproduction (reduction in future survival or reproduction caused by increases in current reproduction) happen even at low levels of reproductive effort (**high overhead costs**), or conversely, when fitness **benefits disproportionately increase with reproductive effort**, e.g., one large flower attracts much more pollinators tyhan fewer smaller flowers)

***Furcifer labordi* - semelparous annual chameleon from the tropical forest in Madagascar**

- rapidly-growing
- high mortality rates
- highly seasonal rainfall and temperature





Furcifer labordi **- semelparous annual chameleon from the tropical forest in Madagascar**

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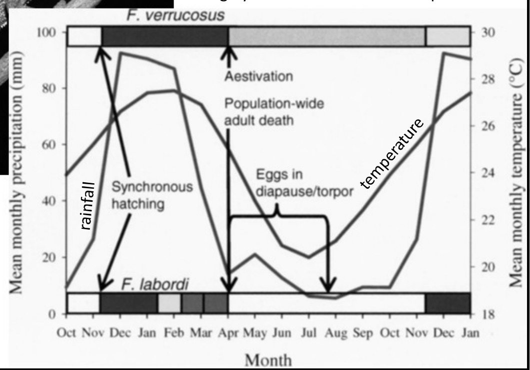


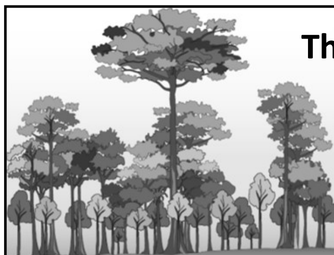
Tropical rain forest is higly 3-D

the higher above the ground, the more light and less humid

FIGURE 3-4
This drawing illustrates a mature dipterocarp forest in Belalong, Brunei. The smaller, younger dipterocarps in the understory exhibit a monopodial crown (which is taller than it is broad). The mature canopy trees exhibit a sympodial crown, broader than it is tall. Such transition in growth form is typical of many tropical tree species.

Kricher 2011

The same, but different



British Gujana

Borneo

Kricher 2011

Tropical rain forest is higly 3-D

the higher above the ground, the more light and less humid

Ontogenetic shifts in the crown shape in dipterocarp trees

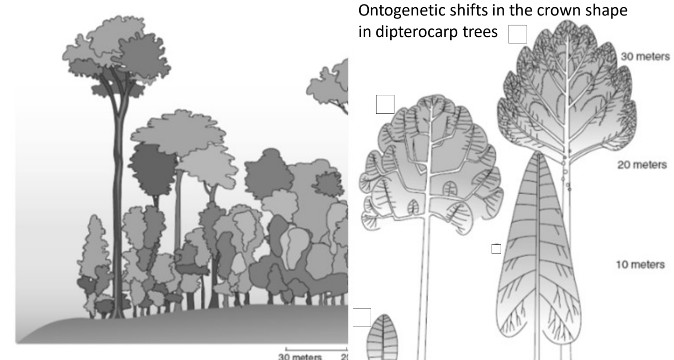


FIGURE 3-4
This drawing illustrates a mature dipterocarp forest in Belalong, Brunei. The smaller, younger dipterocarps in the understory exhibit a monopodial crown (which is taller than it is broad). The mature canopy trees exhibit a sympodial crown, broader than it is tall. Such transition in growth form is typical of many tropical tree species.

Kricher 2011

Nonintuitive pattern: the higher the tree, the narrower the crown – WHY?

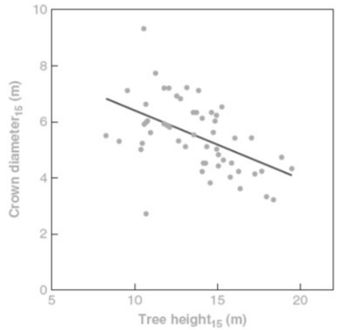


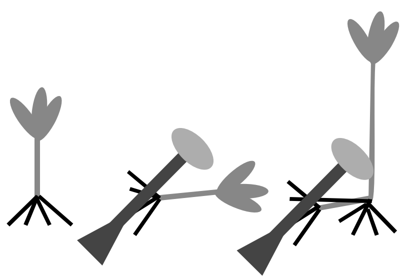
FIGURE 3-6
This graph illustrates the negative correlation between crown diameter and tree height for 53 rain forest tree species. As trees become taller, crowns widen less. Broad crowns would place trees in danger of windfall and other forms of mechanical failure, so there is fitness in having a smaller crown when a tree is tall.

Kricher 2011

Competition for light & shallow decomposition layer in soil promotes high trees with buttressed or surface roots

Flying buttresses, prop/stilt roots: help in swamps or to maintain upward position after disturbance

„Walking palm" *Socratea exorrhiza* in South America



Flying buttresses, prop/stilt roots: help in swamps or to maintain upward position after disturbance

Flying buttresses of *Uapaca guineensis* (Africa)

Flying buttresses, prop/stilt roots: help in swamps or to maintain upward position after disturbance

mangroves

World's mangrove forest

Cauliflory and Caulicarpy very common in tropics pollination & seed-dispersal by animals predominates

Danum Valley, Borneo

Cauliflory and Caulicarpy very common in tropics

Danum Valley, Borneo

Cauliflory and Caulicarpy very common in tropics

Cauliflory and Caulicarpy very common in tropics

Durian tree (South-East Asia)

Many classical examples of the plant-polinator coevolution

Neotropics: hummingbirds & heliconias

Many classical examples of the plant-polinator coevolution

South-East Asia: sunbirds & ginger

Many classical examples of the plant-polinator coevolution

Africa: sunbirds & lobelias

Many classical examples of the plant-polinator coevolution

Darwin noticed that the orchid *Angraecum sesquipedale* (so-called Darwin's orchid) from Madagascar has an extraordinary long spur with nectar (35 cm!!!). In his book about orchids (1862), Darwin predicted that the coevolution with polinators should have created a moth with the adequately long broboscis.

Thomas William Wood, 1867

Many classical examples of the plant-polinator coevolution

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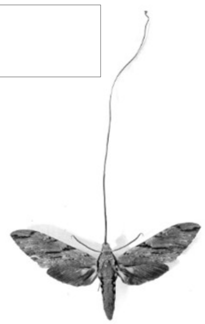


After Darwin's death, biologists found the predicted species, a hawk moth *Xanthopan morganii*

Many classical examples of the plant-polinator coevolution

Mimicry in orchid flowers (deception)

Many classical examples of the plant-polinator coevolution

Why tropical rain forests are so rich in plant species with different life stratiegies?

Many different, but not mutually exclusive mechanisms

Why tropical rain forests are so rich in plant species with different life stratiegies?

L :

falling tre strategies

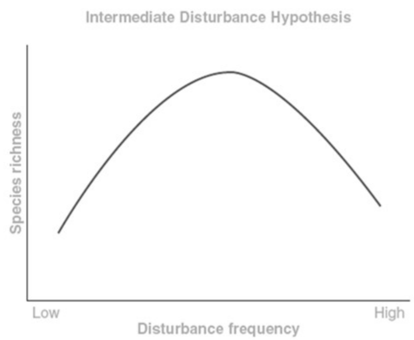
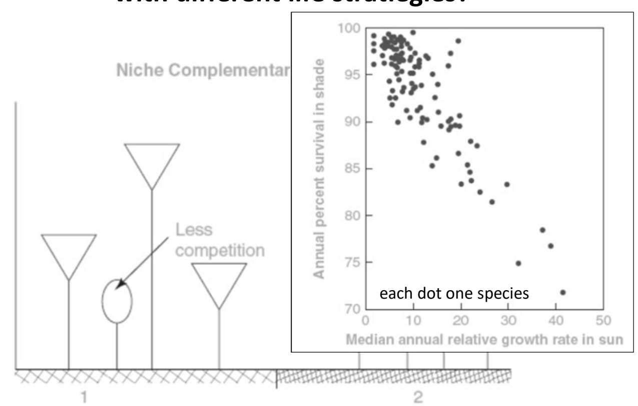


FIGURE 5-3
Species richness is maximal when disturbance frequency is intermediate. Too much disturbance reduces diversity because few species are adaptable to high disturbance. Too little disturbance results in lowering diversity due to competitive exclusion.

Kricher 2011

Why tropical rain forests are so rich in plant species with different life stratiegies?



Kricher 2011

Why tropical rain forests are so rich in plant species with different life stratiegies?

Freque[...] [...]hogenes

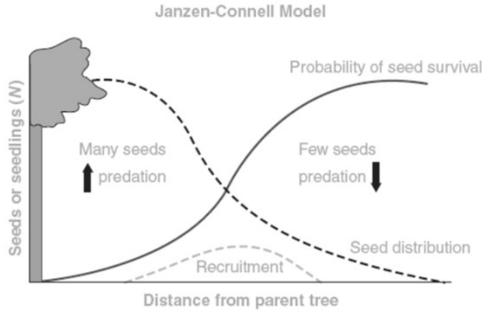
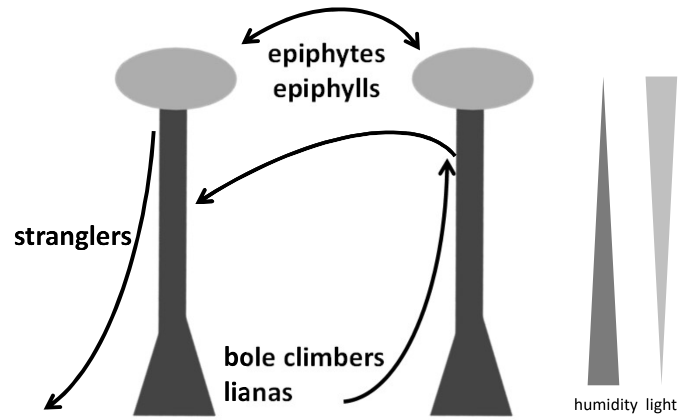


FIGURE 5-6
Predation pressure from pathogens and herbivores is most intense near mature trees, and thus seeds that are moderately distant from the tree survive best. Compare this model with the previous model. Both are similar.

Kricher 2011

Competition for light & alternative strategies



Competition for light & alternative strategies

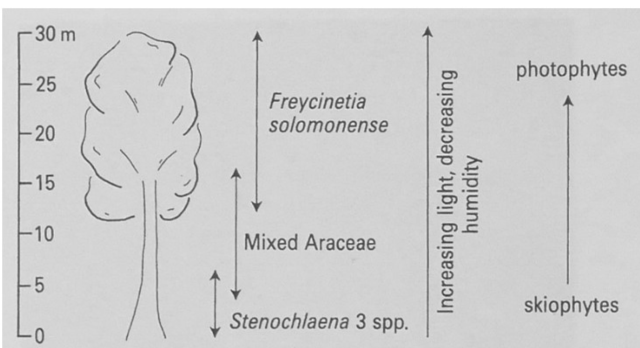


Fig. 3.18. Bole climbers occur in zones. Lowland rain forest, Kolombangara, Solomon Islands. (Whitmore 1974.)

Competition for light & alternative strategies

Lianas

Competition for light & alternative strategies

Strangler fig

Competition for light & alternative strategies

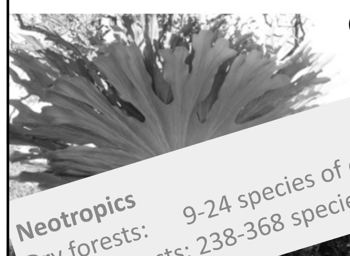
Epiphytes

Birds nest ferns (Asplenium)

Competition for light & alternative strategies

Epiphytes

Orchids
(all tropics)

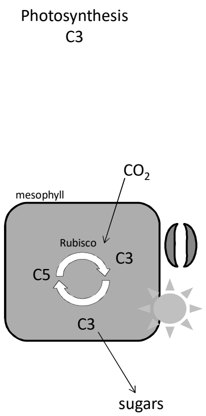


Neotropics
Dry forests: 9-24 species of epiphytes (2% of local flora)
Humid forests: 238-368 species of epiphytes (24% of local flora)

Bromeliads (Neotropics)

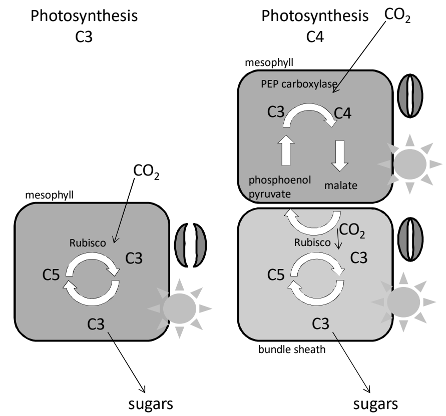
Competition for light & alternative strategies

Crassulacean acid metabolism (CAM photosynthesis) in many epiphytes inhabiting crowns of emergent trees



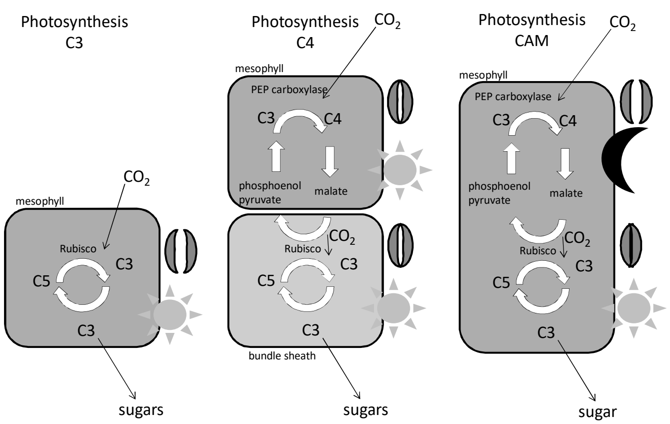
Competition for light & alternative strategies

Crassulacean acid metabolism (CAM photosynthesis) in many epiphytes inhabiting crowns of emergent trees



Competition for light & alternative strategies

Crassulacean acid metabolism (CAM photosynthesis) in many epiphytes inhabiting crowns of emergent trees



Famous CAM plants

Ananas (South Am)

Welwitschia mirabilis – gymnosperms!!
„living fossil" from Namib Desert (Africa)

Agave

Cactuses, Central/North America

Competition for light & alternative strategies

Heterotrophic plants

Pitcher plants: carnivorous plants forming pitfall traps from leaves, belong to *Nepenthaceae* (South-East Asia) and *Sarraceniaceae* (Neotropics) families. Borneo – the biodiversity & endemism hotspot of *Nepenthes* (often climbers)

Competition for light & alternative strategies

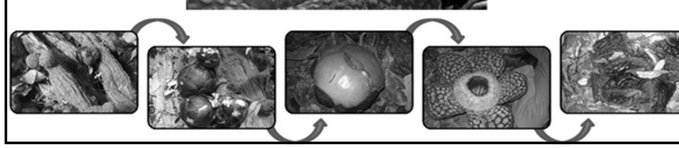
Heterotrophic plants

Hemiparasites (partially autotrophic): sandal-wood trees (*Santalum*, mainly South-East Asia)

Competition for light & alternative strategies

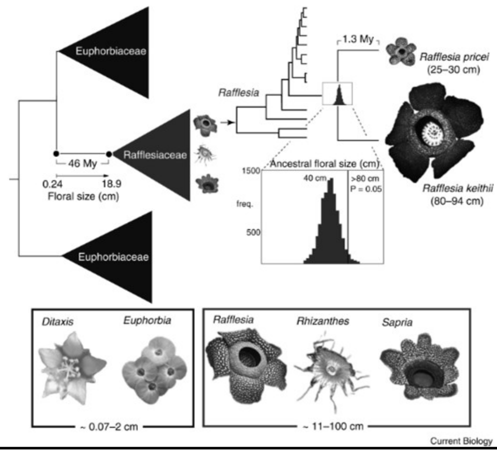
Heterotrophic plants

Holoparasites (full parasites): South-East Asian rafflesias are (sic!!!) **endophytes** of lianas
gigantic carrion flowers mimic rotting flesh (odor, colour, texture, size)



Rafflesiaceae's flowers: extreme size and dramatic interspecific differences (11-100 cm)

Genus *Rafflesia*: recent (last million years) and extremely rapid evolution of flower size



Mimicking rotting flesh attracts pollinators

necrophagous insects: females seeking dead bodies for egg-laying and males seeking mates near dead bodies

Evolution of carrion flowers: selective conditions

1) scattered distribution of plant species

- high biodiversity in tropics means scattered distributions
- specialisations (forest gaps, parasitism) means scattered distributions

2) scattered plants can become limited by pollination

3) many necrophagous insects fly long distances to find food and egg-laying sites

4) insects selected to avoid breeding on fake dead bodies, so plants with carrion flowers selected to be deceptive: odor, size, shape, texture, colour

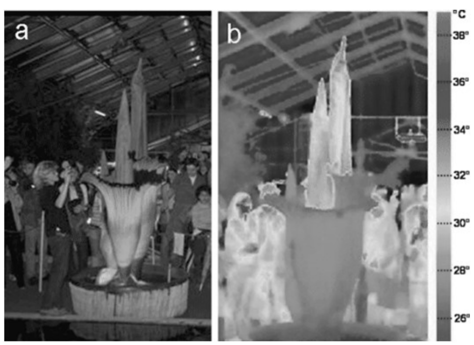
5) frequency-dependent selection: if carrion flowers become abundant, more pressure on insects to detect fake flowers, which selects against carrion flowers, and vice versa. Note that „careful insects" ignore also some true dead bodies, so insects will not evolve to be „too careful".

Size matters

mimicking dead bodies and strengthenning the odor that need to travel long distances to attract long-distance dispersing insects

Insects selected to avoid breeding on fake dead bodies, so plants with carrion flowers selected to be deceptive: odor, size, shape, texture, colour,
but also a production of heat and CO_2 that mimics decomposition!!!

Thermogenesis in Titan arum: an extreme example
Amorphophallus titanum



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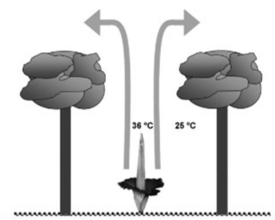
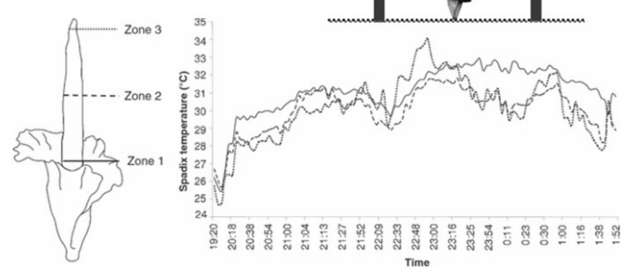
Heating at night creates convective currents that help to send odor long distances





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