Biodiversity in tropics
(A) life history perspective

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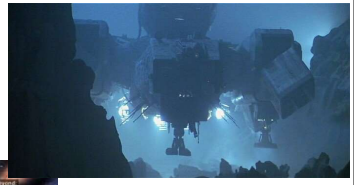
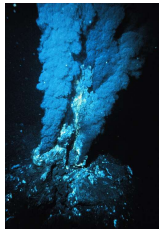
Life History Evolution group
Institute of Environmental Sciences JU

What is life?

If you answer, you know what promotes life and its abundance

Ebola virus
(a tropical thing)

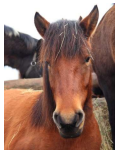




Hydrothermal vents with geothermally heated water discharges („local tropics")

What is life?

If you answer, you know what promotes life and its abundance

Metabolism energy, materials	Reproduction	Information carrier	Evolution transgenerational changes of the information carrier
 YES		ABSENT	ABSENT
 YES highjacked from hosts			INEVITABLE
 YES			INEVITABLE

What is life?

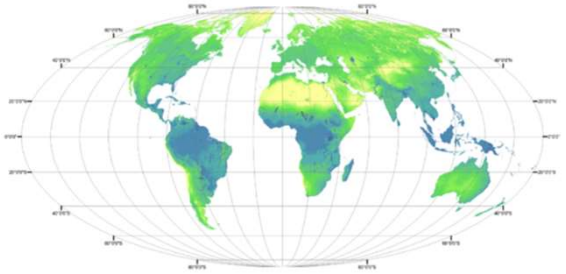
If you answer, you know what promotes life and its abundance

Important implications for understanding why water-rich tropics host high biodiversity

- Life means evolution
- More life means more evolution
- More evolution needs more energy and more materials
- The more diverse energy and material sources, the more diverse life evolution
- The more diverse evolution, the more diverse evolution (tropical „snowball effect")

An example of some global scale trends

Terrestrial tropics characterised by the highest levels of evapotranspiration
(lots of solar energy and no shortage of water)



Actual evapotranspiration

mm/year

< 50 | < 100 | < 200 | < 400 | < 700 | < 1 000 | < 1 500 | < 2 500 | > 2 500

Photosynthesis Equation

$6CO_2 + 6H_2O \xrightarrow{Light} C_6H_{12}O_6 + 6O_2$

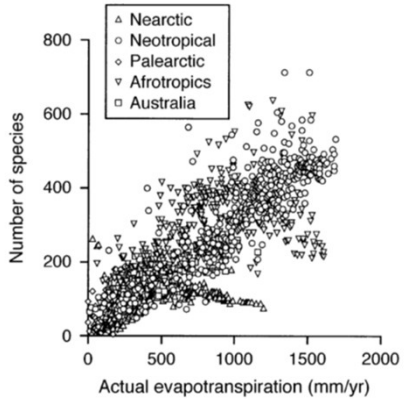
Carbon dioxide | Water | Sugar | Oxygen

the rate of water evaporation, related to temperature and water availability - precipitation

Hoogeven et al. 2015. HESSD 12, 801-838

An example of some global scale trends

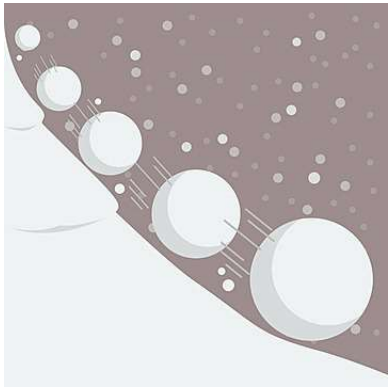
The higher the evapotranspiration, the more species of terrestrial birds



Hawkins et al. 2003. Ecology 84, 1608-1623

Tropical biodiversity in a nutshell

Self-perpetuating „snowball" effects (tropics are rich in coevolution)
The longer the slopes, the larger the snawball effect (tropics are old)



Tropical biodiversity in a nutshell

Let's highlight two evolutionary phenomena

- The rat race competition - no absolute winners because Darwinian fitness is individual reproductive performance relative to others - now and here
- The "Red Queen" coevolution – no absolute winners because constant arms-race mechanism

Now, *here*, you see, it takes all the running you can do, to keep in the same place.

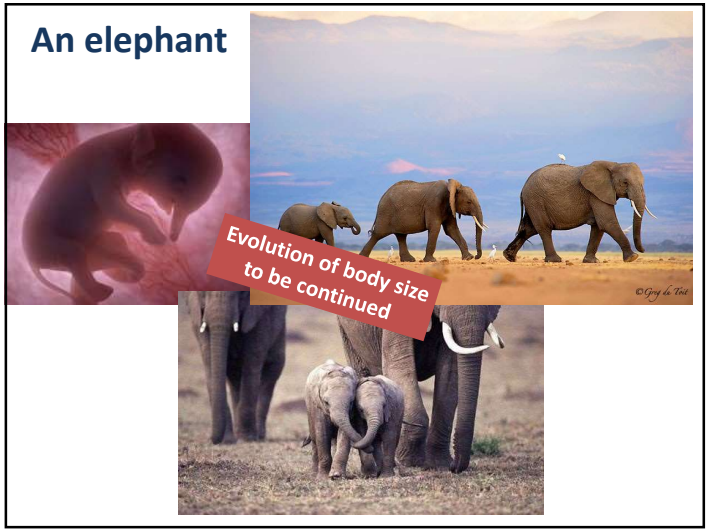
Organisms in populations participate in a constant „rat race"

Alice learns from the Red Queen
„Through the Looking-Glass" (Lewis Carroll, 1871)

Let's change the perspective of an organism or a species

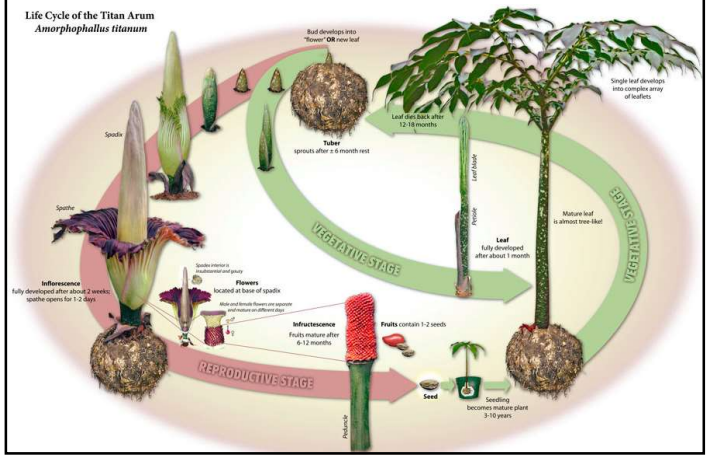
Living things are
life strategies with dynamic life cycles that undergo evolution

An elephant



Evolution of body size
to be continued

Titan arum



Titan arum

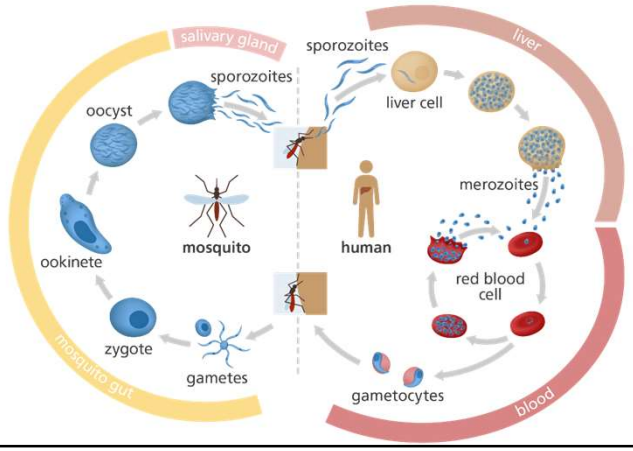
Carrion flowers: heating, mimicry, giant flowers
to be continued

Info & anecdote

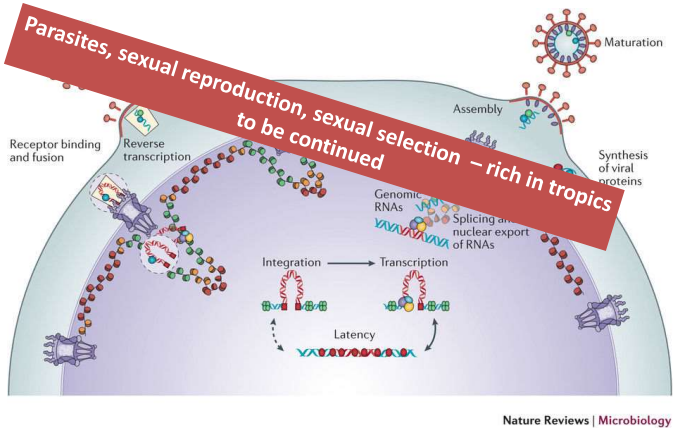
Real name - *Amorphophallus titanum.* Endemic to Sumatra. Produces the largest inflorescence in the world. **Flowers every some years.** Flowers smell rotten meat to attract carrion-eating beetles.

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.

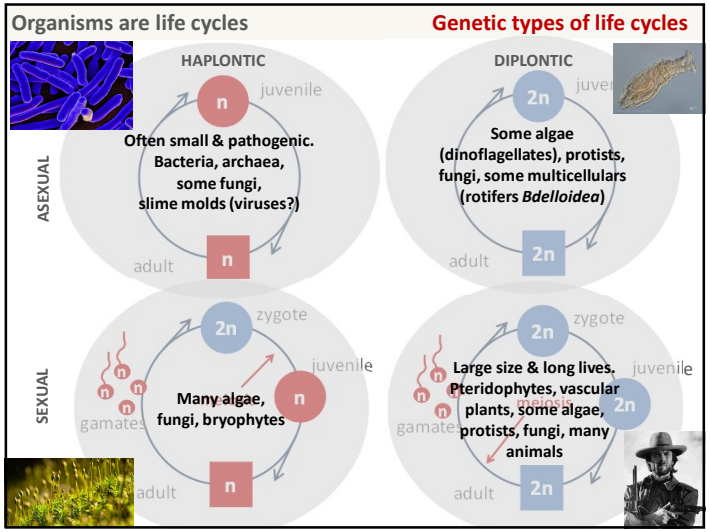
A Plaspodium



HIV



Organisms are life cycles — Genetic types of life cycles



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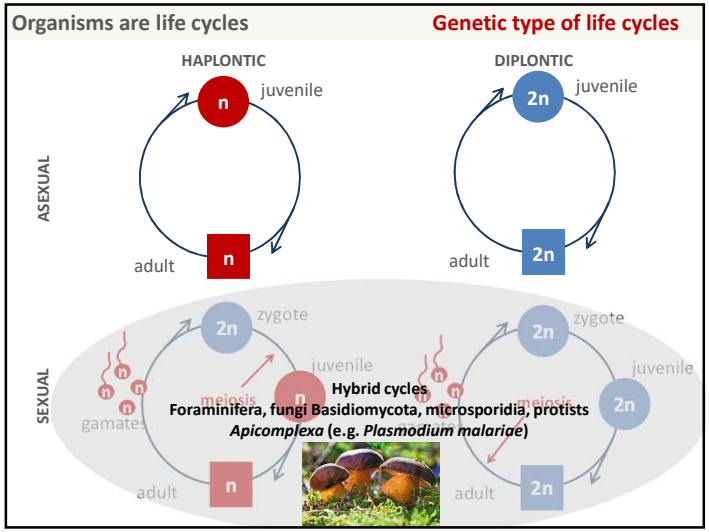

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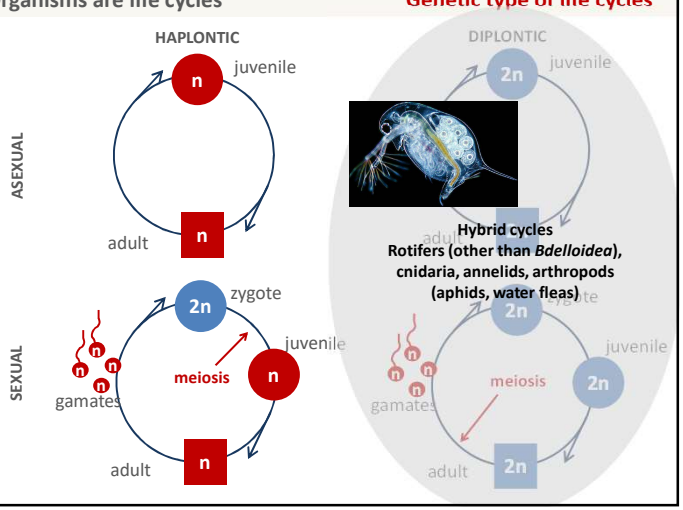

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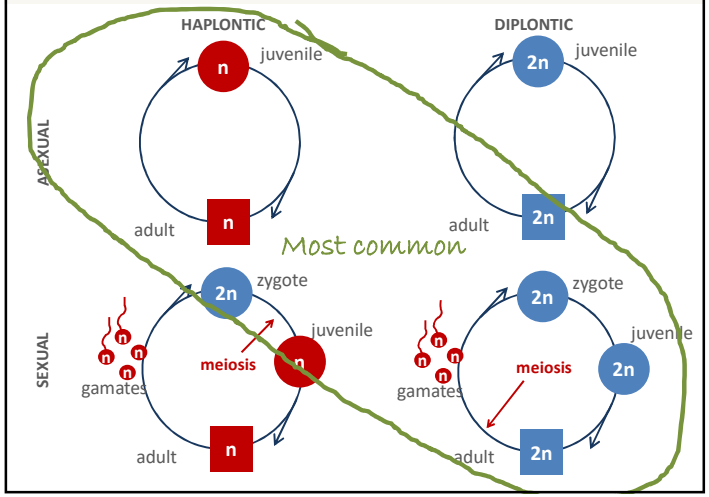

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Review

Cite this article: Tilquin A, Kokko H. 2016 What does the geography of parthenogenesis teach us about sex? *Phil. Trans. R. Soc. B* **371**: 20150538. http://dx.doi.org/10.1098/rstb.2015.0538

What does the geography of parthenogenesis teach us about sex?

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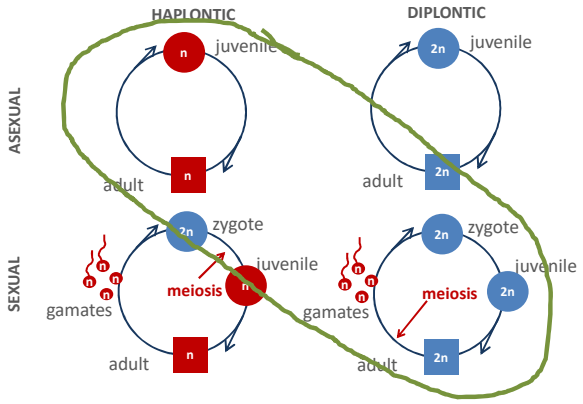
Theory predicts that sexual reproduction is difficult to maintain if asexuality is an option, yet sex is very common. To understand why, it is important to pay attention to repeatably occurring conditions that favour transitions to, or persistence of, asexuality. Geographic parthenogenesis is a term that has

Parthenogenesis (asexual form of reproduction) is often less common at low latitudes or elevations

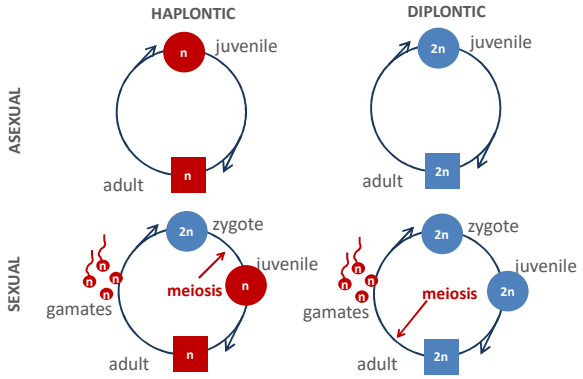
or generally, it is less common in warmer habitats like tropical rainforests that are rich in species and host-parasite interactions

but why?

Tropics - rich in species
Tropics - more different hosts & more specialised parasites
Tropics - higher parasite pressure & more advantages from sexual recombination (the Red Queen coevolutionary mechanism)

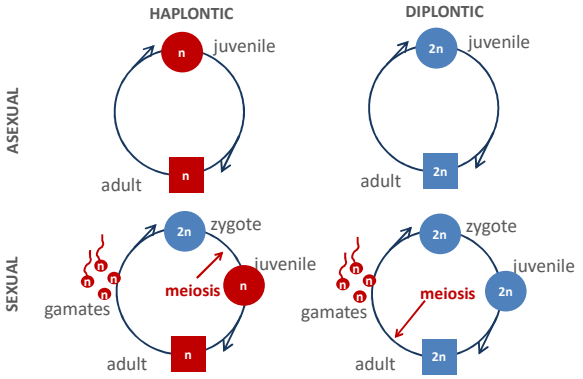


Compare the pace of evolution among populations of organisms with different life cycles



Conclusions

Evolution faster in populations with haplontic vs diplontic organisms
Evolution faster in populations with sexual organisms
Evolution faster in populations with short life-cycle organisms



Pathogenes evolve at enormous pace

large populations, small bodies and haplontic, short life cycles

Bill Hamilton in Kraków explained advantages of sexual reproduction with a help of the Red Queen coevolutionary mechanism

Asexual reproduction produces genetic clones – so next generations are rapidly overtaken by effective genetic forms of parasites

The Red Queen mechanism

- Pathogens rapidly evolve the ability to fight their host's immune system
- In response, hosts must rapidly recombine genes in their offspring to keep up in the arms race
- No winners, but at least no complete losers

Bill Hamilton in Kraków explained advantages of sexual reproduction with a help of the Red Queen coevolutionary mechanism

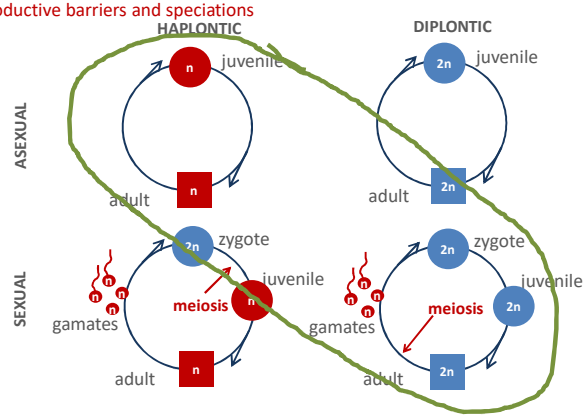
Sexual reproduction produces genetic recombinants – so next generations are not completely overtaken by parasites

Conslusions

Tropics - rich in parasite-host interactions, which promotes sex

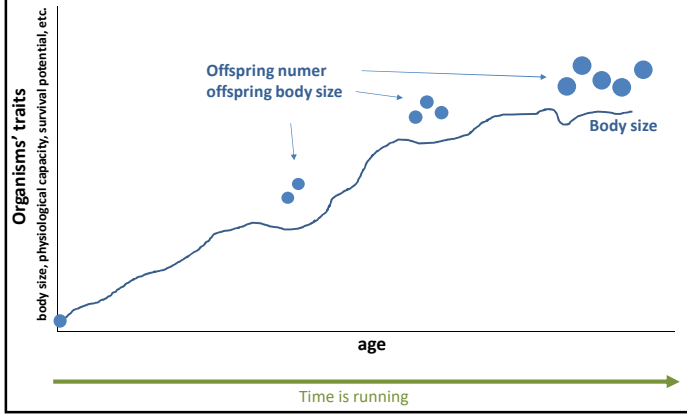
Tropics - rich in sex, which generates a new selective force – sexual selection

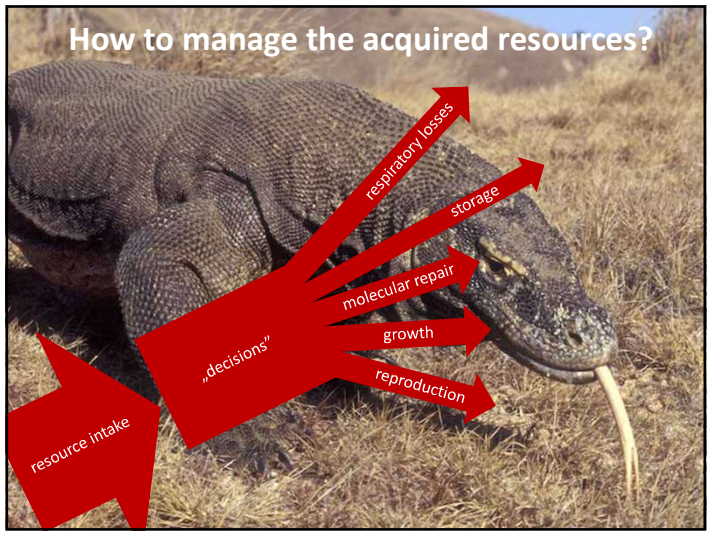
Tropics - rich in sexual selection, and sexual selection is involved in the origin of reproductive barriers and speciations



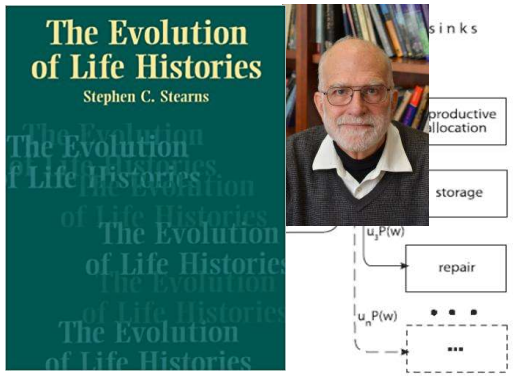
Organisms are life cycles

which also means that the dynamics of life cycles evolve, leading to the diversity of traits/forms (e.g. adult body mass)





Strategy of optimal resource allocation



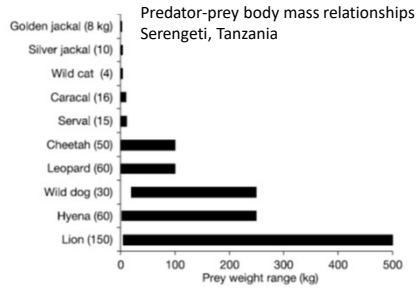
Kozłowski 2000

Body size has strong adaptive value

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

Larger predators get larger prey

recall from the last lecture: also larger hunting groups get larger prey



Predator-prey body mass relationships
Serengeti, Tanzania

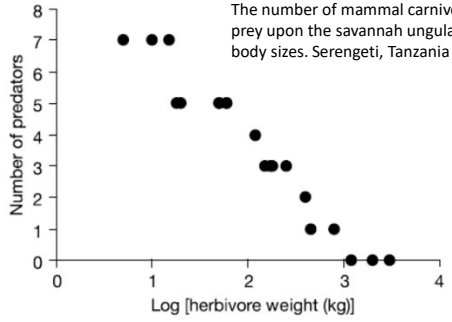
Sinclair et al 2003 Nature

Body size has strong adaptive value

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

Larger prey is safer

recall from the last lecture: also grouping in larger herds is safer for the prey

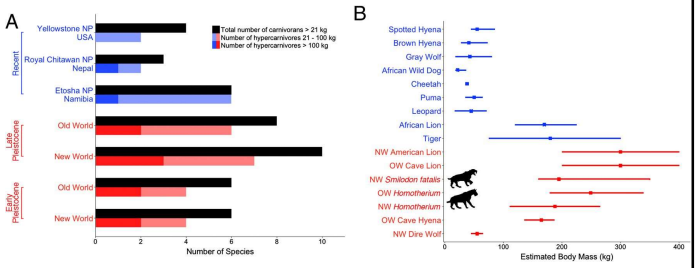


The number of mammal carnivore species that prey upon the savannah ungulates of different body sizes. Serengeti, Tanzania

clair et al 2003 Nature

Large predators: now and past

Today, tropics (especially savanna) are rich in large carnivores



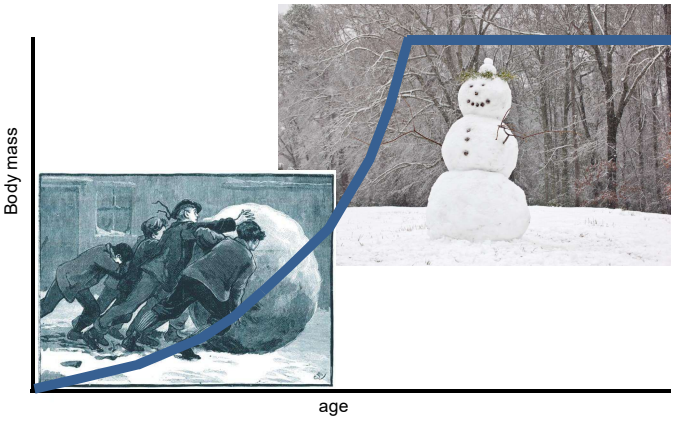
(A) Predator guild composition for four Pleistocene (red) and three extant (blue) communities. Indicated for each guild are the total number of species of carnivorans (hypercarnivores and omnivores, e.g., ursids) with masses >21 kg (black), the subset of these that are hypercarnivores (two toned bar),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

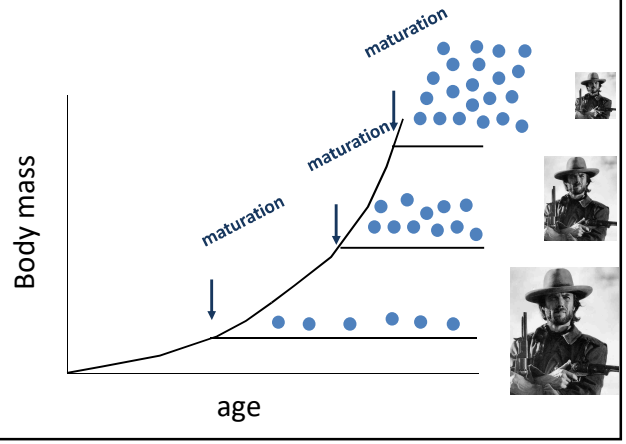
Valkenburgh et al. 2016 PNAS

It is clear that body mass has strong adaptive value, but

adult mass is not „given at birth": to grow you need time & resources, which is risky and costly!



Resources channeled to growth are an investment to the future reproduction

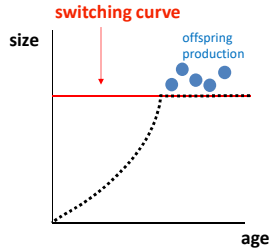


ilise resources to get the highest fitness?

Determinate growth (growth that stops after maturation) if non-seasonal environment

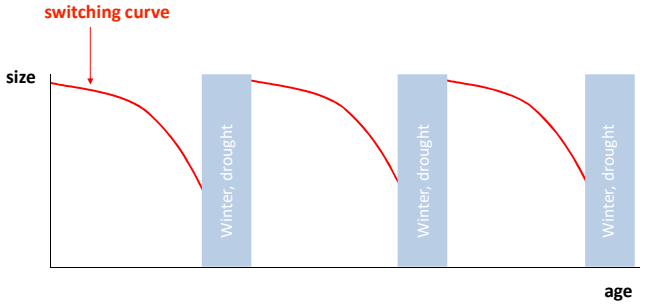
So, generally equatorial tropics select for the determinate growth life strategy and bang-bang swich from juvenile growth to reproduction

No seasons



How to utilise resources to get the highest fitness?

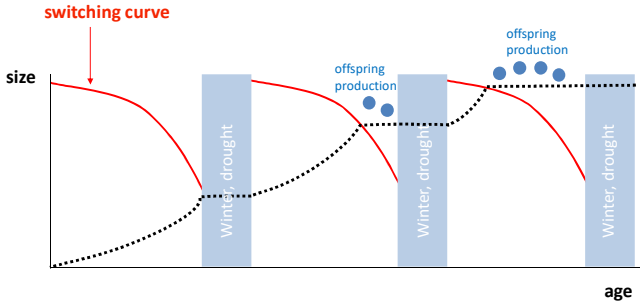
Seasons



How to utilise resources to get the highest fitness?

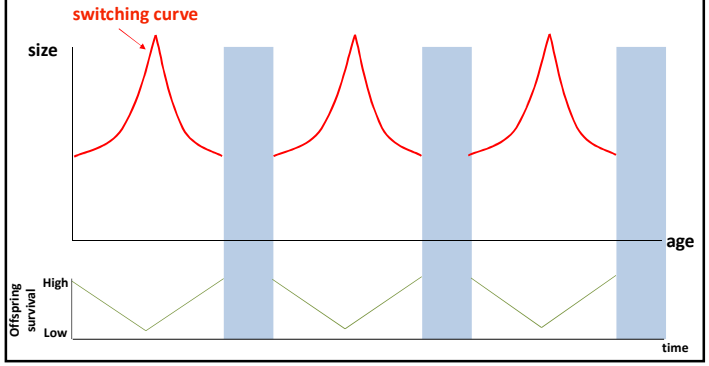
Indeterminate growth (growth that continues after maturation) if seasonal environment

Seasons



How to utilise resources to get the highest fitness?

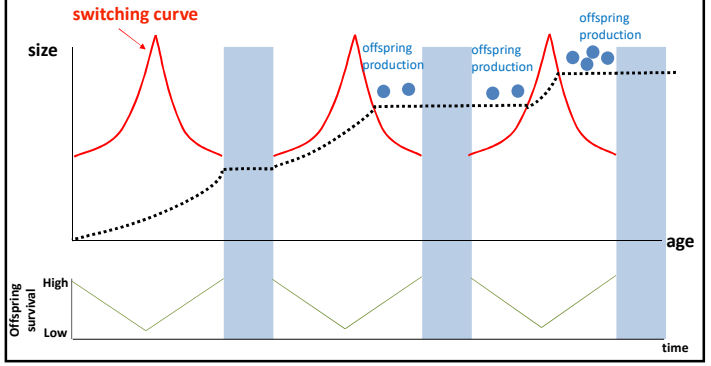
Seasons
and offspring „value" (survival) changes through time



How to utilise resources to get the highest fitness?

Indeterminate growth & complex patterns in the timing of offspring production during a season

Seasons
and offspring „value" (survival) changes through time

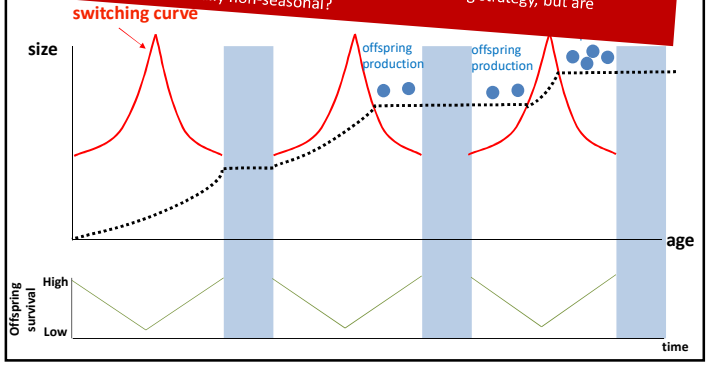


How to utilise resources to get the highest fitness?

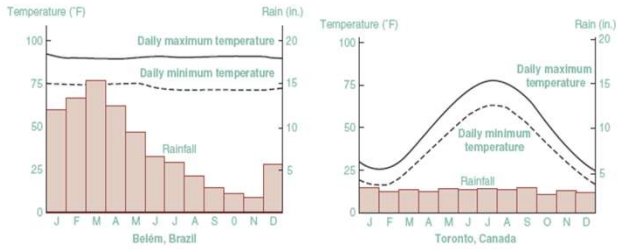
Alternative solution: evolution of capital breeding

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)

Equatorial non-seasonal tropics select for income breeding strategy, but are equatorial tropics really non-seasonal?

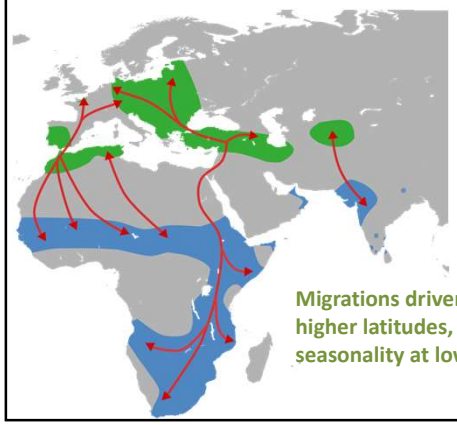


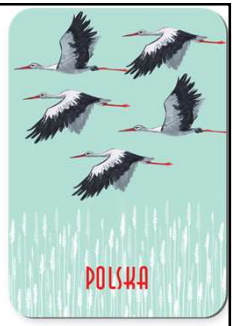
Even equatorial tropics are not invariable



Kricher 2011

„Polish" white storks
a tropical bird that vistis Poland for reproduction

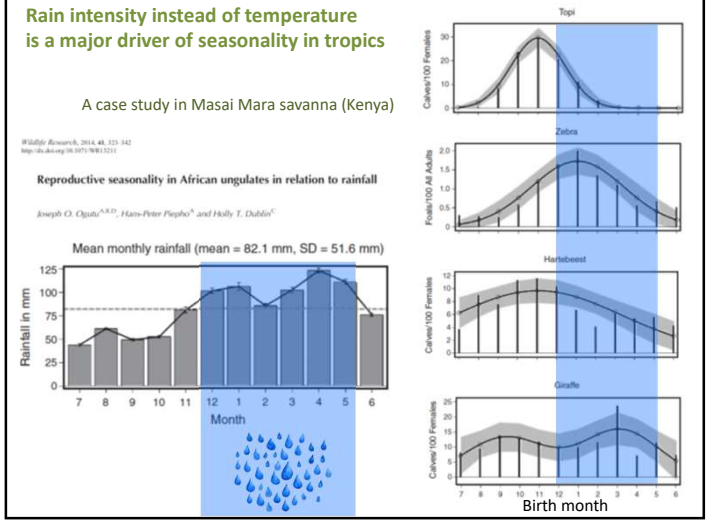




Migrations driven by seasonality at higher latitudes, result in … seasonality at low latitudes (in tropics)

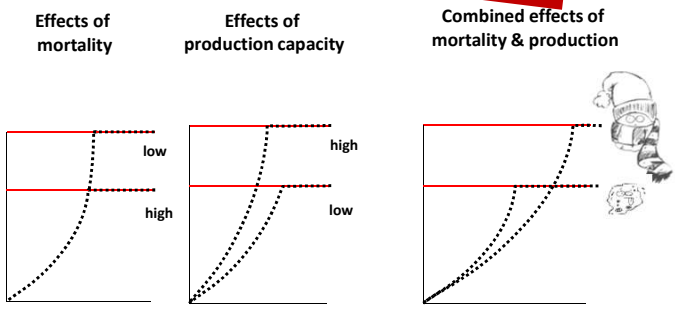
Rain intensity instead of temperature is a major driver of seasonality in tropics

A case study in Masai Mara savanna (Kenya)



How … the highest fitness?

Warm and productive tropics select for earlier maturation at smaller body size



Bergmann's rule

body size decreases when we approach tropics

white-tailed deer
Odocoileus virginianus

Bergmann's rule in endotherms

recall also from the last lecture, that humans evolved decreased body mass in tropical rain forests

Within-species level Meiri & Dayan 2003

Bergmann's rule in ectotherms

amphibians

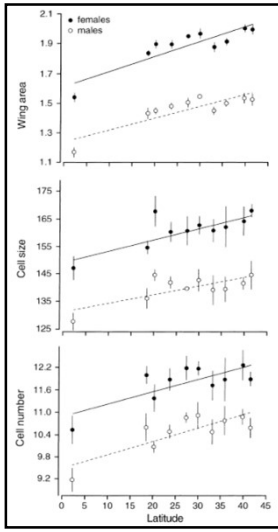
turtles

squamates

Sceloporus lizards

agreement with Bergmann's rule:
- yes
- no

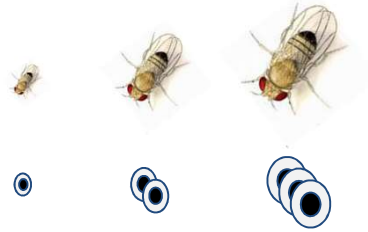
within-species level Ashton 2002, Ashton & Feldman 2003, Sears & Angilletta 2004



Drosophila melanogaster

(African tropical species)

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

Living things are life strategies with dynamic life cycles that undergo evolution: **summing up remarks**

- Tropics are especially rich in ecological interactions (including predation, competition, parasitism)
- Tropics are especially rich in arms race/the Red Queen co-evolutionary mechanisms
- Intense host-parasite interactions in tropics favour sexual modes of reproduction
- High mortality pressure in tropics favours maturation at smaller body size
- Non-seasonal tropics favour life strategies characterised by determinate growth and income breeding
- But, tropics are rarely fully non-seasonal – seasonal pulses in rain intensity
- Diverse ecological niches in tropics, e.g. differing in mortality pressure, select for contrasting life strategies – not everybody will be „as large as physiological limits allow". So, there is a lot of room for contrasting life history strategies, with either fast maturation at smaller body size, or with slow maturation at larger body size

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- Tropics are especially rich in arms race/the Red Queen co-evolutionary mechanisms
- Intense host-parasite interactions in tropics favour sexual modes of reproduction
- High mortality pressure in tropics favours maturation at smaller body size
- Non-seasonal tropics favour life strategies characterised by determinate growth and income breeding
- But, tropics are rarely fully non-seasonal – seasonal pulses in rain intensity
- Diverse ecological niches in tropics, e.g. differing in mortality pressure, select for contrasting life strategies – not everybody will be „as large as physiological limits allow". So, there is a lot of room for contrasting life history strategies, with either fast maturation at smaller body size, or with slow maturation at larger body size

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Tropical rain forest: examples of distinct life strategies

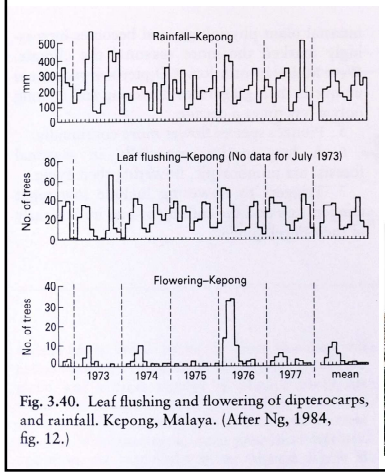


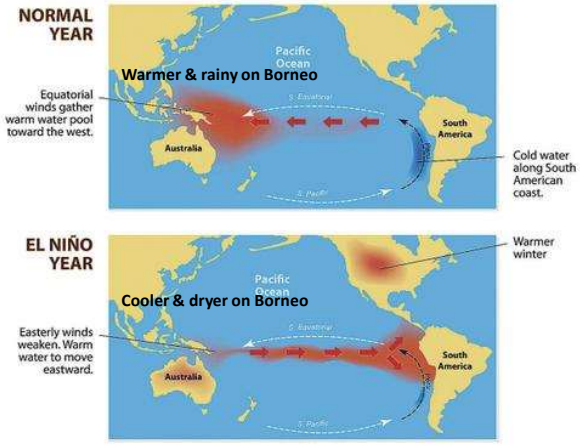
Fig. 3.40. Leaf flushing and flowering of dipterocarps, and rainfall. Kepong, Malaya. (After Ng, 1984, fig. 12.)

Discontinuous flowering, or even mass-flowering and masting (but why?)

Seasonality in precipitation (here South-East Asia) drives leaf growth and flowering of trees

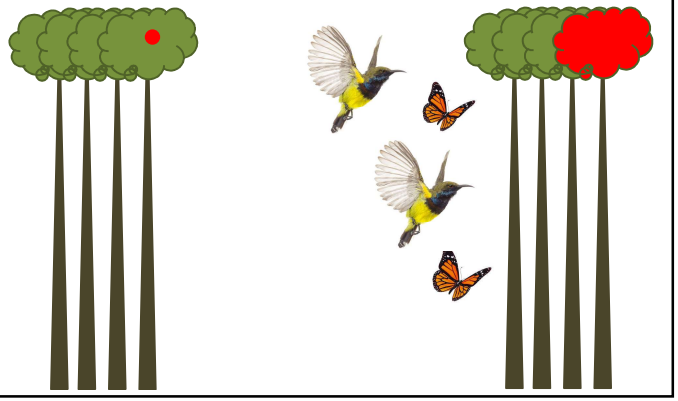
In Bornean dipterocarp tropical forest:
mass-flowering and masting is triggered by El Niño events

THE EL NIÑO PHENOMENON



Discontinuous flowering, or even mass-flowering and masting (but why?)

Capacity to attract attention of pollinators (sensory stimulation)
Pollinators look for cheap food sources (energy expenditure)



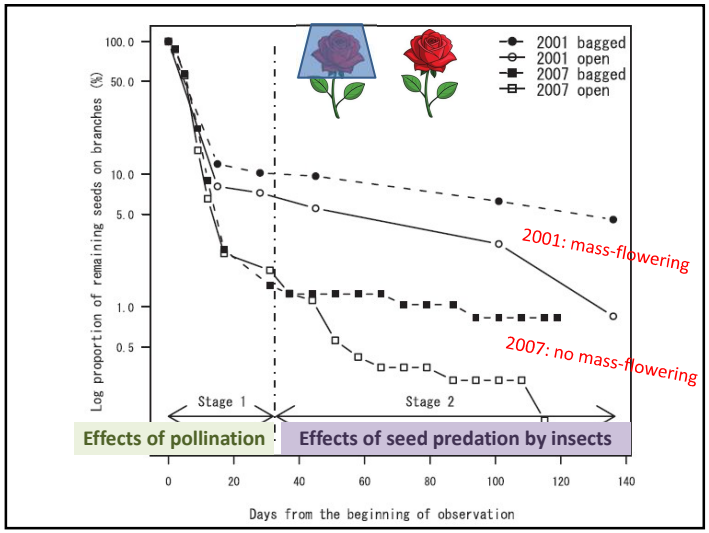
Synchronization of flowering with others in the forest
mass-flowering increases pollination success and decreases seed predation: a case example from Malaysia

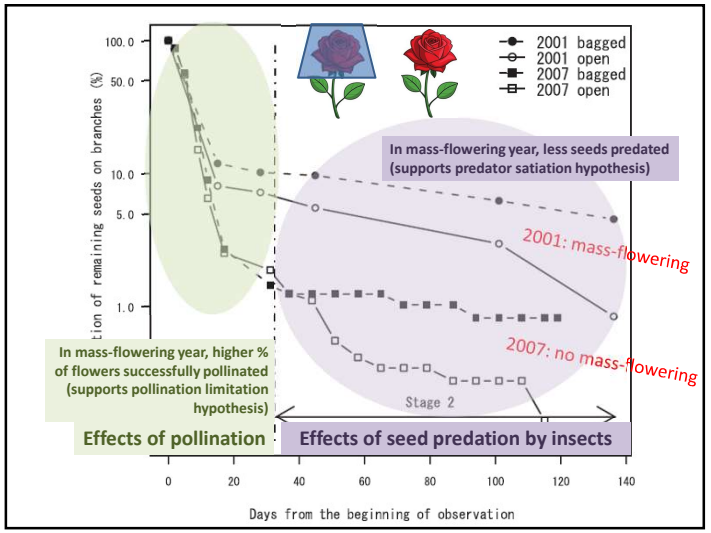
Plant Species Biology (2009) 24, 104–108 doi: 10.1111/j.1442-1984.2009.00243.x

NOTES AND COMMENTS

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

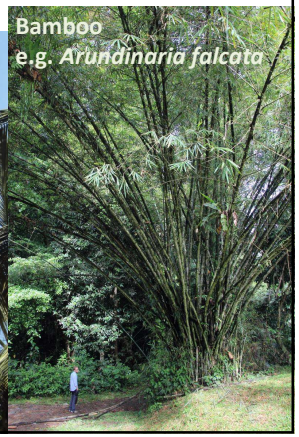
YUJI TOKUMOTO,* MICHINARI MATSUSHITA,* ICHIRO TAMAKI,* SHOKO SAKAI† and MICHIKO NAKAGAWA*
**Graduate School of Bioagricultural Sciences, Nagoya University, E1-1 (300), Chikusa, Nagoya 464-8601, Japan and †Research Institute for Humanity and Nature, Motoyama, Kamigamo, Kyoto 603-8047, Japan*



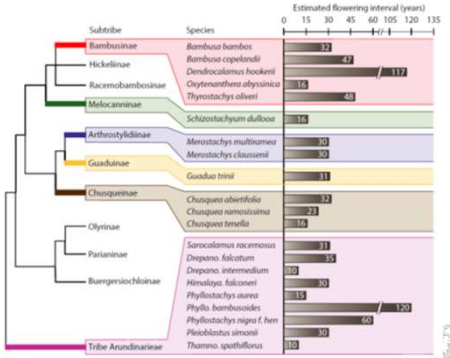


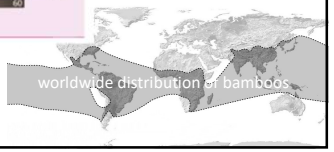
Tropical rain forest: examples of distinct life strategies

Mass-flowering can even lead to death – semelparous life strategy (monocarpy) with a single reproduction act followed by death. It occurs in many monocotyledonous tropical plants (why?)



Bamboos are long lived monocarps that mass-flower synchronously over long time intervals (record 130 years!!!)



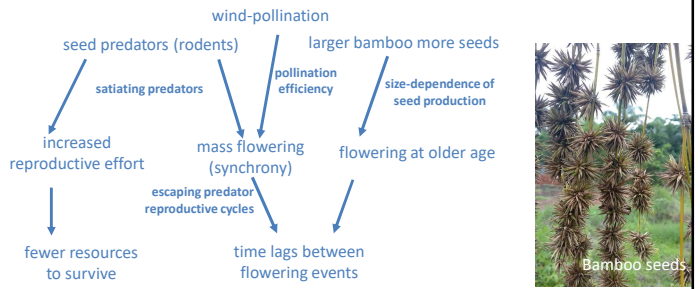


Ecology Letters, (2015) **18**: 653–659

Bamboos are long lived monocarps that mass-flower synchronously over long time intervals (record 130 years!!!)

- Seed production incerases with the size of a mother plant
- More flowers better pollination success
- Satiating predators with excess food (seeds)
- Escaping predator reproductive cycles

Flooding area with offspring and mass dying of bamboos
mass-flowering synchronously over long time intervals



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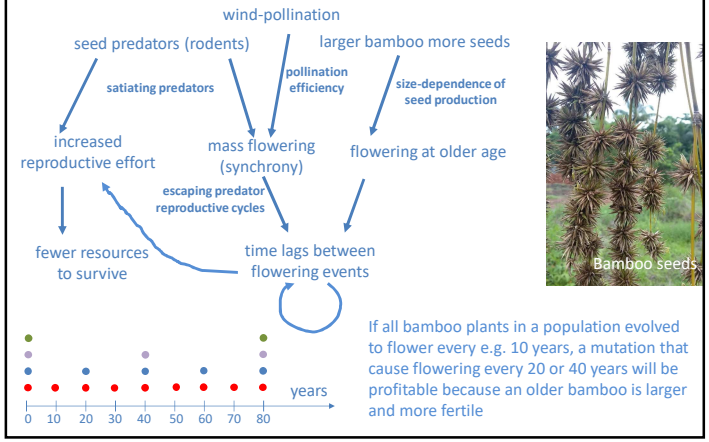
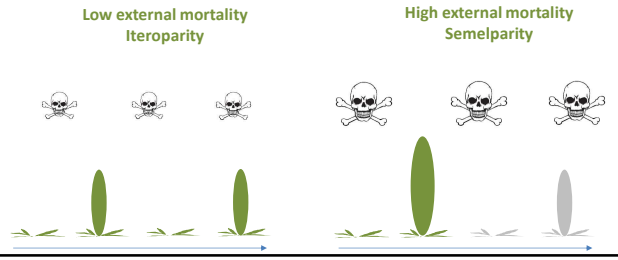


If all bamboo plants in a population evolved to flower every e.g. 10 years, a mutation that cause flowering every 20 or 40 years will be profitable because an older bamboo is larger and more fertile

Theoretical approaches to the evolution of semelparity

When **adult mortality is high**, selection does not favour securing resources for a future reproduction that is unlikely to happen

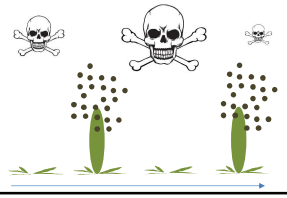


Theoretical approaches to the evolution of semelparity

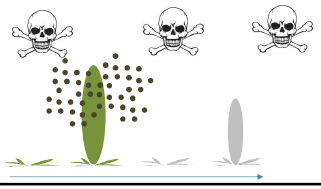
When **offspring mortality is stable through time and predictable**, selection favours semelparity, because there is no need to spread the risk through time

Old English proverb

External mortality variable & unpredictable
Iteroparity



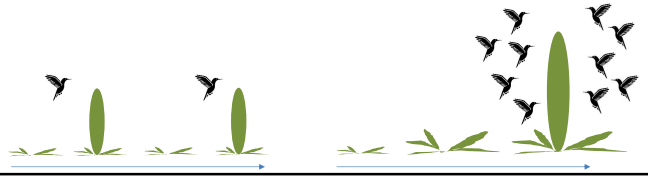
External mortality stable & predictable
Semelparity



Theoretical approaches to the evolution of semelparity

When fitness **benefits disproportionately increase with reproductive investment**

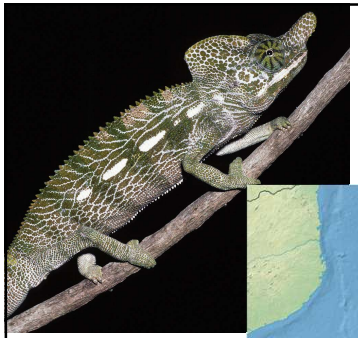
e.g., one large flower attracts much more pollinators than fewer smaller flowers



Enigmatic strategies of sympatric lobelias from the alpine zone of Mt. Kenya, East-Central Africa

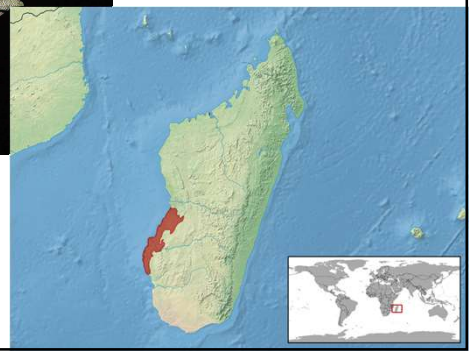
Lobelia telekii - semelparous

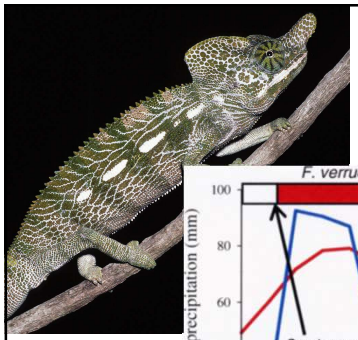
Lobelia deckenii- iteroparous



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

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





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

- rapidly-growing
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Take home thoughts

- These two examples of semelparity and their alternative counterparts indicate that often there are multiple different solutions for achieving the same „evolutionary goal" - maximization of Darwinian fitness
- This explains why life is so diverse
- Think like this
  - ✓ tropics are especially rich in ecological niches & interactions
  - ✓ for each niche, there is a wide range of alternative adaptive life history solutions, resulting in the same Darwinian fitness
  - ✓ this leads to a snow-ball effect: diversity generates diversity