The Habitat Templet

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Biol 417: Evolutionary Ecology

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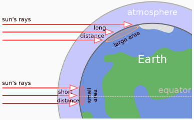
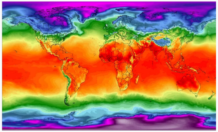
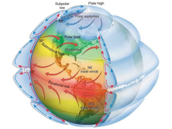
Review

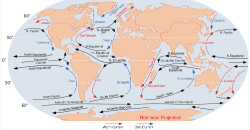
Meteorology

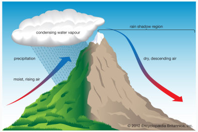
Last lecture we covered how physics, combined with the Earth's geographic structure work to govern meteorological patterns.

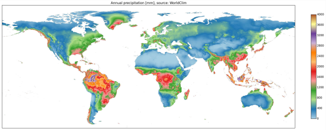






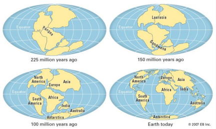






History – A Planet in Flux

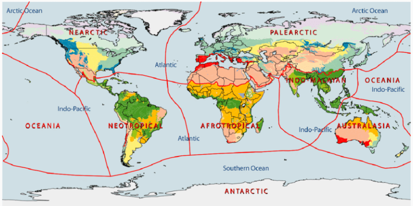
We also covered how the Earth's geographic structure is in constant flux, with new habitats being created and old ones disapearing.



Biogeography

Spatio-temporal variation in physical conditions necessitates variety among organisms from one place/time to the next and is the primary reason why there are so many species.

By dictating which strategies are effective/not in any environment, meteorology, climate, and geography govern the structures of ecosystems, a phenomenon termed ‘Biogeography’



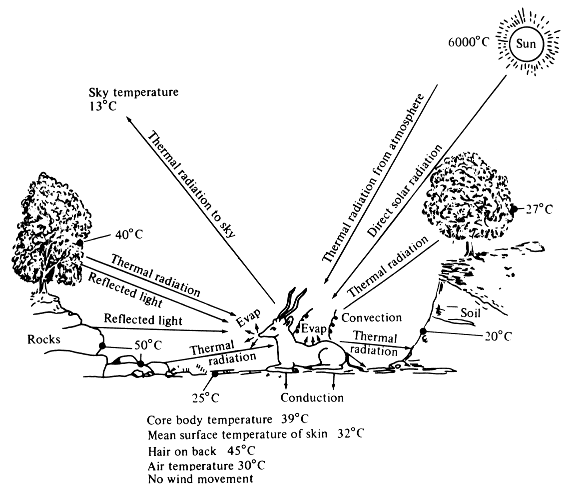
Source: WWF

Today's lecture

Today we will explore the mechanisms underlying why different environmental conditions govern which strategies are effective, and which aren't in any given ecosystem.

Heat Budgets and Thermal Ecology

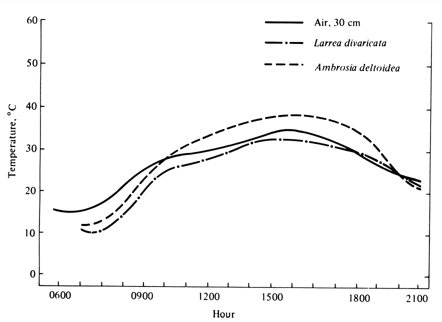
When averaged over time, heat gained by an organism must be exactly balanced by heat lost to its environment.



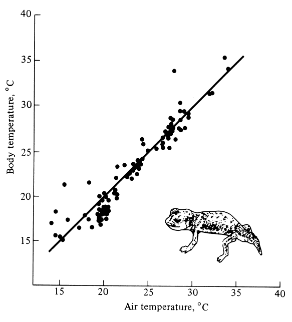
Source: Pianka (2000)

Thermoconformers

In the absence of a trend in mean temperature (local cooling or warming), an organism could balance its heat budget by being entirely passive and simply allowing its temperature to mirror that of the environment (thermoconforming/ectothermy).



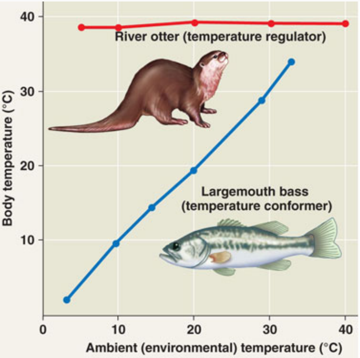
Source: Pianka (2000)

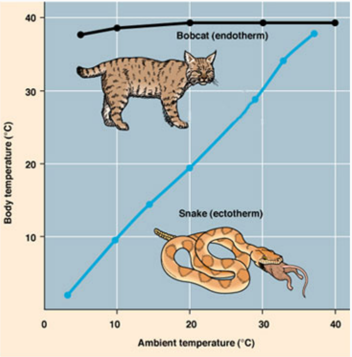


Source: Pianka (2000)

Thermoregulators

An alternative option is to maintain a constant body temperature via physiological or behavioural mechanisms (thermoregulation/ endothermy).



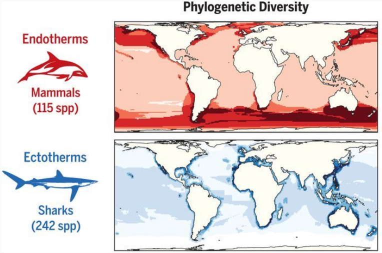


Source: Campbell *et al.* (2002)

Ectotherms don't spend energy on thermal homeostasis and so are low energy animals (1 day of food for a small bird would last a comparably sized lizard a month).

Ectothermy is effective in deserts because individuals can wait out periods of adverse conditions at low energetic costs, but is not effective in cold climates because warm periods are rare.

Meteorology thus governs patterns in the distribution of endo/ecto-thermic species



Source: Grady *et al.* (2019)

Heat dissipation

Organisms living in hot deserts must avoid overheating by being able to minimize heat loads and to dissipate heat efficiently.

Desert animals typically have large ears and tails, are nocturnal, live in burrows/caves, are migratory/wide ranging, and can estivate.

Source: National Geographic

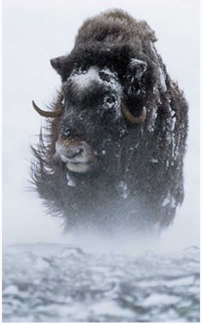
Source: Wikipedia

Heat retention

Organisms living in colder places such as at high altitudes or in polar regions must avoid overcooling.

These animals have evolved efficient means of heat retention, such as insulation by blubber, feathers, or fur, small ears and tails, large body sizes, and hibernation.

Source: Mystery science



Source: Chris Schmid

Water Economy

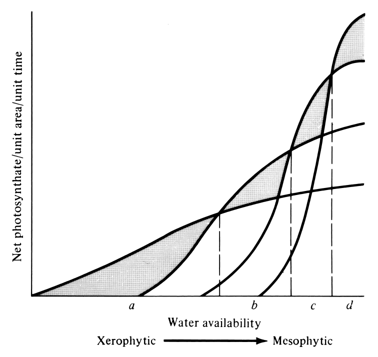
Water economy in deserts

As with heat, water in must be in balance with water out over time. Water conservation is a major challenge for desert organisms.

Source: National Geographic

H_2O sources are few and far between, and evaporative loss is high.

Water is thus a rate limiting resource in deserts.



Source: Pianka (2000)

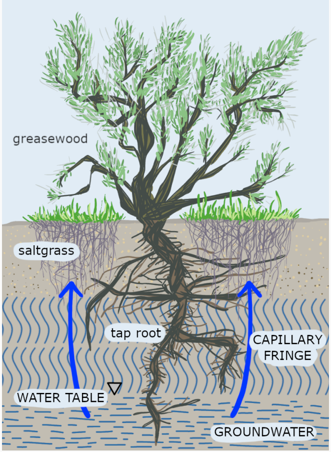
Plants and animals living in desert ecosystems have evolved physiological and behavioural adaptations to optimise water acquisition and economy.

Resource allocation

Perennial shrubs in the Great Basin desert allocate ~90% of their biomass to underground tissue (vs ~10% in mesic forests).

Source: Look Photos

Some plant species in water limited ecosystems have deep taproots that reach the water table, breaking the reliance on surface water.



Source: Nature Conservancy

Others still have evolved structures that allow them to store and protect valuable water.

Source: Gardenerdy

Behavioural adaptations

To conserve water, desert animals tend to be fossorial + nocturnal.









Other limiting resources

Other limiting resources

Numerous materials other than water or heat can be in short supply (or overabundance), including calcium, nitrogen, potassium, sodium, magnesium, chloride, etc...

Whenever key materials are limiting, behavioural or physiological adaptations to cope with these limitations are selected for.

Behaviour and physiology is thus tightly coupled with environmental conditions, which are governed primarily by physical principles.

Physiological Ecology

Physiological ecology

Physiological ecology (or ecophysiology) is the study of how organisms function, adapt, and respond to physical conditions within the environments they inhabit (mechanistic and proximate).

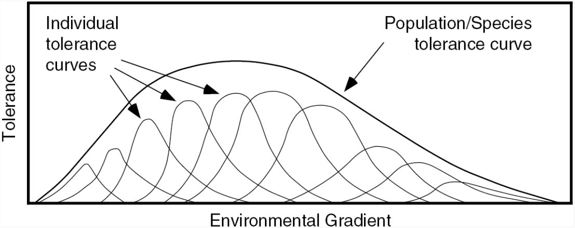
At their simplest, organisms can be viewed as input-output systems. Materials and energy are obtained by photosynthesis and foraging activities, this energy is then converted into reproduction and somatic growth.

Selection will therefore favour strategies that maximise resource acquisition **and** the conversion of resources into progeny.

Physiol. optima and tolerance curves

Physiological processes, resource acquisition, and the conversion of resources into progeny proceed at different rates under different conditions (e.g., temperature, pH, salinity, humidity, nutrient availability, etc...).

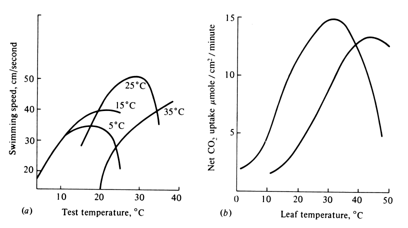
Graphs of performance vs. conditions are known as tolerance curves (Shelford, 1913).



Source: Faith & Lyman (2019)

Optima and tolerance curves cont.

Tolerance curves are typically bell shaped, their peaks represent optimal conditions, their tails represent the limits of tolerance.



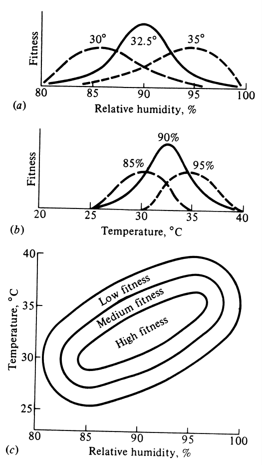
Source: Pianka (2000)

Some individuals/species have very narrow tolerance curves, others have broad tolerance curves, tolerance curves differ for env. factors (i.e., the same individual can have a broad tolerance for temperature, but a narrow range of pH tolerance).

Optima and tolerance curves cont.

Performance or tolerance is often sensitive to two or more environmental variables that can interact to influence tolerance.

This results in a multi-variate tolerance space that describes what conditions an individual/ species is expected to survive/ thrive in.



Source: Pianka (2000)

Take home message

Organisms must balance long term inputs/outputs (heat, water, energy, etc...) or risk being destabilised.

Basic physics, combined with the Earth's geographic structure work to govern the rates of input/output of different resources.

No mater where organisms live their resource budgets must be balanced, so species living in different environments have behavioural/physiological adaptations to modify input/output rates in order to survive and reproduce (static proximate).

Species are constantly tracking changing conditions (over evolutionary timescales) in order to maintain balanced budgets and optimise resource allocation and fitness (dynamic ultimate).

Next Lecture

Next lecture we will focus on how meteorological patterns and the habitat templet drive patterns of biogeography.

References

Campbell, N.A., Reece, J.B. & Mitchell, L.G. (2002). Biology.

Faith, J.T. & Lyman, R.L. (2019). *Fundamentals of Ecology and Biogeography*, Cambridge University Press, pp. 12–47.

Grady, J.M., Maitner, B.S., Winter, A.S., Kaschner, K., Tittensor, D.P., Record, S., Smith, F.A., Wilson, A.M., Dell, A.I., Zarnetske, P.L. *et al.* (2019). Metabolic asymmetry and the global diversity of marine predators. *Science*, 363.

Pianka, E.R. (2000). *Evolutionary Ecology*. 6th edn. Benjamin/Cummings, San Francisco.

Shelford, V.E. (1913). *Animal Communities in Temperate America: As Illustrated in the Chicago Region; a Study in Animal Ecology*. 5. Geographic Society of Chicago.

Pianka, E. (2000). Evolutionary Ecology, Chapter 5.