# (3) Environment, evolution and animal adaptation

# Environment as a directional force of evolution.

# Major constraints to animal life.

# Large environmental variations (temporal and spatial variations).

ENVIRONMENT, EVOLUTION AND ADAPTATION

* Talk about the ENVIRONMENT and the constraints it imposes on animal life;
* How these constraints lead to the EVOLUTION of species and, consequently, adaptation;
* The myth that animals are optimally adapted to the environment;
* Speak about the universe of very diverse of adaptations.

ENVIRONMENT AS A DIRECTIONAL FORCE FOR THE EVOLUTION OF ANIMALS

The environment conditions the evolution of organisms at a morphological, physiological, behavioral level, and also the evolution of communities.

This is because the environment forces animals to adapt.

But adapt to what? Review concept of niche. Includes space and function of the species in the ecosystem. Niche occupied (set of biotic and abiotic characteristics in which the species lives) and niche played (role that the species plays in an ecosystem).

Environment acts through natural selection. Environment sets a challenge that evolution, through natural selection, resolves, resulting in adaptation.

*Figure*

In a hypothetical situation of an animal that feeds on a gradient of prey sizes:

When the number of large prey decreases (*e.g.* human hunting) and they have to hunt smaller prey, the adaptive peak changes and there will be a selection of individuals more adapted to hunt small prey.

Adaptation can be defined as the set of characteristics of an organism that make it better suited for a certain environment.

Adaptation can be morphological (e.g. run more) but also behavioural, physiological (e.g. digest harder bones), ecological...

**Are animals optimally adapted to the environment in which they live?**

 (Important issue to understand animal ecology)

Actual niche and potential niche. One always chasing the other...

A mismatch between environmental conditions and adaptation can result in ecological dysfunctions that are difficult to explain… Many times the ecology of a species is the result not of current conditions but of those to which it has been subject throughout its evolutionary history.

**Conclusion 1: Animals are never truly adapted, because in the evolutionary time scale the environment is always changing.**

If change is rapid, animals may become extinct. For example, the Iberian lynx has been on the verge of extinction mainly because it has not been able to adapt to the reality created by the impact of new diseases on the rabbit (myxomatosis and viral hemorrhagic disease)…

**+Nature of environmental pressure is quite variable. Environmental pressure can be divided into 3 types:**

**Directional** (in rapidly changing environment) - phenotype changes. If environment changes quickly, species become “late”=misfits. If it changes too quickly, species can become extinct.

**Stabilizing** (in +- constant environment) - constant phenotype. If environment changes...

**Diversifying** (in mosaic environment) - various phenotypes. This type of pressure can also cause maladaptations... Let's see how:

Role of gene flows – counteracts local adaptations. If flow is greater than local adaptive advantage species is not locally adapt.

Limited flow can result in geographic gradients. *E.g.* hares ears. Flow prevents ears from evolving to the optimal size for each region…

**Conclusion 2: Animals may not be optimally adapted to the local conditions, because gene flow prevents this adaptation**

Another question related to this topic...

**Are all animal characteristics subject to environmental pressure?**

Only features relevant to the environment are subject to pressure. The rest may not change or be subject to random changes.

There are many animals with vestiges of adaptations to past realities… Not always easy to identify…

**Conclusion 3: Not all animal characteristics correspond to adaptation to the environment in which they live.**

**Not only it is frequent that animals are not optimally adapted to the environment in which they live, but also not all animal characteristics correspond to adaptation to that environment.**

*In short: We must not assume that ecosystems work in complete balance, and that they are made up of species perfectly adapted to each other and the environment... Often animals are not optimally adapted to the environment in which they live, and often some animal characteristics do not correspond to adaptation to that environment.*

*The Biosphere is actually a huge adaptation game, involving millions of species and environmental variables, in which the environment is always changing. The objective of the game is to survive the changes, who are always creating new challenges and relentlessly eliminate species that do not adapt. Or those that adapt worse… The process is slow, but it doesn’t stop…*

ENVIRONMENT:

BIG CONSTRAINTS TO ANIMAL LIFE.

Let's remember what are the minimum conditions for life: availability of:

(1) **water** - the necessary medium for vital processes

(2) **energy** - to make organisms work

(3) **chemical nutrients** - (carbon, nitrogen, oxygen), which form the substances of life.

Environment varies enormously, largely depending on the availability of these basic elements for life…

This environmental variability is the cause of the great diversity of animal life forms.

Two major types of environmental variations: (1) **temporal variations** and (2) **spatial variations**.

**How do animals respond to temporal changes of the environment?**

Two types of time variations:

(1) Regular variations

(2) Irregular variations

**Regular variations**

*How do animals respond to these predictable variations? i.e. what adaptations have evolved to adapt to them?*

(1) Migrations at various scales

- **Local**

- **Regional**

- **Continental**

- **Oceanic**

(2) Hibernation and aestivation

- Spend unfavorable period in lethargy. It involves important physiological adaptations, but the advantages are so great that it arises independently in many animal groups.

(3) Make food reserves.

(4) Seasonal morphological changes.

(5) Complex life cycles. Example:

**Irregular variations**

*How do animals respond to these unpredictable variations? Examples of adaptations:*

(Example 1) Dispersal capacity. Unpredictable environmental conditions can lead to local extinction but good dispersal ability allows restocking from other areas.

xO O O O Ox O O O O

  O xO O O xO

O O xO Ox        Ox

*Cyprinodon* forms metapopulations – Remember what metapopulations are? Fragmented populations where dispersal has to compensate for extinction

Natural selection selects genotypes with greater dispersal power, i.e. with huge offspring.

**Cost of dispersal is huge, but adaptive value, in response to unpredictable changes in the environment, too!**

(Example 2) Maintenance of genetic diversity to respond to potential changes in the environment.

(Example 3) Defend excessive resources (for a normal year). *E.g*. some territorial animals that defend territories with too many resources.

(Example 4) Environmentally controlled polymorphisms.

Example: Migratory locusts

Signal that determines direction of development – ​​density…

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Another example of environmentally controlled polymorphism:

Insects of genus *Gerrys* (water striders) in temperate regions of the North - Example of adaptation to changes in the environment, in some cases regular, in others irregular.

There are species with wings and others without wings or with very short wings. What accounts for this variability?

Isn't it always better to have wings? What is the **advantage of not having wings**? Save energy, allowing greater investment in reproduction.

Species that live in **ephemeral lakes** **should have wings**? Yes, so they can disperse when the lake dries up or freeze. Dispersal capacity is important adaptation to temporal variations of the environment

Should species living in **permanent lakes have wings?** No. You don't need to disperse so much...

But there are more complex situations, requiring more complex adaptive responses. E.g.:

Species that live in **Persistent but unpredictable lakes** - there are individuals with short wings and others with long wings. Dimorphism genetically determined.

In cold regions species that live in **seasonal lakes (water freezes), should they have wings?** They have 2 annual generations. Generation that is born in spring has no wings. Generation that is born at the end of summer has wings, disperses to forest areas where they remain in winter. Solution that optimizes the adaptation to each season…

**How can two seasonally distinct forms coexist?** Keeping development flexible, developing in the most appropriate way for the circumstances.

**How do animals know which form is most appropriate?** Receiving information from the environment (in this case ambient temperature or photoperiod).

Therefore, water striders have several strategies for adapting to the changing environment:

1. Polymorphism (wings and wingless, unpredictable lakes)
2. Seasonal dimorphism (through flexible development maintenance)

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**How do animals respond to spatial changes of the environment?**

They explain the large patterns of distribution of animals and are co-responsible for the great diversity of life forms. Let's talk about 3 major spatial variations:

1. Air *vs* water
2. Climate
3. Other organisms

1. **Water vs Air**

Most important of the variations (contrasts): water vs. air. There are physical factors that make life in these two environments very different. Which?

(1) Water is about 800x denser than air.

(2) Water is about 50 times more viscous than air.

(3) Water has 30x less oxygen.

(4) Light fades very quickly in water.

(5) In the water... There is a lot of water...

(6) Thermal properties of air and water are very different. Specific heat of air 500x less than that of water, (it has less thermal inertia).

1. **Climate**

Huge climate variety (in terms of climate elements - temperature, dryness, winds, etc…)

Different species occur in climatically different areas, depending on the adaptations they have evolved.

Not all animal groups have evolved capabilities to adapt to certain situations, which in some cases limits their current distribution… Examples:

* Mammals without the ability to hibernate may not be able to live in cold climates
* Birds unable to migrate may not be able to nest in cold climates
* Species without cooling systems cannot live in hot climates

But could they not easily evolve these abilities to adapt and colonize cold climates?

Not always…

Niche conservatism theory – It postulates that animals are geographically limited because they are “prisoners” of the fundamental, climatic , niche in which their ancestors evolved.

Animal groups that evolved in the tropics and then radiated have difficulty adapting to temperate climates/regions. Why?

The ancestral species may have lost (or never had) adaptations necessary for hibernating or migrating (which were not important in the tropical climate).

The species that descend from it will not have these adaptations either, so they are restricted to tropical climates. It is assumed that this explains the greater diversity of species in tropical regions, since most animal groups are of tropical origin.

Thus animal species and groups may be geographically limited **not only by the current climate, but also by the climates in which their ancestors evolved**…

Niche conservatism increases the importance of climate in determining the distribution of animals…

1. **Other organisms**

Plants

Competitors

predators

Parasites (*e.g.* the tsetse fly *Glossina*)