PBIO-141
Sensory and Physiological Ecology of Plants

2: Terminology and viewpoint

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January–February 2022

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Outline

About the course

General system theory

Hierarchy and scale

A video for discussion

About the course

Learning objectives (in brief)

Are that at the end of this course:

- Learn the language of sensory and physiological ecology of plants.
- Learn the basic ”workings” of plants and how they have adapted and how they can acclimate to environment.
- Learn concepts and a way of looking at plants based on the current scientific ideas.
- Learn how to find answers to questions about acclimation and adaptation of plants through experiments.
- Learn how to find, interpret and use information to solve problems and answer questions related to plant ecology.
- However, you will **not** have to memorize detailed information that is available in books, journals or the internet.

Contents of the course

More details available in Moodle. All the points listed below are discussed emphasising acclimation and adaptation.

- Introduction
- The shared environment of plants
- Sensory biology
- Adaptation and acclimation of carbon and energy metabolism
- Adaptation and acclimation of water uptake and loss
- Adaptation and acclimation to mineral nutrient supply
- Adaption and acclimation of morphology and anatomy
- Plasticity in a changing or artificial habitat

Understanding vs. memorization

Teaching and learning

- The role of examples (in this course and elsewhere) is to make a concept tangible…
- …easier to grasp than a purely abstract idea.
- When studying focus on the concepts…
- …once you grasp a concept, or learn the idea…
- …you will be able to find or make up another suitable example when needed.

Examples

- I will use examples from both wild species and cultivated species. Mostly higher plants from terrestrial environments.
- In recent years physiological research has made frequent use of *Arabidopsis thaliana*.
- *Arabidopsis thaliana* is a useful model, but the variation in the plant kingdom is enormous: in size, shape, function, growth rate, and lifespan.
- This variation is the result, at least in part, of variation in past and current growth environments.
- Natural selection is constrained by evolutionary history.
- Random events also play a role, especially in small populations.

General system theory

Basic concepts

- Similar structures and properties are present in all systems.
- Possible behaviour is determined by the structure of a "whole thing".
- The structure emerges from the interactions among its "component parts".
- If interactions exist, then the contribution of the parts to the behaviour of the "whole" depends on the nature of interactions.
- Behaviour of a complex whole cannot be predicted from the behaviour of the parts.
- "Emergent properties" appear as a result of the interactions.

Basic concepts

- Systems can be nested in other systems.
- Thus a hierarchy appears.
- A crucial concept is feedback, which can be positive or negative.
- *Thinking in systems* is applicable to engineering, computing, human society, business administration, biology, ecology, medicine, etc.
- Even to managing everyday life by an individual.
- At its simplest, *Thinking in systems* .can be defined as being aware of the "big picture".

Hierarchy and scale

What is hierarchy? 5 + 5 min

Hierarchies in biology

- Think examples of the application of the concept of *hierarchy* in biology.

Hierarchy I

The term *hierarchy* is frequently used in an intuitive way, but Allen and Starr (1982) have developed a theory, mainly focused on ecological systems.

> *By hierarchy we understand a system of behaviour relationships where upper levels limit and control the lower levels in a greater or smaller measure depending on the* ***time constants*** *of their behaviour.*

Hierarchy II

- Where *time constant* of a response is the length of time between when a response to a stimulus starts to be observable until it reaches a certain level close to the maximum that the given stimulus will induce. It is a measure of the speed of change of a response to an instantaneous stimulus.
- In contrast *lag* is the delay between the application of the stimulus and the start of an observable response.

Hierarchy III

The degree of control, that is the asymmetry of the relationship, depends on the time constants of the behaviour.

> When we study the mechanism of a system at one level, we can ignore what changes much more slowly (has a larger time constant).

examples?

Hierarchy IV: examples

- For example if we study the evolution of plants on Earth we can ignore the big bang and the expansion of the universe (and many other things).
- If we are interested *only* (narrowly?) in the response of photosynthesis to light in Arabidopsis, we can ignore the evolution of plant species.
- If we are interested only in the primary reactions of photosynthesis we can use in our experiments isolated chloroplasts and ignore the plant.

Levels of organization

An example of a hierarchy is the hierarchy of levels of organization

Ecosystem $\rightarrow$
Community $\rightarrow$
Population $\rightarrow$
Individual $\rightarrow$
Organ $\rightarrow$
Tissue $\rightarrow$
Cell $\rightarrow$
Organelle $\rightarrow$
Molecule $\rightarrow$
Atom $\rightarrow$
Subatomic particle

Scale

Temporal scale Fast physiological responses, acclimation, and adaptation happen at different temporal scales. The processes involved are different.

Spatial scale For example when studying transpiration, we can do it at different scales: the leaf, the tree crown, the forest, etc. The main controlling environmental variables may be different.

Mechanism and ‘reason’ (=justification)

- *Upward and downward causation* in biology.
- We achieve a *mechanistic explanation* for an observed phenomenon by studying the levels below. e.g. We study whole plant growth in two different habitats. We build a mechanistic explanation from the growth and responses of individual organs: leaves, stems, roots.
- We build a *narrative explanation* for the phenomenon by looking at the levels above. e.g. In this example we find a reason or justification for the differences based on natural selection, but we do not study the evolutionary process itself.
- Of course we can set the focus at any level in the hierarchy and what is mechanism or narrative explanation will move along. examples?

A video for discussion

Talk by Ariel Novoplansky 🎞

Observation without preconceptions plus theory are important when developing new hypotheses...

🎞 (15 min) https://youtu.be/aClSp71zfro

Next steps

- By now I expect you and me to share enough of a language and frame of mind to discuss without misunderstandings.
- If some ideas remain unclear, do ask at any time.
- If we had enough time we have watched the video of the TEDx talk by Prof. Ariel Novoplansky, but if not please watch it at home. Discuss about it in the corresponding Moodle forum. Remember that discussion can include what implications the phenomena described may have in a question of your own interest, how watching the talk may have changed your views about plants, questions about something that you did not understand, or something that you would like to criticize.

References

References

- Allen, T. F. H. and T. B. Starr (1982). *Hierarchy. Perspectives for Ecological Complexity*. Chicago: The University of Chicago Press, p. 310.
- Ballaré, C. L. and A. J. Trewavas (2009). "Plant behaviour special issue.". In: *Plant Cell and Environment* 32.6, p. 605. DOI: 10.1111/j.1365-3040.2009.01974.x.
- Falik, O., Y. Mordoch, D. Ben-Natan, M. Vanunu, O. Goldstein, and A. Novoplansky (2012). "Plant responsiveness to root-root communication of stress cues.". In: *Annals of botany* 110.2, pp. 271–280. DOI: 10.1093/aob/mcs045.

References ii

Falik, O., Y. Mordoch, L. Quansah, A. Fait, and A. Novoplansky (2011). "Rumor Has It...: Relay Communication of Stress Cues in Plants". In: *PLoS ONE* 6.11, e23625. DOI: 10.1371/journal.pone.0023625. URL: http://dx.doi.org/10.1371%2Fjournal.pone.0023625.

Jones, R., R. Hämäläinen, and E. Saarinen (2015). *Being Better Better: Living with Systems Intelligence*. CreateSpace Independent Publishing Platform. ISBN: 9781507866207. URL: https://books.google.fi/books?id=RbThsgEACAAJ.

Meadows, D. (2008). *Thinking in systems: a primer*. White River Junction, Vt: Chelsea Green Pub. ISBN: 1603580557.

Novoplansky, A., O. Falik, S. Mauda, and L. Kersting (Apr. 2021). "The ecological implications of interplant drought cuing". In: *Research Square*. [Preprint]. DOI: 10.21203/rs.3.rs-402580/v1.