PBIO-141
Sensory and Physiological Ecology of Plants

3: Signals, cues, information and evolution

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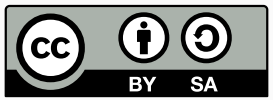

Outline

Hierarchy and scale

Controversies in plant sensory biology

A different controversy

Experiments and surveys

Practical = experiment

A video for discussion

Hierarchy and scale

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?

Cause and effect in Biology 10 + 5 min

$\rightarrow$ *fitness* $\rightarrow$ genome $\rightarrow$ epigenome $\rightarrow$ phenome $\rightarrow$ *fitness* $\rightarrow \cdots$

- Which transitions, shown as $\rightarrow$, depend directly on the environment?
- "Evolution determines physiology" or "Physiology determines fitness"?
- The course of evolution is not the result of natural selection alone!

Multiple viewpoints are possible, and not necessarily contradictory!

Cause and effect in Biology 10 + 5 min

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Controversies in plant sensory biology

Recent controversial concepts in plant biology

- Plant communication $\rightarrow$ Widely accepted
- Plant behaviour $\rightarrow$ Mild controversy
- Plant intelligence $\rightarrow$ Strong controversy
- Plant consciousness $\rightarrow$ Widely rejected
- Plant neurobiology $\rightarrow$ Widely rejected

A problem of terminology

- Plant communication $\rightarrow$ meaning is clear
- Plant behaviour $\rightarrow$ meaning is fuzzy
- Plant intelligence $\rightarrow$ meaning is obscure
- Plant consciousness $\rightarrow$ meaning is opaque
- Plant neurobiology $\rightarrow$ meaning is contradictory

A problem of experimental evidence

- Plant communication → strong evidence
- Plant behaviour → strong evidence
- Plant intelligence → depends on definition
- Plant consciousness → known unknowable (?)
- Plant neurobiology → no evidence of function

Some publications

"On the importance of information-acquiring systems in plant-plant interactions" Aphalo and Ballaré 1995
Plant Behaviour and Intelligence Trewavas 2014
"Plants Neither Possess nor Require Consciousness" Taiz et al. 2019
"Explaining preemptive acclimation by linking information to plant phenotype" Aphalo and Sadras 2021

A different controversy

The need for context awareness

- *I exclude here the controversy about GMO themselves.*
- Genetic manipulation has worked for breeding simple traits $\rightarrow$ no controversy
- Genetic manipulation has worked for complex traits $\rightarrow$ strong controversy
- To an agronomist producing a GMO crop genotype with more efficient photosynthetic metabolism is a success only if it results *in a cultivar with improved performance in farms*.
- That some molecular biologists consider/"sell" such a result on photosynthesis as a breakthrough towards ending famine or some similar major goal can deeply upset most agronomists…

What is the evidence

- Genetic manipulation has worked for breeding simple traits $\rightarrow$ strong evidence
- Genetic manipulation has worked for complex traits $\rightarrow$ one or two isolated “special cases” out of very many attempts
- In my view the problem is not in GM as a method, it is in not understanding that improvement in a trait like photosynthesis rate is almost never directly reflected in yield
- An organism is like a choir, if a single singer starts singing louder than others, it makes the performance of the choir worse rather than better, unless the singer is a solist…

Some publications

"Improving Photosynthetic Efficiency for Greater Yield" Zhu et al. 2010
Darwinian agriculture: how understanding evolution can improve agriculture Denison 2012
"Improving photosynthesis" Evans 2013
"Making science more effective for agriculture" Sadras et al. 2021
"Translational research in agriculture. Can we do it better?" Passioura 2020
"Increasing Photosynthesis: Unlikely Solution For World Food Problem" Sinclair et al. 2019

Experiments and surveys

Types of experiments (refresher)

Manipulative experiments. With manipulative experiments it is possible to *directly* demonstrate cause-effect relationships.

Observational experiments. When manipulative experiments are not possible, direct demonstration of cause-effect relationships can be very difficult.

Impossible experiments. In many situations manipulative experiments are physically or ethically impossible to carry out.

Simulations. When we do experiments with models instead of the real system we call them simulations.

examples?

Experiments and causality

- Demonstration of causes. In manipulative experiments we (attempt to) keep everything equal among treatments except for the experimental variable whose effect we want to test.
- In observational studies we cannot be sure of which things are different among the different situations ("treatments"), so we can make guesses about causes, but can seldom directly demonstrate them.
- In observational studies we can use path analysis to indirectly strengthen the evidence for causation (we add an additional dimension, usually time).
- examples?

Practical = experiment

Some ideas of treatments to test

1. Pulsed/fluctuating light vs continuous
2. Light of different colours (visible ones)
3. Light of different “colours” (ultraviolet)
4. Different temperatures or air humidity
5. Different daylengths

Some ideas of measurements

1. Water use (weighing)
2. Temperature of leaves
3. Growth
4. Stomatal conductance
5. Pigments (Dualex)

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.

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