# Can plants predict the future?

## How and why?

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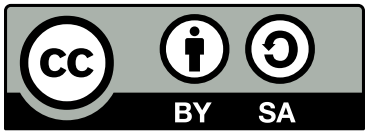

# Outline

# Physiology and molecular biology studies

## Evolutionary viewpoint frequently missing

- Looking at the sensory abilities of organisms from an evolutionary and fitness perspective should be nothing new for today's audience.
- In the case of plants this approach has been rarely used...
- ...based on the assumption that sensory capabilities and specially information processing are very limited in plants.
- Now we know that this assumption does not hold.

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# Plants' "senses"

## What can plants perceive

- Light amount ('moonlight' to full sun).
- Light wavelength (270 nm to $\approx$ 800 nm).
- Light direction.
- Temperature.
- Gravity.
- Mechanical stimulus.
- Chemoperception (volatiles in the atmosphere, solutes in the soil).
- Magnetic fields (?).
- Electric fields (?).
- Sounds and mechanical vibration (?).

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# Plant-plant "communication"

## Emission of informational signals

- Volatiles to the atmosphere:
  - These are sophisticated cocktails that carry information about the species of pathogen or herbivore attacking the emitter
  - These signals are 'used' by neighbouring plants, but also in the case of herbivores, attract the predators of the herbivores.
- Chemicals to the soil as warning signals (?) and territorial marks (????).
- Information transfer from plant to plant with mycorrhizal fungi as middlemen (??).
- Light signals (reflection) to deceive neighbours (???), but also attract pollinators.

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# Within plant "communication"

## Coordination

- Plants have a modular architecture.
  - Each "module" is to some extent autonomous but exchanges information with the rest of the plant.
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# Plants' "intelligence"

## Information processing

- Detection of timing of events (based on circadian clock).
- Detection of spatial and temporal gradients.
- Ability to combine information from several sources, leading to different outcomes.
  - positive and negative interactions.
  - responses dependent on ratios.
  - responses dependent on temporal sequence of signals.
- Plants store information for different lengths of time:
  - from minutes to a fraction within their lifetime.
  - maternal effects such trans-generational epigenetic inheritance.

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# Forecasting

## Is it a useful concept in relation to fitness?

- We depend on informally forecasting all sorts of events every minute while awake.
- Sometimes we do this consciously, but most of the time we are not aware of what our brain is doing.
- We use forecasts at very different time scales and to many different ends.
- If we use the abstraction of information, and for a moment forget about how its processing is implemented. . .
- . . . it is easy to imagine that every organism must have evolved the capacity to "forecast" future events important for fitness.
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# Can plants forecast the future?

## Preemptive acclimation

- Several plant responses can be only explained from the evolutive/fitness point of view as being a 'preparation' to tolerate or escape future stress events or take advantage of future favourable conditions.
  - Preemptive shade avoidance as a response to reflected far-red light from neighbouring plants.
  - Possibly (a hypothesis we are studying) preemptive acclimation to future soil drying in response to high ultraviolet-B irradiance.
  - Eavesdropping-on/communicating-with neighbours to preemptively acclimate/prepare for drought, herbivore attacks, even to synchronize flowering among individuals.

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2. Well developed discipline for animals
3. Less developed for plants
4. Why?
5. . . . plants' behaviour is not easy for humans to observe (slow. . . )
6. . . . intellectually we find the idea of brainless organisms *solving problems* and *assessing risks* alien
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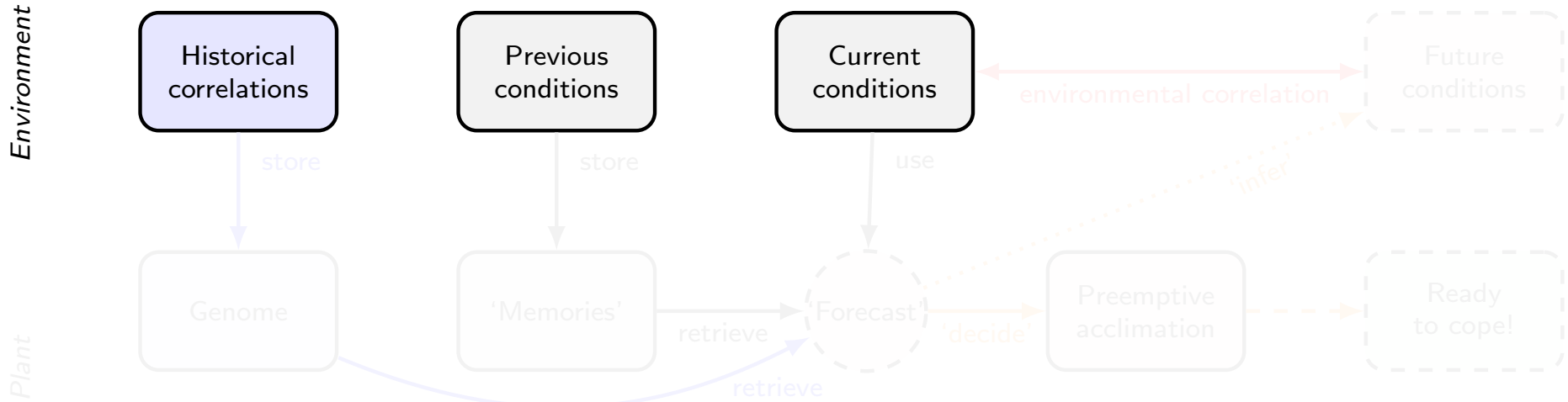
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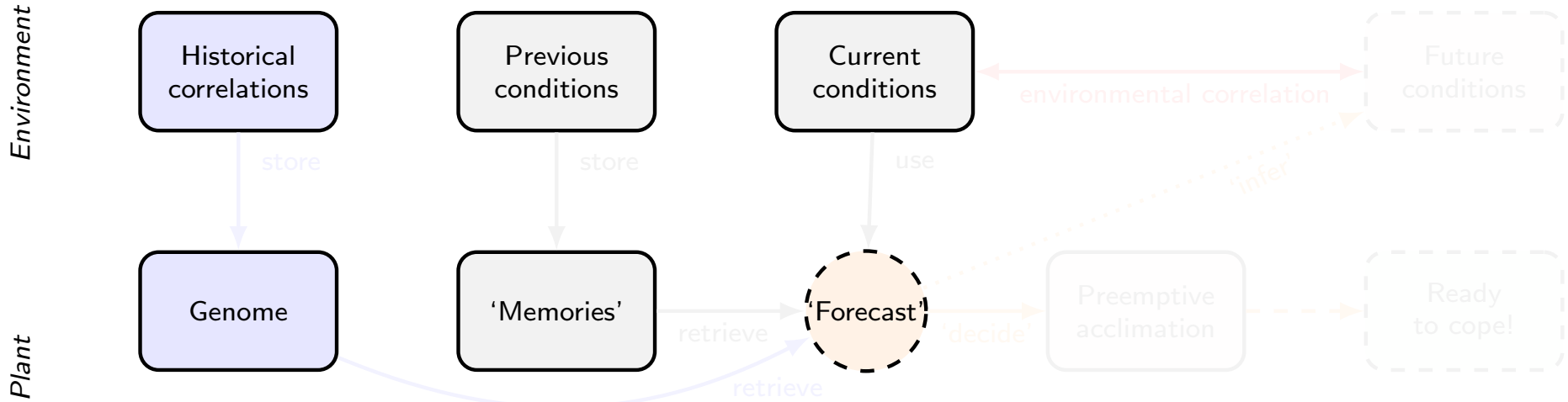
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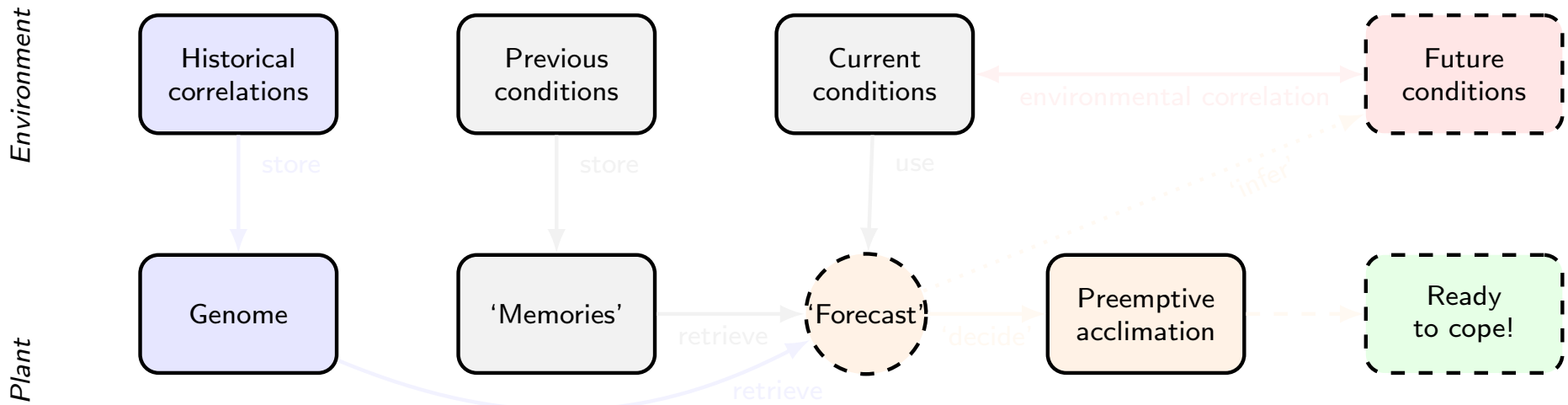
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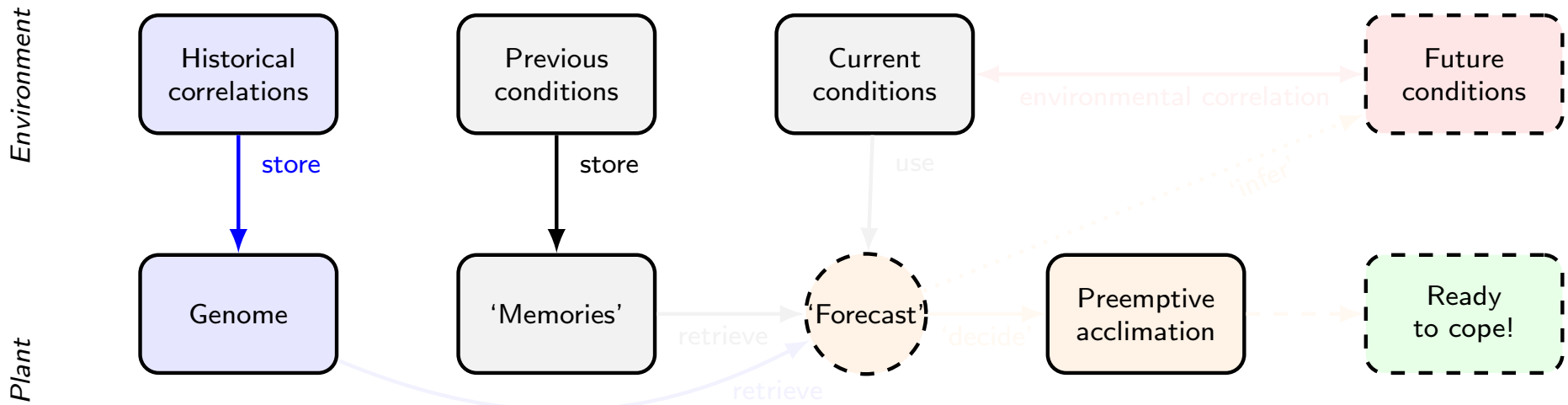
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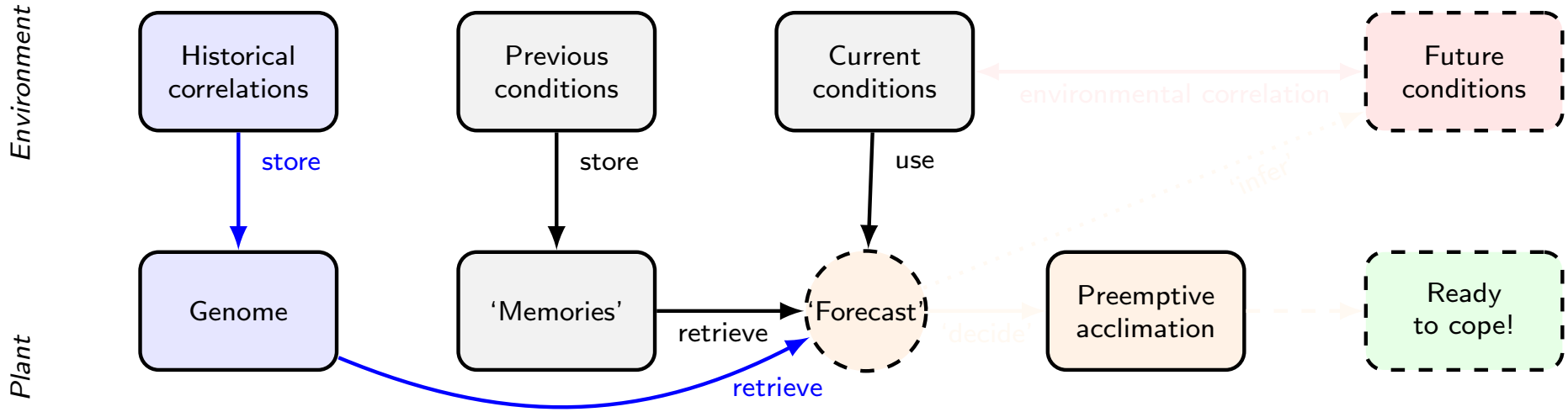
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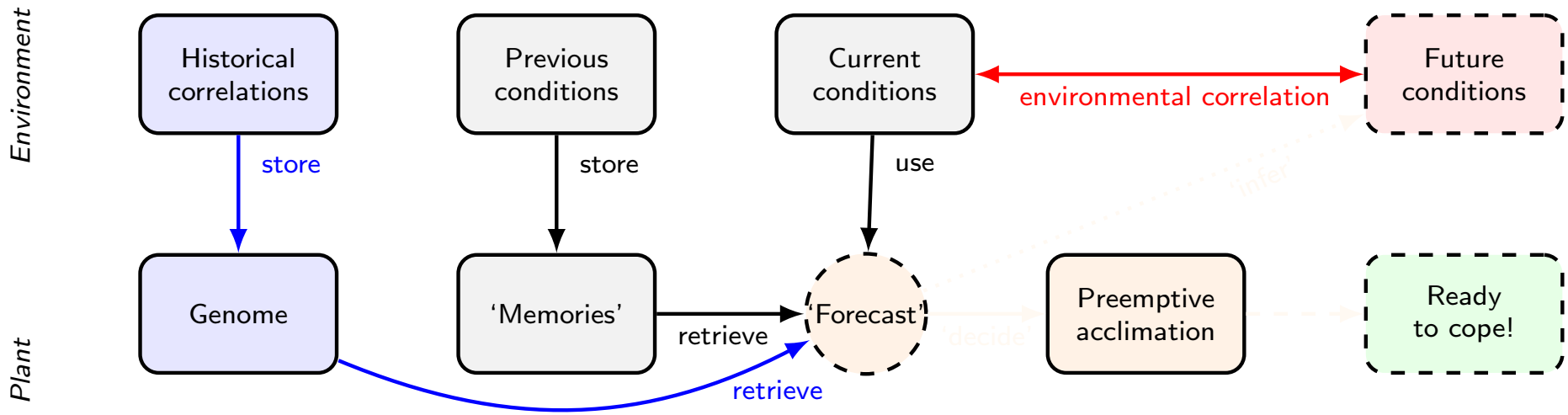
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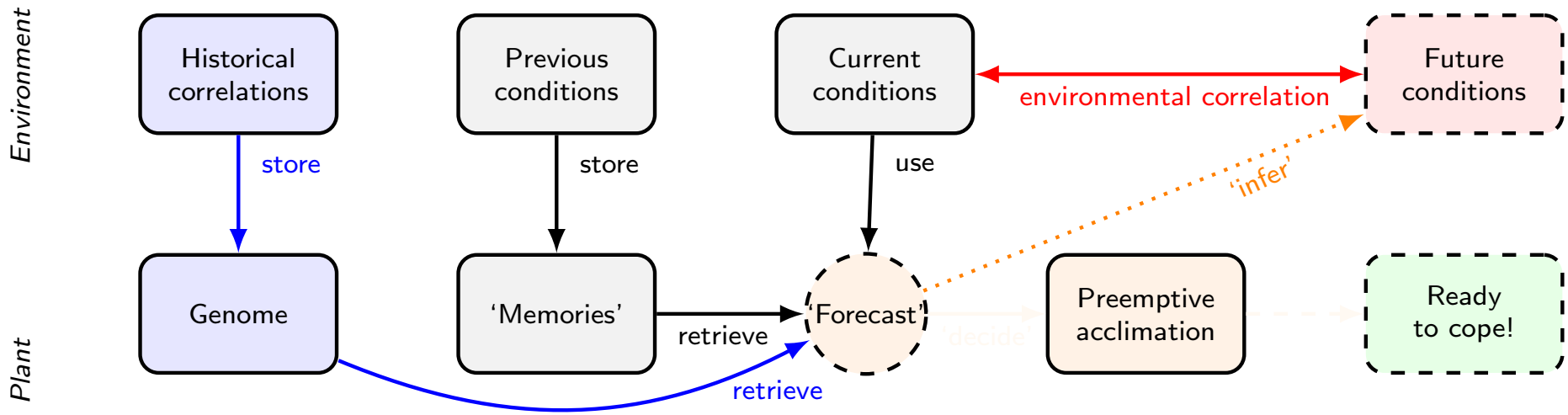
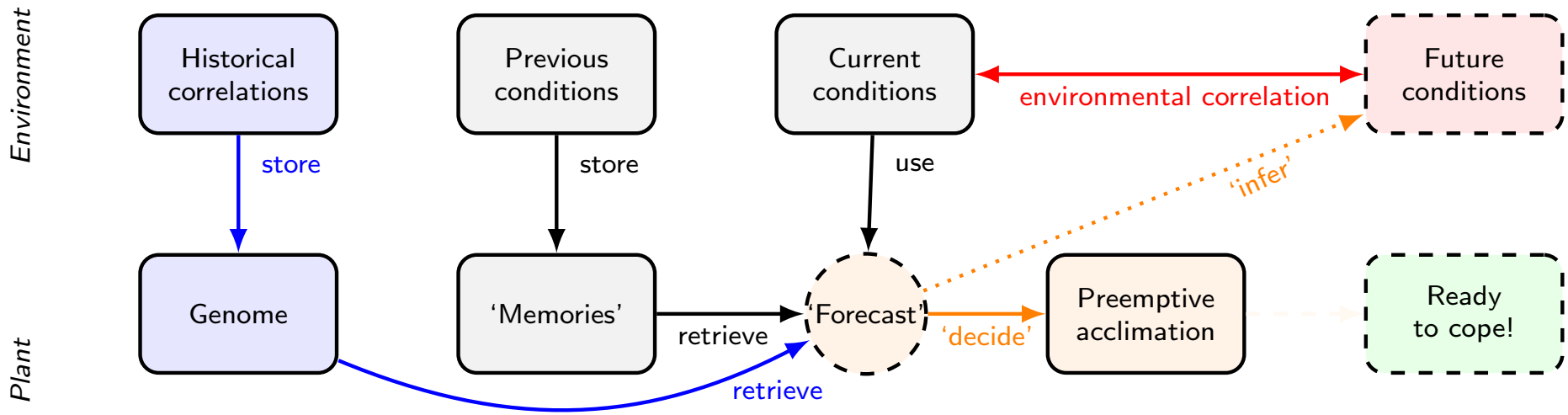

Environment
Plant
Historical correlations
Previous conditions
Current conditions
Future conditions
environmental correlation
store
store
use
'infer'
Genome
'Memories'
Forecast'
Preemptive acclimation
Ready to cope!
retrieve
retrieve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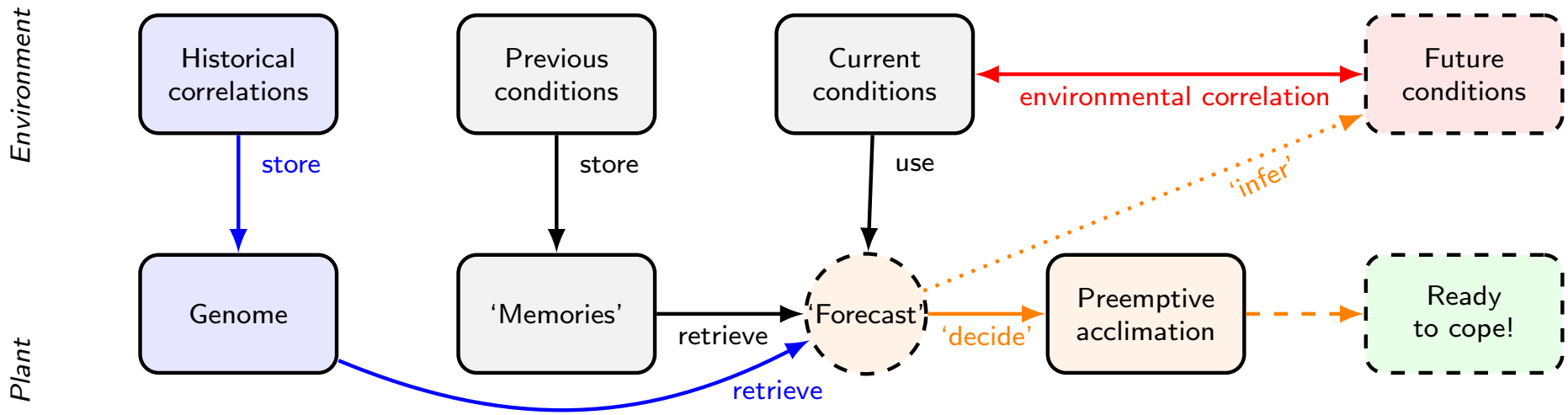
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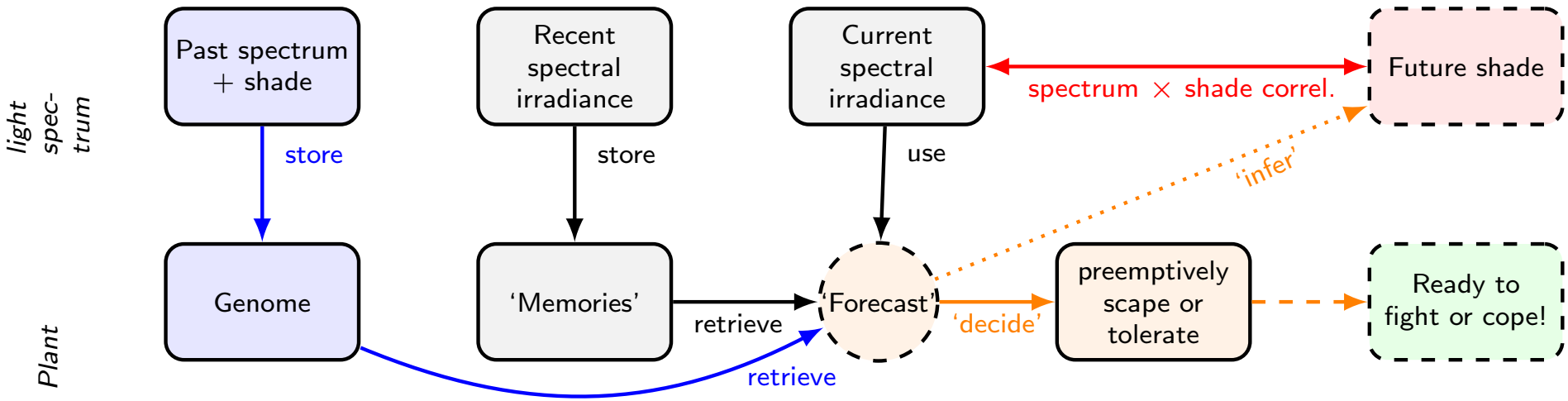
light spec- trum
Plant
Past spectrum + shade
Recent spectral irradiance
Current spectral irradiance
Future shade
spectrum × shade correl.
store
store
use
'infer'
Genome
'Memories'
Forecast'
preemptively scape or tolerate
Ready to fight or cope!
retrieve
'decide'
retrieve

# Learning

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- To me this is not real learning...
- I would define *deep learning* to be able to use as sources of information correlations that were not experienced or used as sources of information by ancestors...
- (assuming that plants cannot learn from each other...)

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# Itelligence

- Could we derive from *systems intelligence* a definition of intelligence that is independent of the physiological 'implementation' in different organisms?

# Behaviour

- I do not have problems with *plant behaviour*, I think it is just a question of the speed at which the behaviour takes place, and the low visibility by the smaller distances for movement.

# How does the problem look?

- from philosophy?
- evolution?
- from animal behaviour?
- animal sensory ecology?
- ...

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# Thanks for listening!

# Contact and acknowledgements

For additional information on our research, please have a look at our web site at http://blogs.helsinki.fi/senpep-blog/.

I can be contacted at mailto:pedro.aphalo@helsinki.fi

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