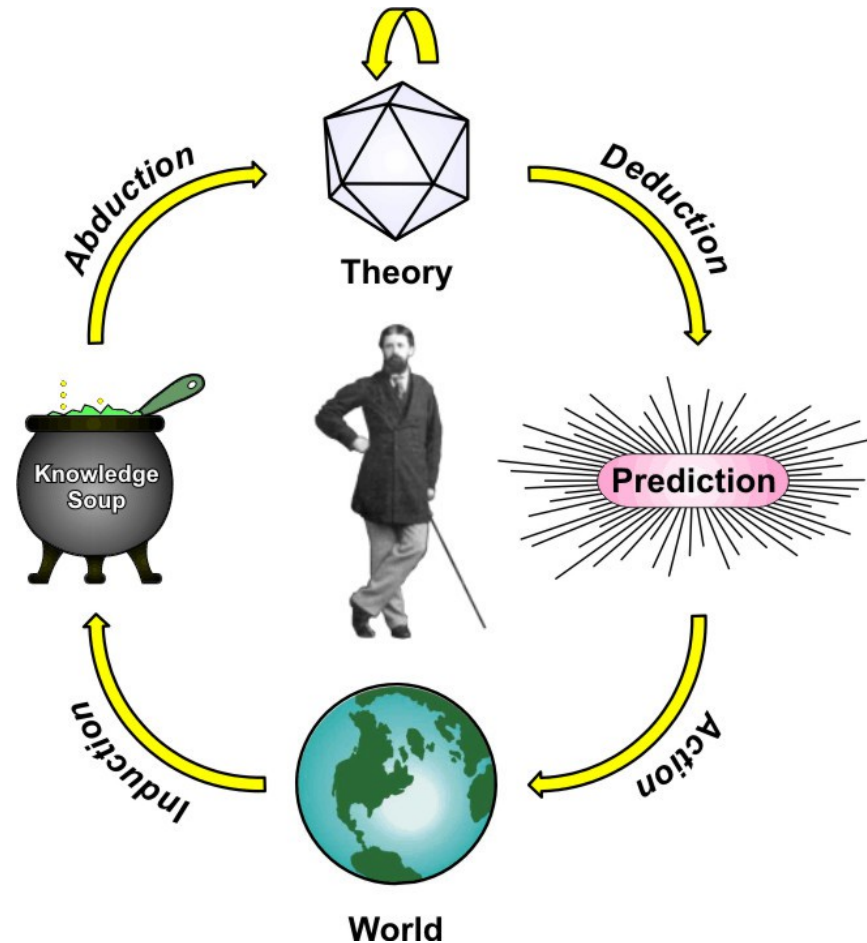


The Cognitive Cycle



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The Cognitive Cycle

All learning, from simple habits to scientific research, is based on similar methods of observation, reasoning, and action.

By trial and error, people revise and extend their beliefs to make better predictions about the world, society, and themselves:

- Observations generate low-level facts.
- Induction derives general axioms from multiple facts.
- A mixture of facts and axioms is an unstructured *knowledge soup*.
- Abduction selects facts and axioms to form a hypothesis (theory).
- Analogies may relabel a theory of one topic and apply it to another.
- Deductions from a theory generate predictions.
- Actions test the predictions against reality.
- Effects of the actions lead to new observations.
- Frequently used perception-action patterns become habits — overlearned responses that are computed by the cerebellum.

Cycles within cycles may be traversed at any speed — from milliseconds to hours to research projects that take years.

Knowledge Soup

Charles Sanders Peirce (CP 6.348):

Get rid, thoughtful Reader, of the Okhamistic prejudice of political partisanship that in thought, in being, and in development the indefinite is due to a degeneration from a primal state of perfect definiteness. The truth is rather on the side of the Scholastic realists that the unsettled is the primal state, and that definiteness and determinateness, the two poles of settledness, are, in the large, approximations, developmentally, epistemologically, and metaphysically.

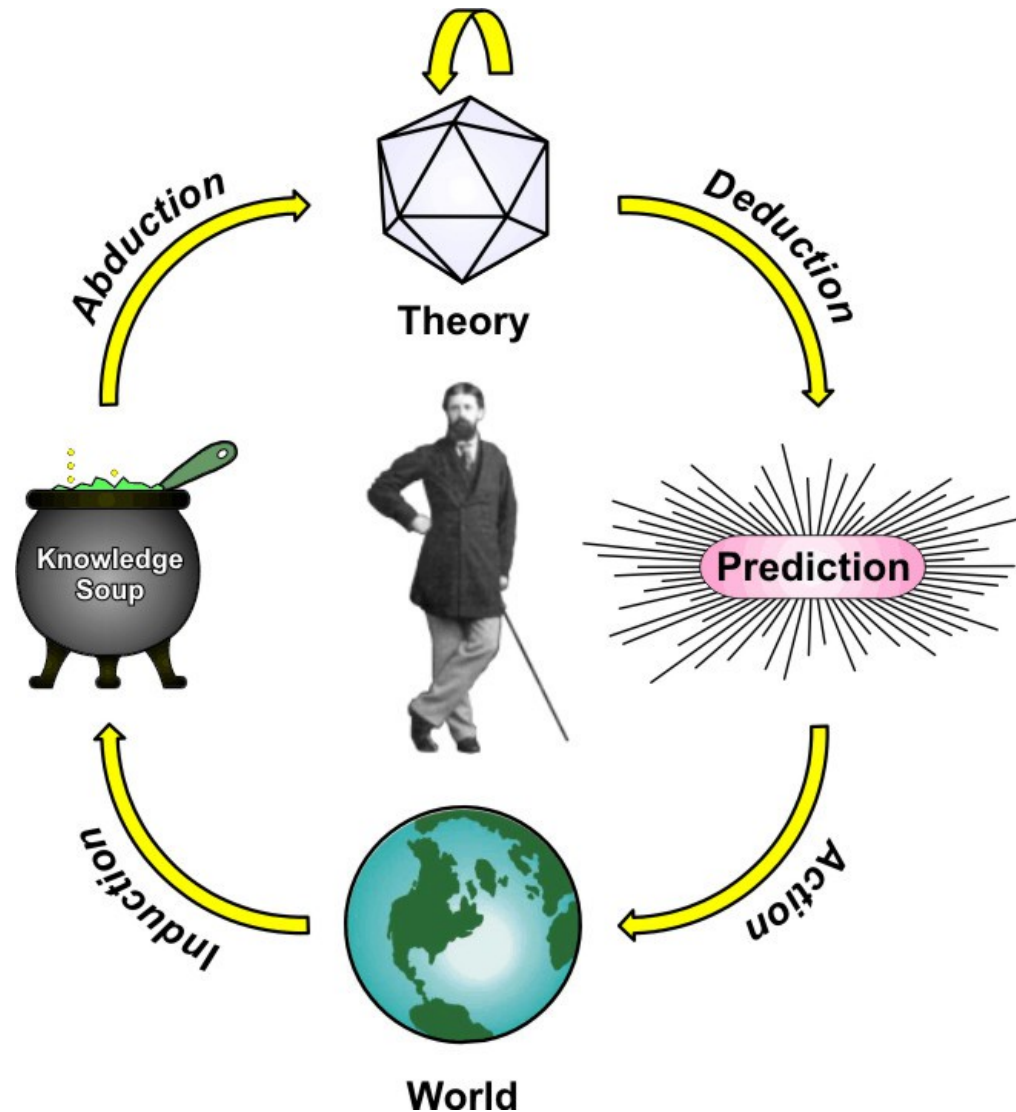
Alfred North Whitehead, *Essays in Science and Philosophy*

Human knowledge is a process of approximation. In the focus of experience, there is comparative clarity. But the discrimination of this clarity leads into the penumbral background. There are always questions left over. The problem is to discriminate exactly what we know vaguely.

Robert Frost, *A Lover's Quarrel with the World*

I've often said that every poem solves something for me in life. I go so far as to say that every poem is a momentary stay against the confusion of the world.... We rise out of disorder into order. And the poems I make are little bits of order.

Observing, Learning, Reasoning, Acting



**The reasoning methods identified by C. S. Peirce.
Similar cycles occur in science and everyday life.**

Knowledge Soup

A heterogeneous, loosely linked mixture: *

- **Fluid, lumpy, and dynamically changing.**
- **Many lumps are or can be structured in a computable form.**
- **But they may be inconsistent or incompatible with one another.**

In anybody's head, knowledge soup is

- **The totality of everything in the brain, including the cerebellum, the brain stem, and all signals from and about the body.**

In the WWW, knowledge soup is

- **The totality of everything people downloaded from their heads, recorded automatically, or derived by any computable method.**

Linked Open Data is useful for finding and classifying anything in the soup – whether loose items or structured lumps.

But understanding the contents of the LOD poses the same challenge as understanding natural language.

* Sowa (2004) [The challenge of knowledge soup](#).

Language is Central to Human Learning

People use language to express every aspect of life.

The cognitive cycle integrates linguistic and nonlinguistic data:

- **New data (experiences) accumulate from observations in life.**
- **Statistical methods are useful for finding generalizations.**
- **But those generalizations must be integrated with previous knowledge.**
- **Routine abduction may use statistics to select patterns from the soup.**
- **But creative abduction is necessary to invent new patterns.**
- **Belief revision integrates various patterns into larger, better structured patterns called hypotheses or theories.**
- **Deduction generates predictions from the theories.**
- **Actions in and on the world test the predictions.**
- **New observations provide supervision (rewards and punishments).**

Language is essential for expressing novel patterns and for learning the novel patterns discovered by other people.

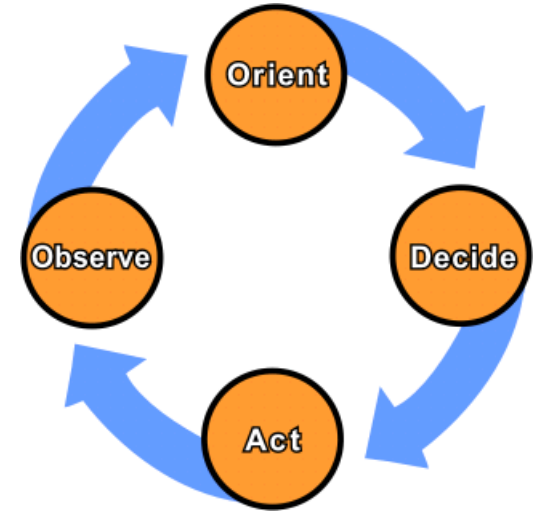
Boyd's OODA Loop

John Boyd drew a four-step diagram for training fighter pilots to observe and respond rapidly.

The first two steps – Observe and Orient – involve the occipital, parietal, and temporal lobes.

The next two steps – Decide and Act – involve the frontal lobes for reasoning and motor control.

The four steps and the associated brain areas:

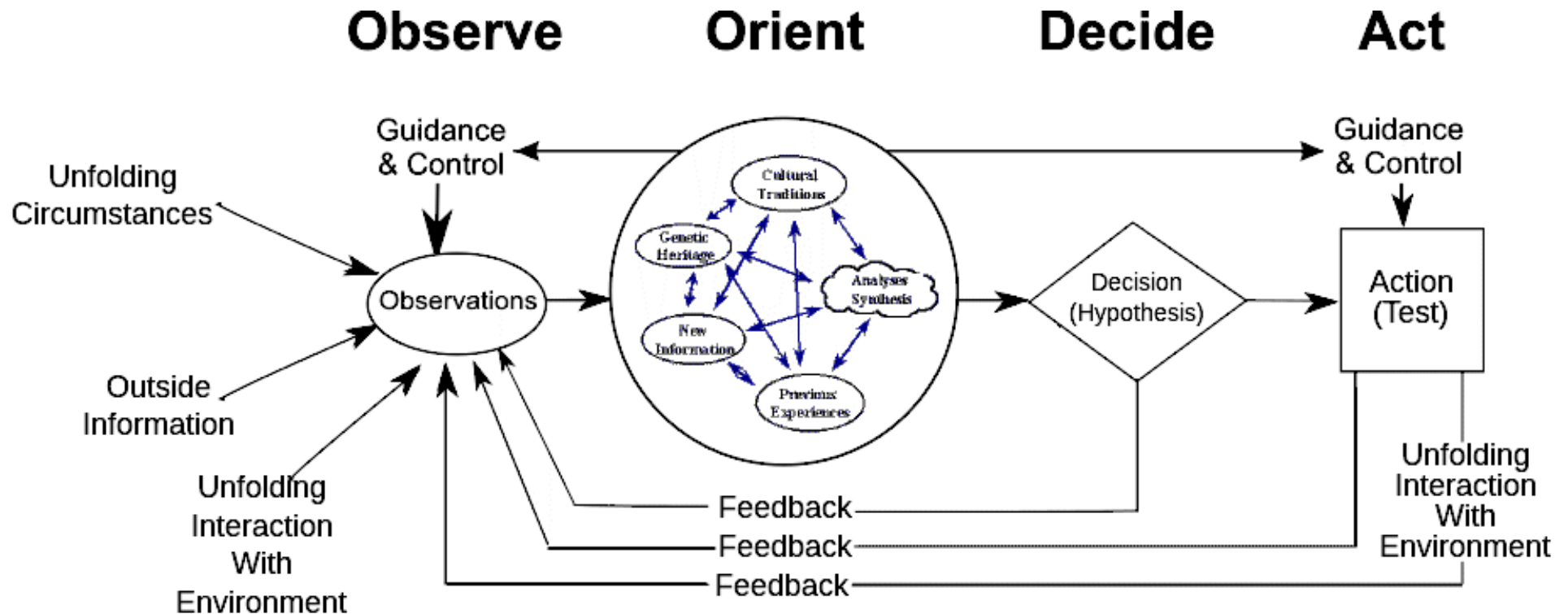


- 1. Observe:** Visual input goes to the primary visual cortex (occipital lobes), but object recognition and naming involve the temporal lobes.
- 2. Orient:** Parietal lobes relate vision, touch, and sound in “cognitive maps.”
- 3. Decide:** Reasoning is under the control of the frontal lobes, but other areas store the “knowledge soup” and the “mental models.”
- 4. Act:** “Action schemata” are patterns in the premotor cortex of the frontal lobes. Signals from the motor cortex go to the muscles.

In emergencies, each step must be traversed in milliseconds.

The fastest responses are controlled by the VR in the cerebellum.

Extended OODA Loop

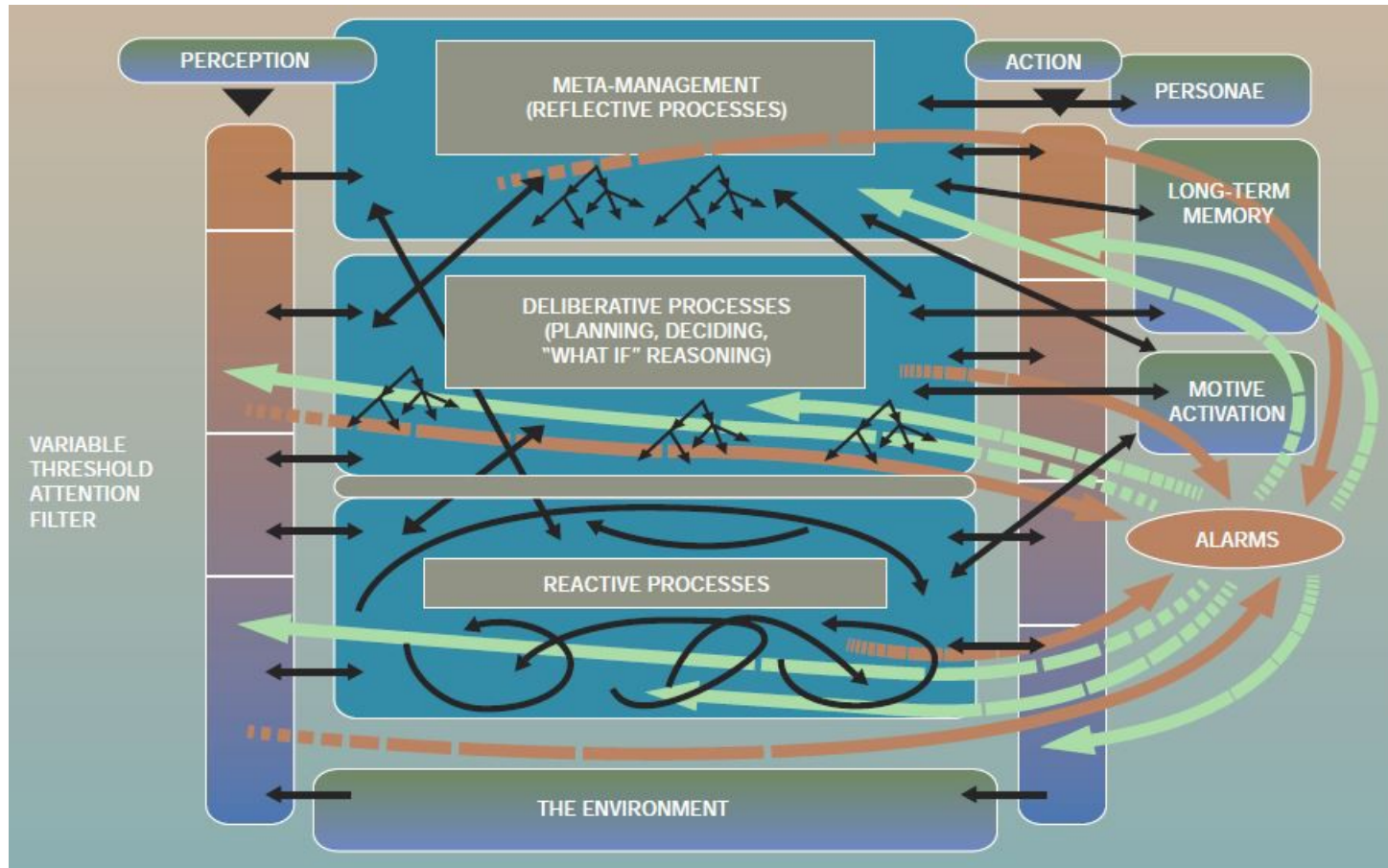


Cycles are self-correcting: Any error in one cycle can be detected and corrected in later cycles.

Over the years, Boyd added more detail to the OODA Loop and applied it to decision-making processes of any kind.

Both versions are compatible with Peirce's cycles.

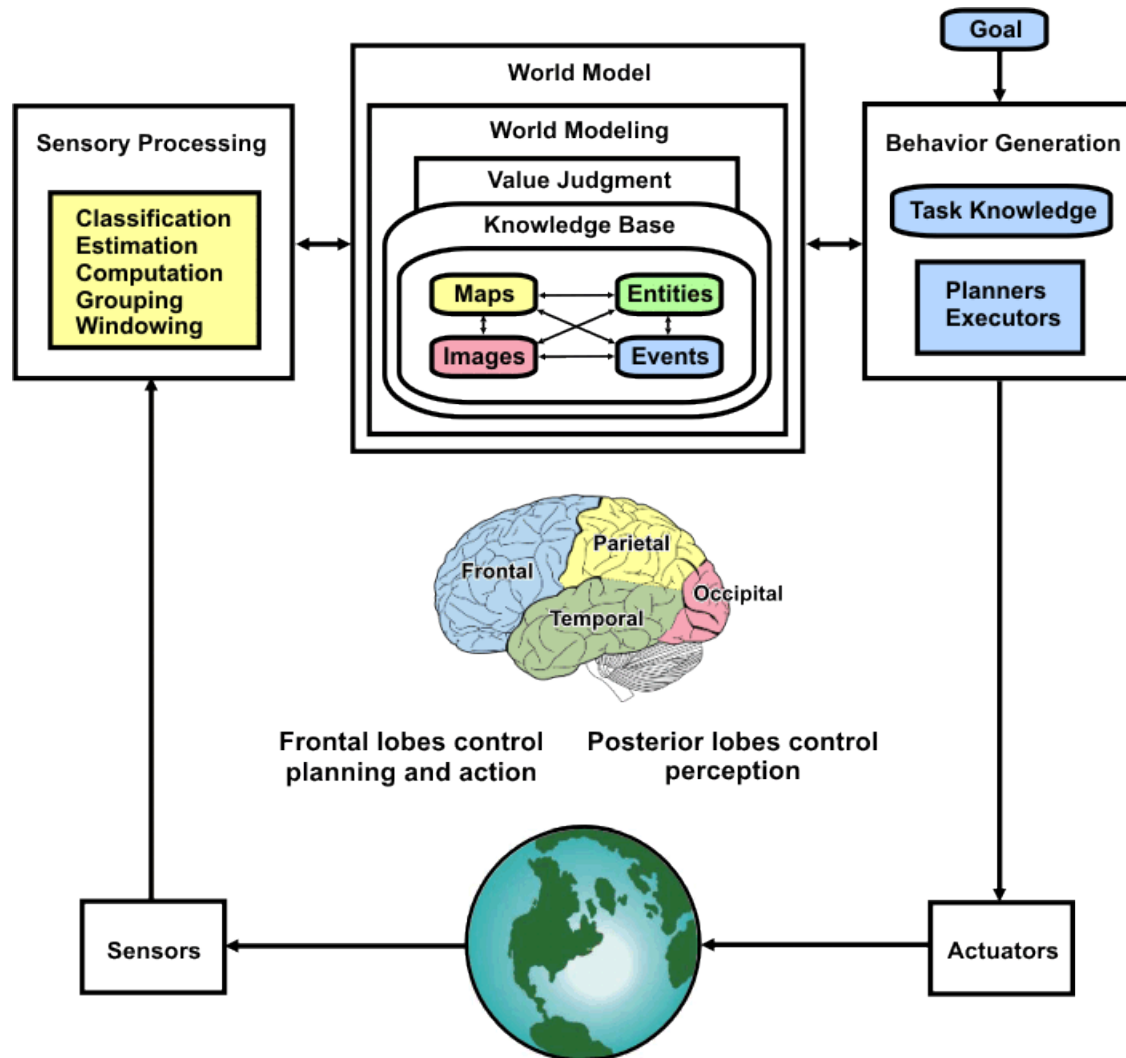
The H-Cogaff Architecture



The Hierarchical Cognition Affect architecture by Aaron Sloman includes a cycle similar to Peirce's or Boyd's. *

* From [An architecture of diversity for Commonsense Reasoning](#) by McCarthy, Minsky, Sloman, et al. (2002)

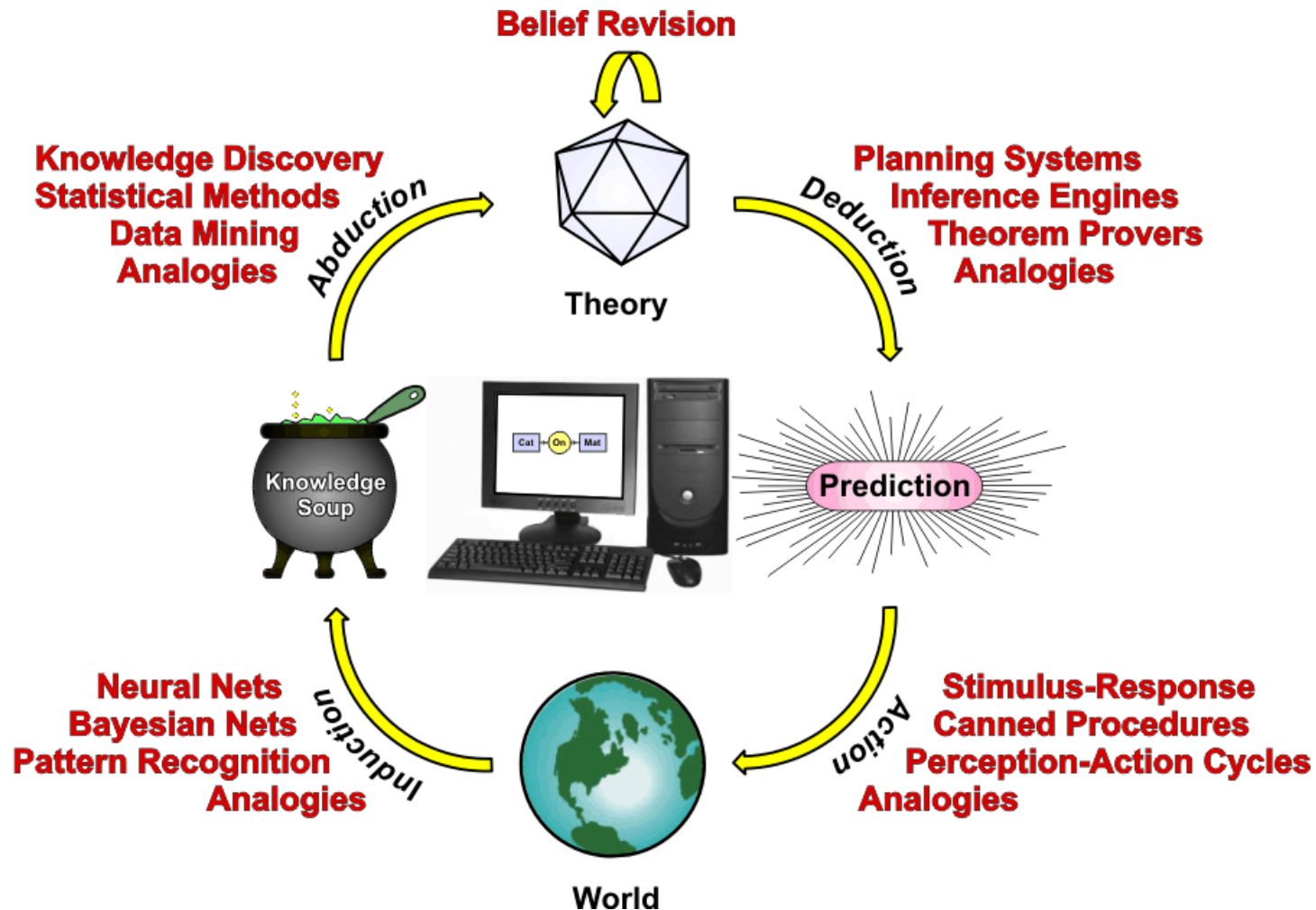
Albus Cognitive Architecture



A cycle that resembles those by Peirce, Boyd, and Sloman.

See Albus (2010), <http://www.james-albus.org/docs/ModelofComputation.pdf>

Implementing the Cycles



An open-ended variety of methods for learning and reasoning.

Knowledge Discovery

Observation by Immanuel Kant:

Socrates said he was the midwife to his listeners, i.e., he made them reflect better concerning that which they already knew, and become better conscious of it. If we always knew what we know, namely, in the use of certain words and concepts that are so subtle in application, we would be astonished at the treasures contained in our knowledge...

Platonic or Socratic questions drag out of the other person's cognitions what lay within them, in that one brings the other to consciousness of what he actually thought.

From his Vienna Logic

We need tools that can play the role of Socrates.

They could help us discover the implicit knowledge in data from any source, especially the WWW.

Conclusion

Many theories capture important aspects of cognition:

- Symbolic methods support formal deduction and computation.
- Embodied theories emphasize the dependence of mind on body.
- Dual coding theories relate the symbolic and embodied methods.
- The cerebellum supports virtual reality as a foundation for cognition.
- Artificial neural networks are valuable for pattern recognition.
- Cognitive linguistics relates language to all of the above.
- Biosemiotics emphasizes the continuity from bacteria to humans.
- Philosophers have analyzed and debated these issues for millennia.

Peirce's semiotic relates and integrates everything:

- Signs are the basis for all aspects of perception, learning, cognition, reasoning, communication, and action by all living things.
- His research in logic, philosophy, science, mathematics, lexicography, psychology, and early computing devices gave him the insights. *

* See <http://www.jfsowa.com/pubs/csp21st.pdf>

Related Readings

For more information, most slides have URLs or citations.
For the general bibliography, see <http://www.jfsowa.com/bib.htm>

Publications by John F. Sowa:

The virtual reality of the mind (2016) <http://www.jfsowa.com/pubs/vrmind.pdf>

Signs and reality (2015) <http://www.jfsowa.com/pubs/signs.pdf>

The role of logic and ontology in language and reasoning (2010)
<http://www.jfsowa.com/pubs/rolelog.pdf>

From existential graphs to conceptual graphs (2013)
<http://www.jfsowa.com/pubs/eg2cg.pdf>

Peirce's tutorial on existential graphs (2011)
<http://www.jfsowa.com/pubs/egtut.pdf>

Signs, processes, and language games: Foundations for ontology (1999)
<http://www.jfsowa.com/pubs/signproc.pdf>

Slides of presentations:

Peirce, Polya, and Euclid: Integrating logic, heuristics, and geometry (2015)
<http://www.jfsowa.com/talks/ppe.pdf>

Natural logic (2016) <http://www.jfsowa.com/talks/natlog.pdf>

Cognitive Memory (2017) <http://www.jfsowa.com/talks/cogmem.pdf>