

Evolutionary Epistemology

A PERSONAL INTERPRETATION OF JOHN BOYD'S DESTRUCTION AND CREATION

Franklin C. Spinney

July 31, 1997

Republished here by permission.

Disclaimer:

This presentation represents my interpretation of John Boyd's September 1976 paper. (Updated by some of his subsequent work and my views) While I worked closely with him and helped him to produce this paper, it is his creation and my role was that of an understudy. Consequently, any misrepresentation of Boyd's work or errors are mine alone and this briefing should not be considered a definitive description of his work--*FCS*

Aim:

To understand how the MIND evolves an interior mental [orientation](#) (or changing constructs of meaning or what Thomas Kuhn called "paradigms") ... To permit ... individuals and groups to shape & adapt to changing external conditions (i.e., a changing environment)

POINTS OF DEPARTURE

Biological Imperative:

- Creates purposive behavior (i.e., GOAL Striving): to survive on our own terms ... or put another way, to increase our capacity for [independent action](#).

Environment: (Limited Resources and Skills)

Real world constraints limit capacity for independent action and threaten survival.

Implication:

- Combination of goal striving & scarcity sets the stage for COMPETITION among individuals and groups as they struggle to OVERCOME environmental constraints.

Consequence:

- To survive and grow relatively free of debilitating constraints, individuals and groups MUST MAKE DECISIONS and TAKE ACTIONS to overcome physical obstacles and social competitors.

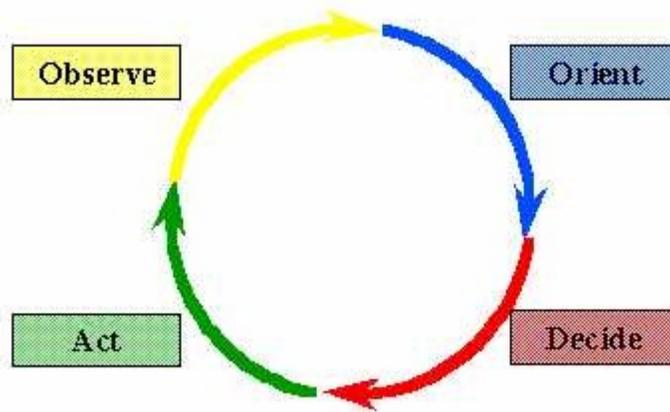
CENTRAL QUESTION:

How do we generate the mental concepts needed to support this decision-making activity? ... Put another way ... How do we evolve mental concepts to ...

- Identify WHAT decisions and actions are necessary or appropriate?
 - MONITOR the effect of actions to support subsequent decision-making activities?
-

Simplistic Answer

We use a sensor system to observe events in the external environment. We orient ourselves to the meaning of those observations. We decide and we act ... And then we observe the effects of that action and recycle



Problems with Simplistic Answer

All observations of the external world are filtered through the cognitive apparatus of the observer ... And therefore ... observations should not be separated from the various interior mental processes of each observer.

Implication:

Any description of a complex reality can be viewed through a variety of mental concepts that individuals use to represent observed reality (i.e., the multitude of different perspectives which make up one's mental orientation.)

Question:

How does one evolve a relevant orientation for apprehending the complexity of observations in the real world?

There are two ways for evolving and manipulating mental concepts to represent observations:

1. Analysis:

- Breaking down a comprehensive whole into its constituents and the relations among those constituents. (Deduction, differentiation, destruction)

2. Synthesis:

- Starting with parts and building toward a comprehensive whole. (Induction, integration, construction)
-

Analyses & Synthesis

INTERPLAY OF OBSERVATIONS & ORIENTATION:

AN INTRODUCTION TO THE DIALECTIC NATURE OF *UNDERSTANDING* AND *CREATIVITY*

Understanding--Analysis of a pre-existing domain:

- Pyramids and the question of multiple perspectives

Creativity--Analyses & synthesis:

- Boyd's thought experiment: example of a destructive deduction and the creation of new domains

HISTORICAL EXAMPLE

- The evolution of cosmology
-

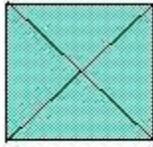
Analysis:

- [Understanding](#) in the context of a single domain.

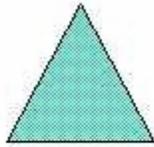
Focus of effort:

- We gather variety of observations about a single domain, break down & correlate these observations from a variety of perspectives ... and ... combine these correlated perspectives into a comprehensive description of that domain.
-

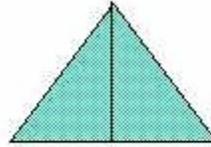
WHAT IS A PYRAMID?



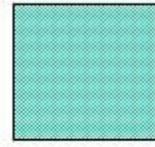
Top



Side



Corner



Bottom

To understand a pyramid, the observer analyzes it from multiple perspectives and correlates & combines the relationships among those perspectives.

Point:

Dissection & re-assembly can produce a richer understanding, but the “constrained integration” always takes us back to the same pyramid.

Creativity

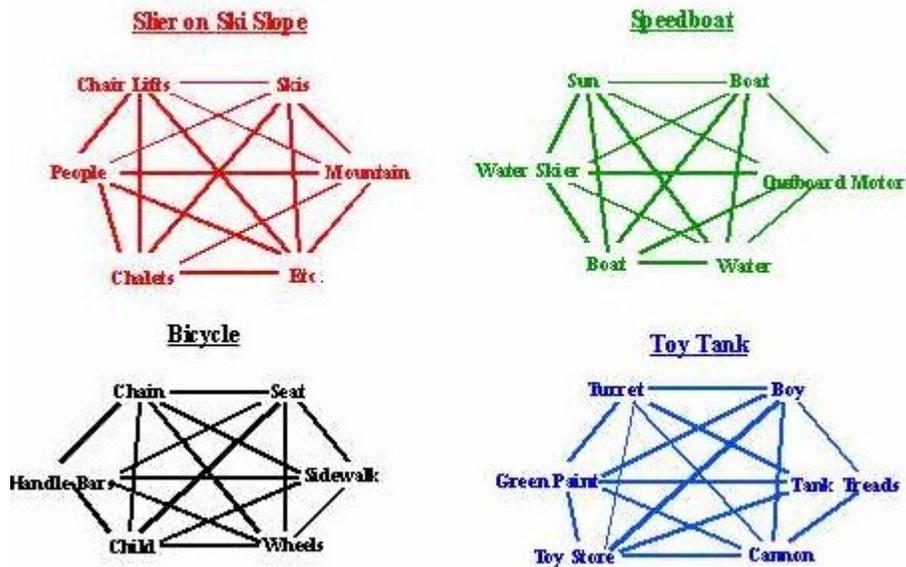
BOYD'S THOUGHT EXPERIMENT

Step 1:

Imagine four separate images (or domains): Each image is a pre-existing whole with a unique identity

Step 2:

Analysis (deduction): Each image is a domain that can be understood in terms of its parts and the relations among the parts



Step 3:

Let's shatter the correspondence between the parts and the domains.

Result: A destructive deduction

UNCERTAINTY & DISORDER IN THE PLACE OF
MEANING & ORDER!

Boy Water Skier Wheels
People Handle Bars Mountains Water
Chair Lifts Chalets Sun Outboard Motor
Child Seat Cannon Sidewalk
Tank Treads Toy Store Green Paint Turret
Chain Etc. Skis
Boat Boat

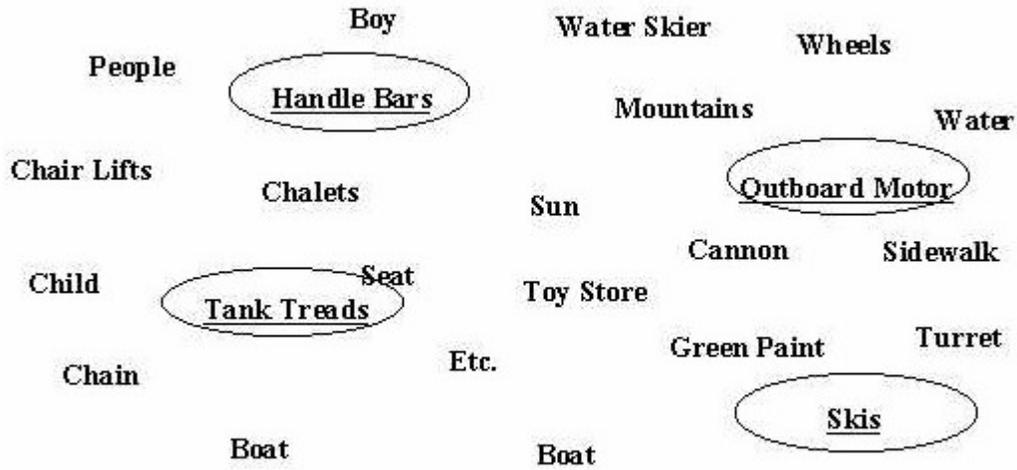
HOW DO WE CONSTRUCT ORDER AND MEANING OUT OF THIS MESS?

We can synthesize a new domain, if we can find common qualities & connecting threads, attributes, or operations among some of the constituents swimming in the sea of anarchy:

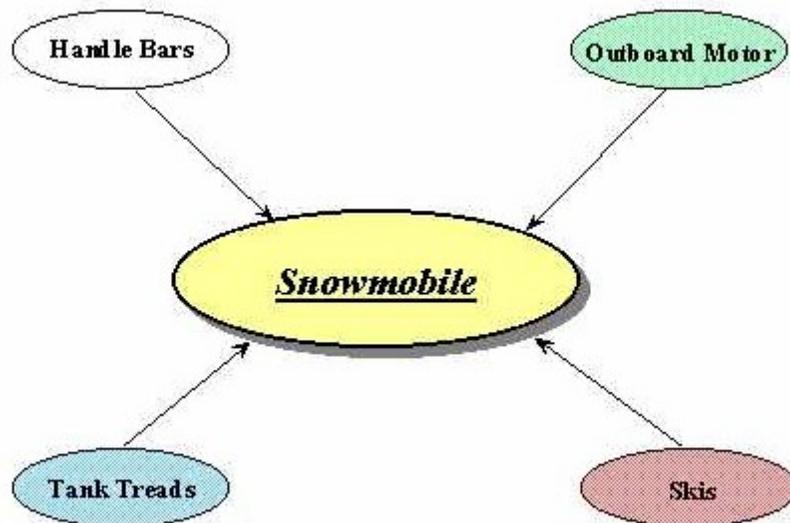
Boy Water Skier Wheels
People Handle Bars Mountains Water
Chair Lifts Chalets Outboard Motor
Sun
Child Seat Cannon Sidewalk
Tank Treads Toy Store Green Paint Turret
Chain Etc. Skis
Boat Boat

Let's try again,

Does anyone see any **common qualities** & connecting threads, attributes, or operations in this sea of anarchy?



A New Domain or Concept Description Created by Linking Previously Unrelated Constituents



To be viable and remain relevant, the new description of reality must be continuously refined by checking & verifying its

- [Internal consistency and reversibility](#)
- Match-up with external reality

But ...

As the focus of effort turns inward to refine the precision or subtlety of both observations and the concept description, the newer level of precision/description will eventually exceed the original precision ... and when this occurs ... we should expect to see mismatches and inconsistencies between the newer, more precise observations and the concept description of those observations.

Why will [mismatches](#) emerge?

If we assumed otherwise, it would be the same as saying newer, more precise or different observations and interactions would always combine to produce the same synthesis as the older, more primitive observations and interactions.

Perhaps a real-world example will help to clarify this crucial point.

Evolution of Our Mental Orientation to Celestial Observations (140 AD to 1905 AD)

Music of the Spheres → **Celestial Clockwork** → **Space-Time-Mind**

CLAUDIUS **PTOLEMY** (CIRCA 140 AD) AND THE MUSIC OF THE SPHERES

- Earth is center of a universe made up of 8 spheres which rotate around the earth.
- Outer sphere holds the stars, which do not move relative to the earth
- Each of the 7 inner spheres holds a “planet” (i.e., the moon, sun, Mercury, Venus, Mars, Jupiter, and Saturn) which moves along one or more epicycles [a path traced by rolling a smaller circle on the circumference of the sphere]
- Problem: although the system of Ptolemy gave reasonable agreement with the timetable of the planets, more precise observations called for more and more epicycles to maintain the match up of the concept description with observed reality.

Result:

An ever-increasing inward-focus of effort as astronomers struggled to update Ptolemy’s world view ... And consequently ... by the 1400s, the increasing internal complexity of Ptolemy’s system had fatally weakened its intellectual coherence and set the stage for a new synthesis.

THE DESTRUCTION OF THE PTOLEMAIC ORIENTATION - KEY PRECURSORS

Music of the Spheres  **Celestial Clockwork**  **Space-Time-Mind**

1. Copernicus (1473-1543) - Simplification via Paradigm Shift

- Contribution: greatly simplified the mathematical description of the universe by assuming the sun to be the center of rotation. Problem: assumed (erroneously) that orbits of planets were perfect circles. His predictions did not match all detailed observations, so he could not get rid of all epicycles.

2. Tycho Brahe (1546-1601) - Increased Precision of Observations

- Contribution: extraordinary astronomer -- assembled vast base data base of very precise observations (W/O telescope & did not accept Copernicus' theory).

3. Johann Kepler (1571-1630) - Matchup via Precise Mathematical Description

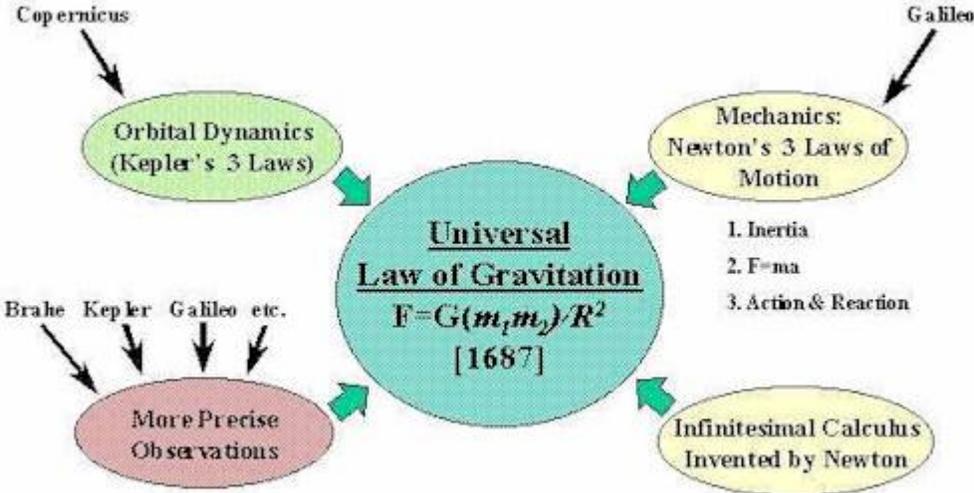
- Contribution: used Brahe's data & own observations to convert Copernican system in to an precise mathematical map of planetary motion based on three laws of motion. (Orbits = ellipses, equal area sweeping/time, and $(\text{year})^2 = k(\text{distance from sun})^3$).

4. Galileo (1564-1642) - Mathematical Precision, Experimental Method, Basis in Physics

- Contribution: experiments established the modern foundation for the mechanics of motion
 - Invented use of pendulum as precise instrument to measure time.
 - Proved falling objects accelerate at a uniform rate, regardless of mass ($d=1/2at^2$).
 - Inertia - proved moving mass will keep moving until some force acts to stop it.
 - Used telescope to postulate "divine clockwork" (rotation) of Jupiter's moons.
-



Newton's Grand Synthesis (Snowmobile)



Result:

- An elegantly simple, mechanical orientation that predicted the motion of planets with stunning accuracy.



Newton's orientation shaped observations & experiments for 200 years as scientists turned inward to flesh out Newton's paradigm

Newton's orientation also helped to shape an explosion in technology, which led to more precise instruments and more subtle observations.

Experimental evolution:

Inward focus & more subtle observations set the stage for eventual mismatches between Newton's predictions & experimental observations

Perhaps the most spectacular example is the Michelson-Morely experiment

THE MICHELSON-MORELY EXPERIMENT & THE SEARCH FOR MORE PRECISE MEASUREMENTS (1881-1887)

Albert Michelson constructed an interferometer as a tool to permit more precise measurements of speed of light: Measures the differences in light waves by measuring the size and number of black and white bands (interference fringes) which appear when light waves get out of step (or phase) with each other.

Aim of experiment:

- Use interferometer to measure speed of earth through the "ether" by comparing the difference between speed of light in direction of motion to speed of light perpendicular to motion

THE NEWTONIAN ORIENTATION DEPENDED ON AT LEAST TWO UNIVERSAL CONSTANTS:

1. Gravitation -- explicit
2. Time -- implicit: a consequence of the inertial frame of reference (fixed relative to the stars) which permitted Galilean transformations.

MICHELSON'S & MORELY'S ASSUMPTIONS (SHAPED BY THE NEWTONIAN ORIENTATION):

- Ether is the inertial medium in space that carried lights waves & earth
- Speed of light in direction of earth's motion = speed of light + earth's speed
- Speed of light perpendicular to earth's motion = speed of light

EXPERIMENTAL RESULTS: INCONSISTENT WITH THE PREDICTIONS OF A NEWTONIAN ORIENTATION

1. No interference fringes appeared, which implied (incorrectly) the earth was not moving (relative to the ether or the inertial frame of reference)
 2. Speed of light + any other velocity = the speed of light (inconsistent with inertial frame of reference and Galilean transformation)
-



Einstein's Synthesis: The Special Theory of Relativity

EINSTEIN RESOLVED THE ANOMALY BY CHANGING THE UNIVERSAL CONSTANTS IN THE NEWTONIAN ORIENTATION

Two Universal Constants:

1. Gravity (Like Newton)
2. Speed of Light (In Place of Time)

Result - A New Orientation (or a New Snowmobile):

- Galilean transformation replaced by Lorentz transformation -- a moving object will appear to diminish in length in the direction of travel as its velocity approaches the speed of light or moving clock will appear to be running more slowly
- Equivalence of mass and energy ($E=mc^2$ and phenomenon of mass increasing as its speed approaches the speed of light).
- Universe must be thought of (mind) as a continuum of spatial and temporal distance. (The measure of separation involves spatial and temporal terms.)

OBSERVATION

Each new synthesis shapes the nature of future observations as well as the research program for developing the concept description.

ON THE OTHER HAND

The evolution of cosmology from Ptolemy to Einstein shows how the interplay of observations and orientation produces a never ending cycle of increasing mismatches, destruction, and creation.

While historians (esp. [Kuhn](#)) have recognized this pattern, Boyd went further by arguing that there are theoretical reasons why this cycle is an *inevitable fact of life*

THEORETICAL REASONS FOR EVENTUAL MISMATCHES

GÖDEL'S PROOF

- Any consistent system of axioms is incomplete--i.e., it contains true statements that can not be deduced from the postulates that make up the system.
Generalization: even though a system may be consistent, its consistency can not be demonstrated within the system (must appeal to systems outside it).

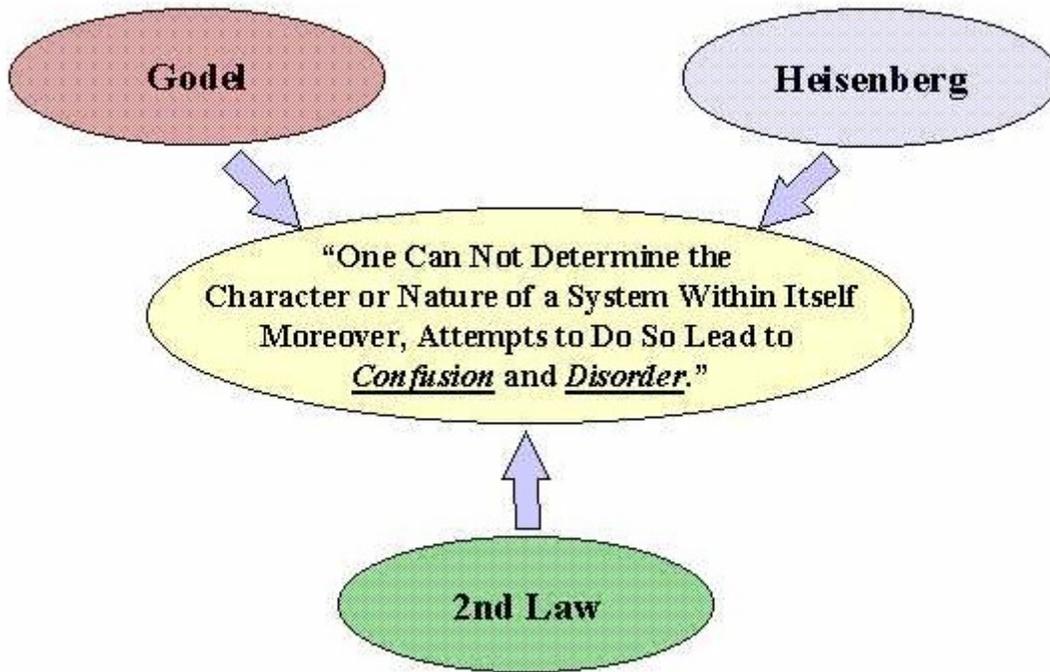
Heisenberg

- Can not simultaneously determine position and velocity of a particle.
Generalization: when the precision of the observer approaches the precision of the observed, the observer perceives uncertain or [erratic behavior](#).

2ND LAW OF THERMODYNAMICS

- All natural processes create entropy. Generalization: entropy must increase in a system that cannot communicate in an ordered fashion with other systems external to itself
-

BOYD'S SNOWMOBILE



Implication

THE NEVER ENDING CYCLE OF INCREASING MISMATCHES, DESTRUCTION, AND CREATION IS THE NATURAL MANIFESTATION OF A DIALECTIC ENGINE -- AN ANALYTIC/SYNTHETIC PROCESS POWERED AND REGULATED BY--

- The continuous effort to survive and improve one's capacity for independent action, ...and ...
- The alternating cycles of entropy increase toward more disorder and entropy decrease toward less disorder.

Let us now probe more deeply into the nature of observations ... and ... the relationship between the observer and the observed ... and the way we ... synthesize these observations into a useful picture of reality.

OBSERVATIONS CAN BE CATEGORIZED BY THE INTERACTION BETWEEN THE OBSERVER AND THE OBJECT OF OBSERVATION

Basic Assumptions of Different Orientations:

Classical Physics (Newton & Laplace): The universe is a *system of reversible deterministic events* that exists as an objective reality independent of the observer. observations are events in themselves, and a complete description of these events is theoretically possible. Uncertainty about the description is, therefore, the result of ignorance. [Bronowski 2: 63-4]

Relativity (Einstein): The universe is a *system of reversible deterministic events* that exists as an objective reality, but one's description of that reality is dependent upon the position of the observer in the system. Between each event and the observer, there must pass a signal, e.g., ..., a ray of light, which can not be taken out of the observation. The fundamental unit of observation is the relation between the event, the signal, and the observer. Uncertainties about the system as it is are the result of ignorance (God does not play

dice.), but some events are unknowable to man because of the nature of the signal -- e.g., the constant speed of light makes it impossible to apprehend simultaneous events at a great distance. [Bronowski 2: 102-3]

Quantum Mechanics & the Principle of Complementarity (Bohr's interpretation of Heisenberg's Uncertainty Relation): Events at the atomic level can only be described in terms of alternative possibilities and relative probabilities of occurrence: Heisenberg showed why it is impossible to make precise, simultaneous measurements of the position and momentum of an electron. Bohr interpreted this result to mean that (1) the interaction between the object of observation (the quantum system) and the observing mechanism is *nondecomposable*; (2) no single observation or observing mechanism can completely describe the system; and (3), while various observations may describe complementary portions of the same reality, it is impossible to combine them into a single, complete description of the whole of reality. [Prigogine: 222-9; *Britannica*: V15, 159 & V23, 876]

Natural Science: Evolutionary Biology, Culture, & Epistemology (Lorenz, Popper, Campbell, Hall, Boyd, etc): Events in the external world are perceived through an evolutionary cognitive apparatus -- a neurosensory system that acquired its present form through interaction with and adaptation to the subset of events in the outer world which affects survival. Since these sensing mechanisms superimpose partial images of the outer world on the fluctuating mental states of the internal neurosensory organization, it is necessary to compensate for the physiological and psychological mechanisms present in the observer to construct a viable image of reality. [Lorenz 1:1-19, Campbell: 47-89]

Summary

(OBSERVATIONS CAN BE CATEGORIZED BY THE INTERACTION BETWEEN THE OBSERVER AND THE OBJECT OF OBSERVATION)

Newton & Laplace (and most Defense "Analysts," Social "Scientists", & Economists)

- **No interaction:** Unit of observation = [object of observation]
- Sterile theory of "objective" or "absolutist" observer in social science.

Einstein

- **No interaction:** Unit of observation = [object-*signal*-observer]
- Sterile theory that everything is relative in social science.

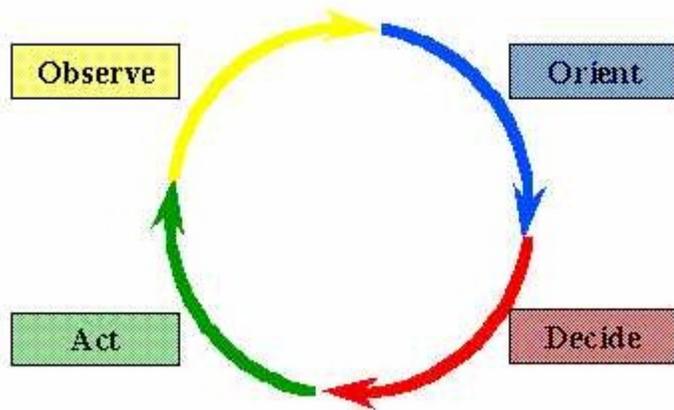
Heisenberg & Bohr

- Process of observation *shapes* the object of observation
- Units of observation =[alternative possibilities & relative probabilities]

Darwin to Lorenz to Boyd

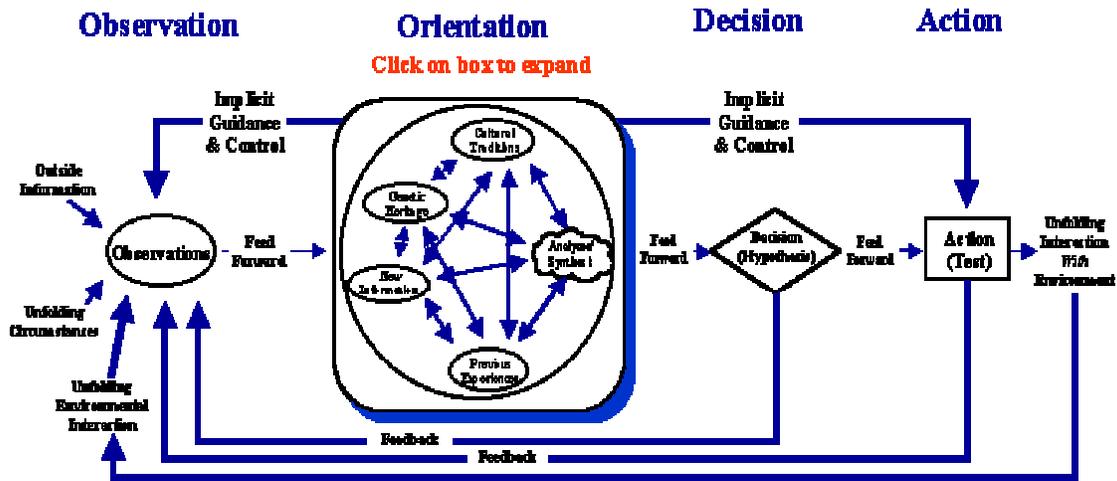
- Observing apparatus *shapes* and *is shaped by* the object of observation and the interaction of environmental pressure (co-evolution)
- Units of Observation =[subset of external events which affect survival]

While this simple view of the OODA loop is a useful shorthand for describing these ideas,



The relationships between Observation & Orientation and Analyses & Synthesis help us understand why ORIENTATION is the heart of the OODA Loop.

The OODA "Loop" Sketch



Insights:

Note how orientation shapes observation, shapes decision, shapes action, and, in turn, is shaped by the feedback and other phenomena coming into our sensing or observation window.

Also note how the entire "loop" (not just orientation) is an ongoing many-sided implicit cross-referencing process of projection, empathy, correlation, and rejection.

The OODA "Loop"

The analytic/synthetic process by which our mental orientation interacts with the external world is an evolving, open-ended, far-from-equilibrium process governed by control loops embodying positive as well as negative feedback

EPISTEMOLOGY IS AN UNPREDICTABLE EVOLUTIONARY PHENOMENON