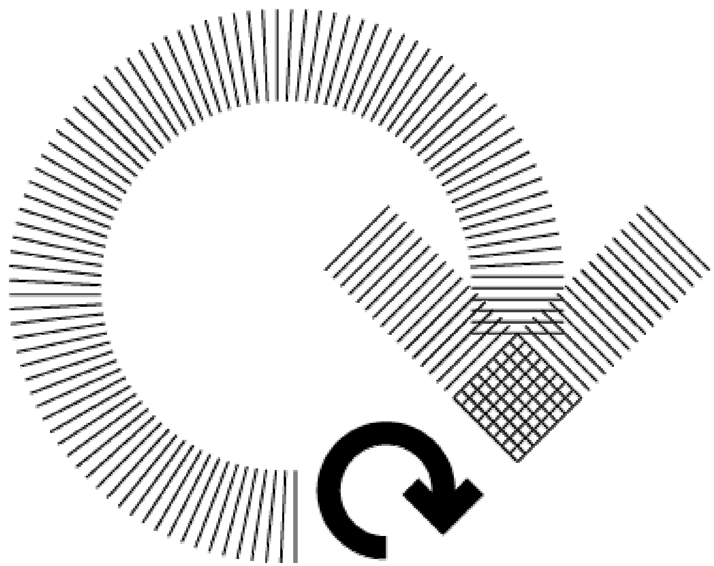
Introduction to Cybernetics and the Design of Systems



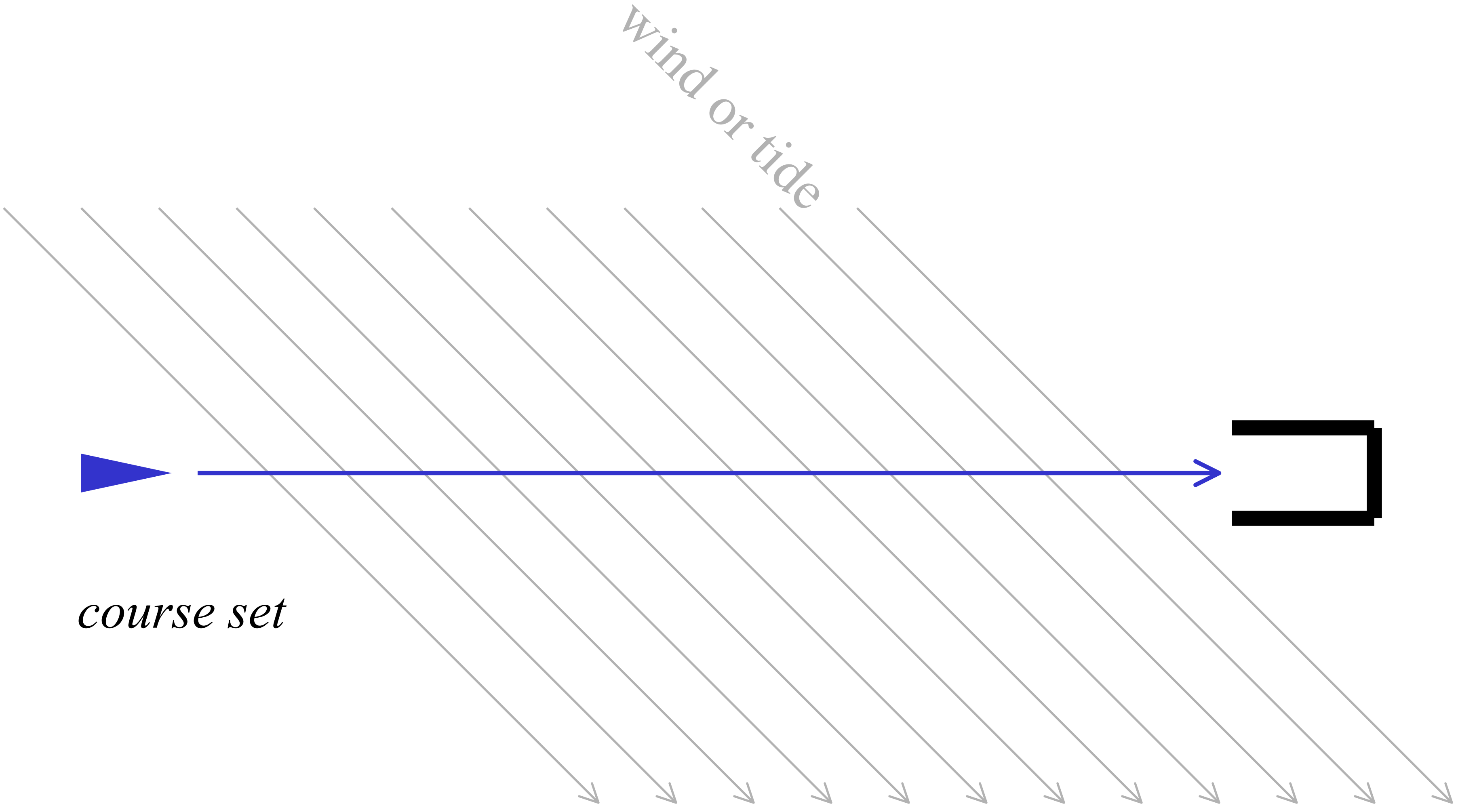
Cybernetics named

From Greek ‘kubernetes’

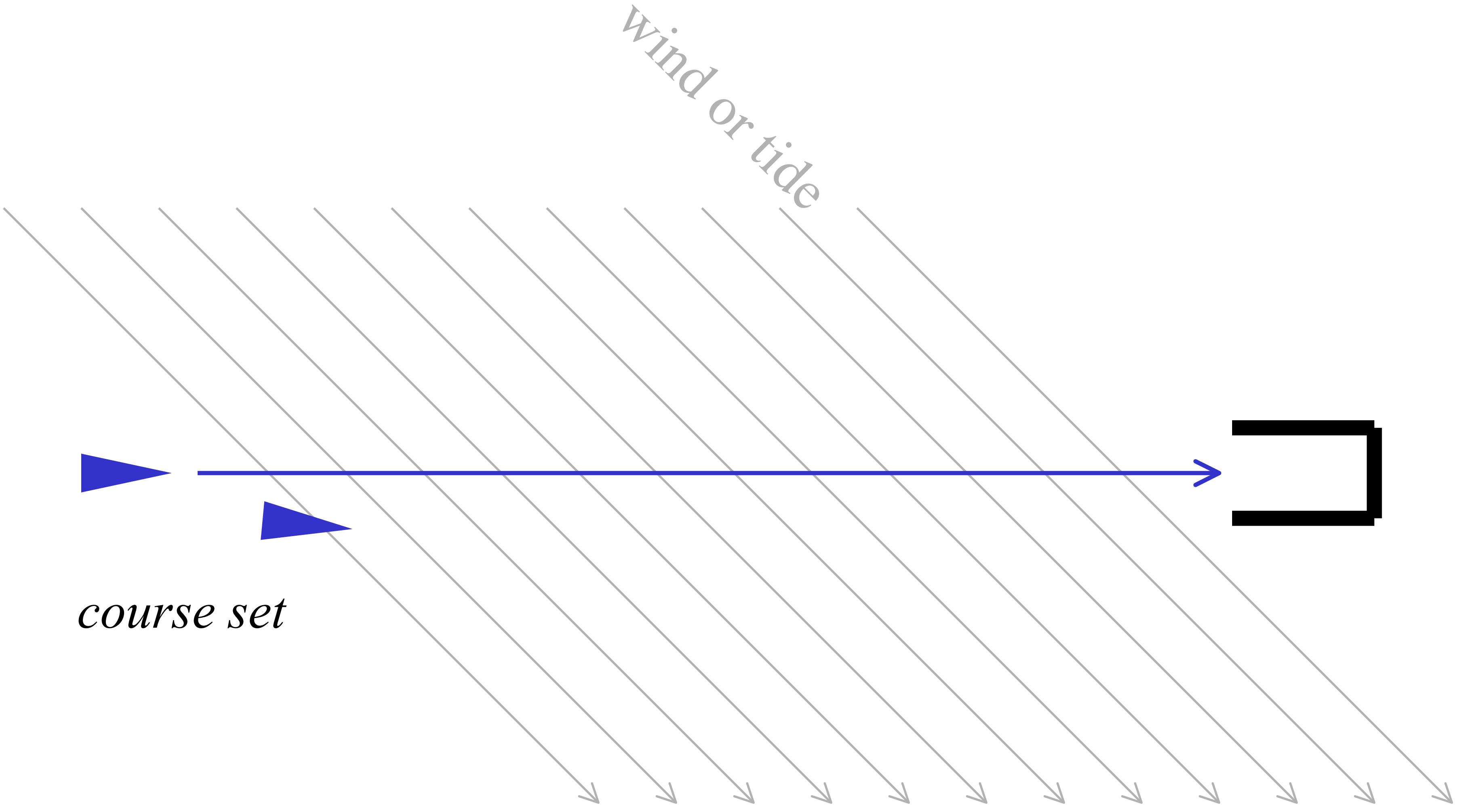
— same root as ‘steering’

— becomes ‘governor’ in Latin

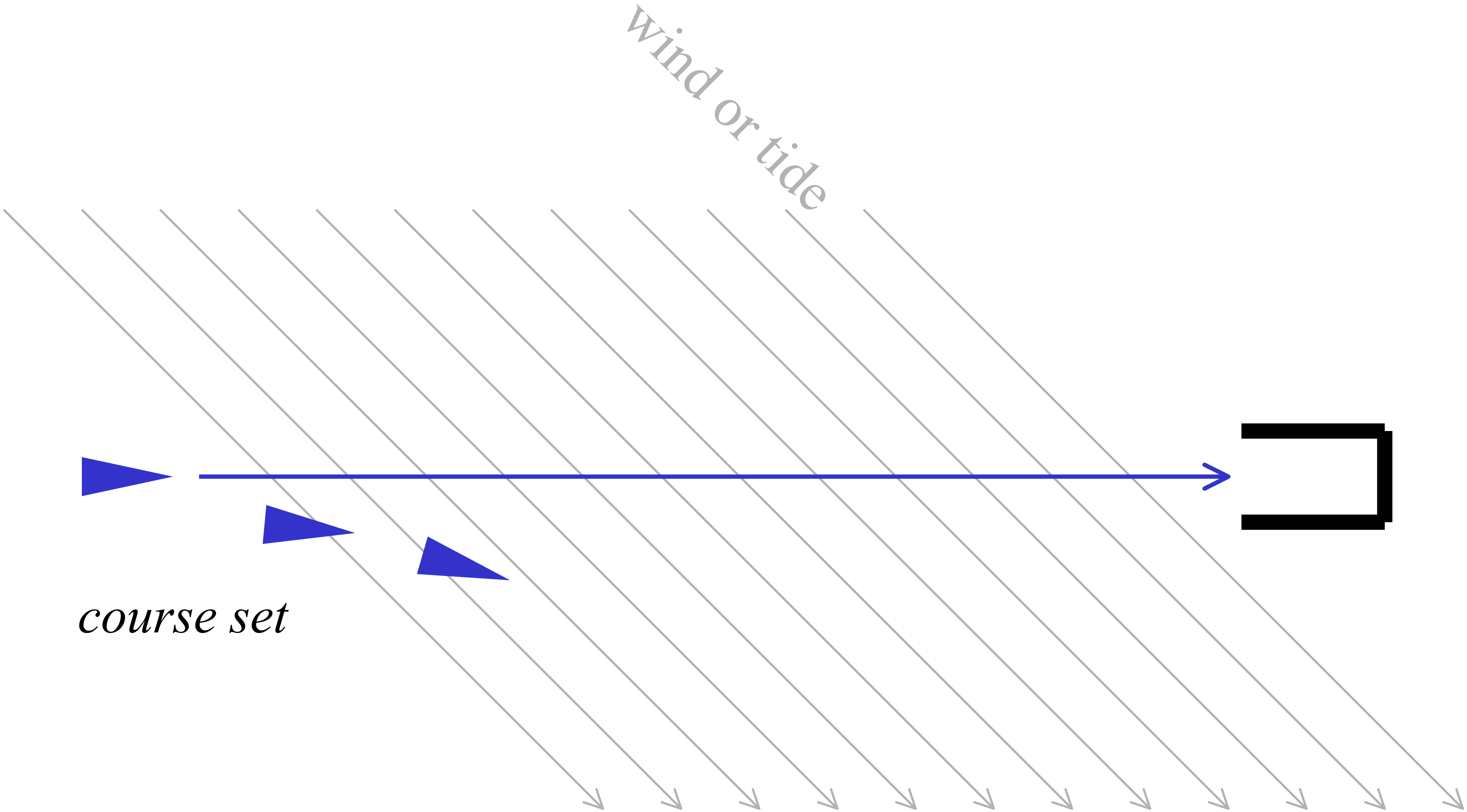
Steering



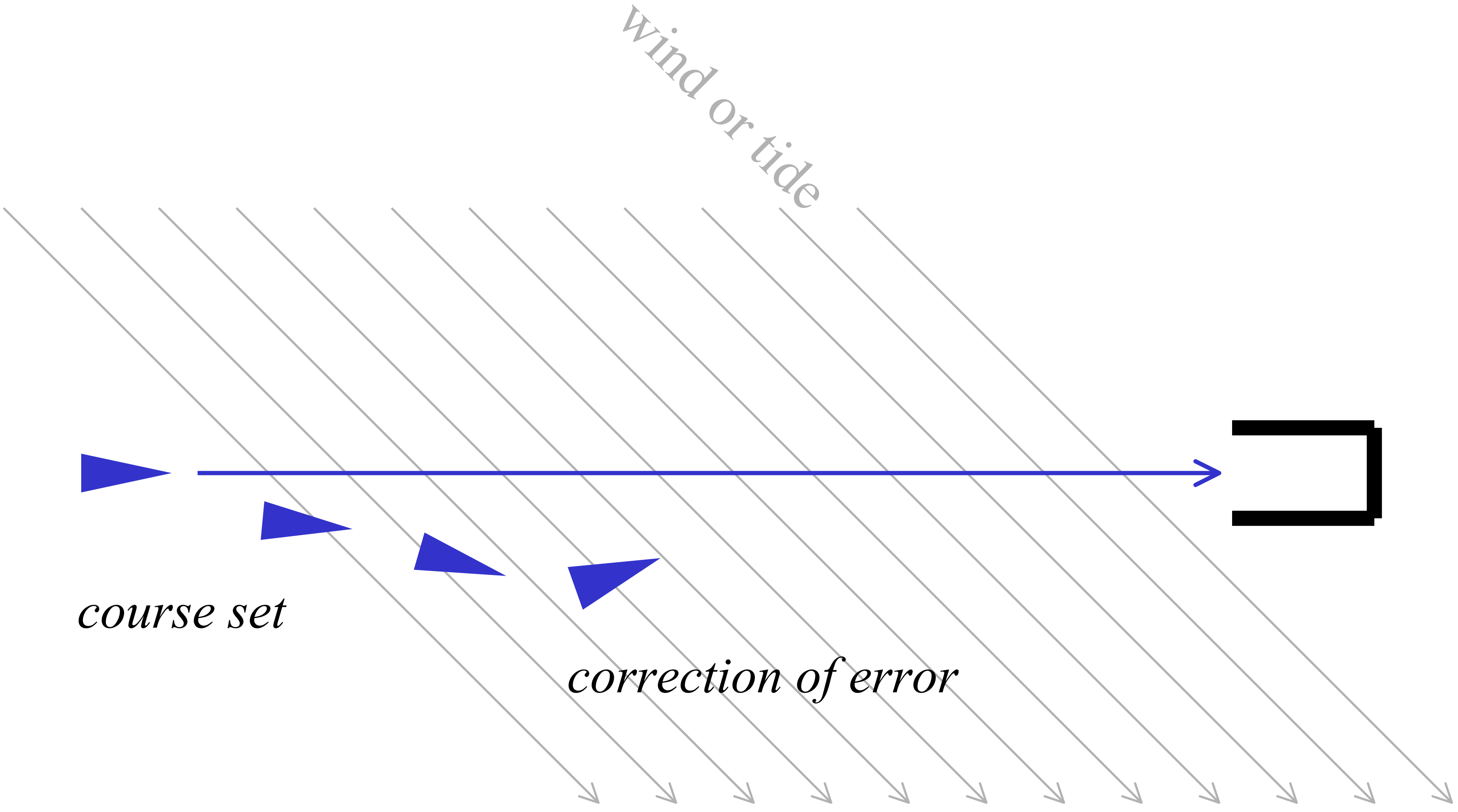
Steering



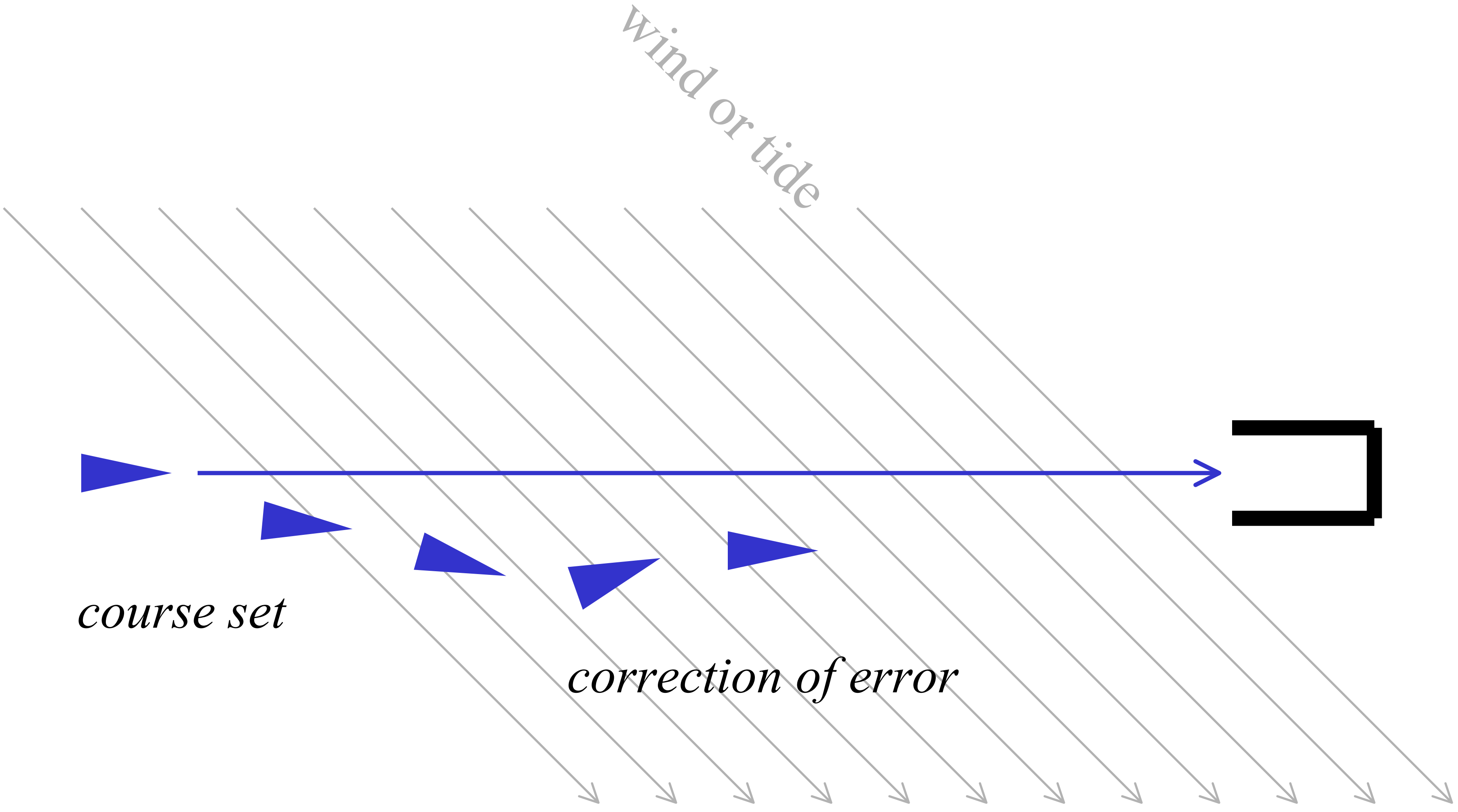
Steering



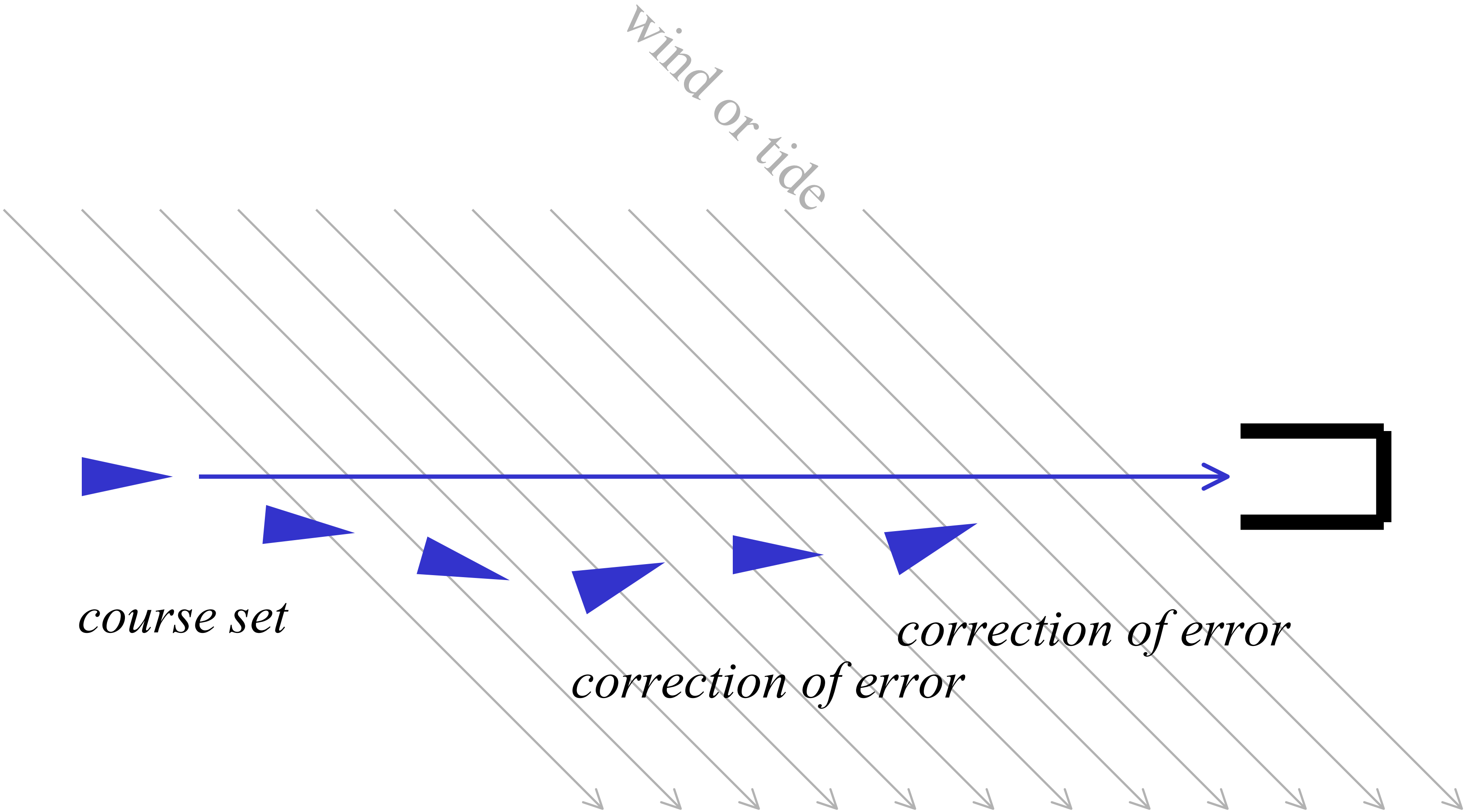
Steering



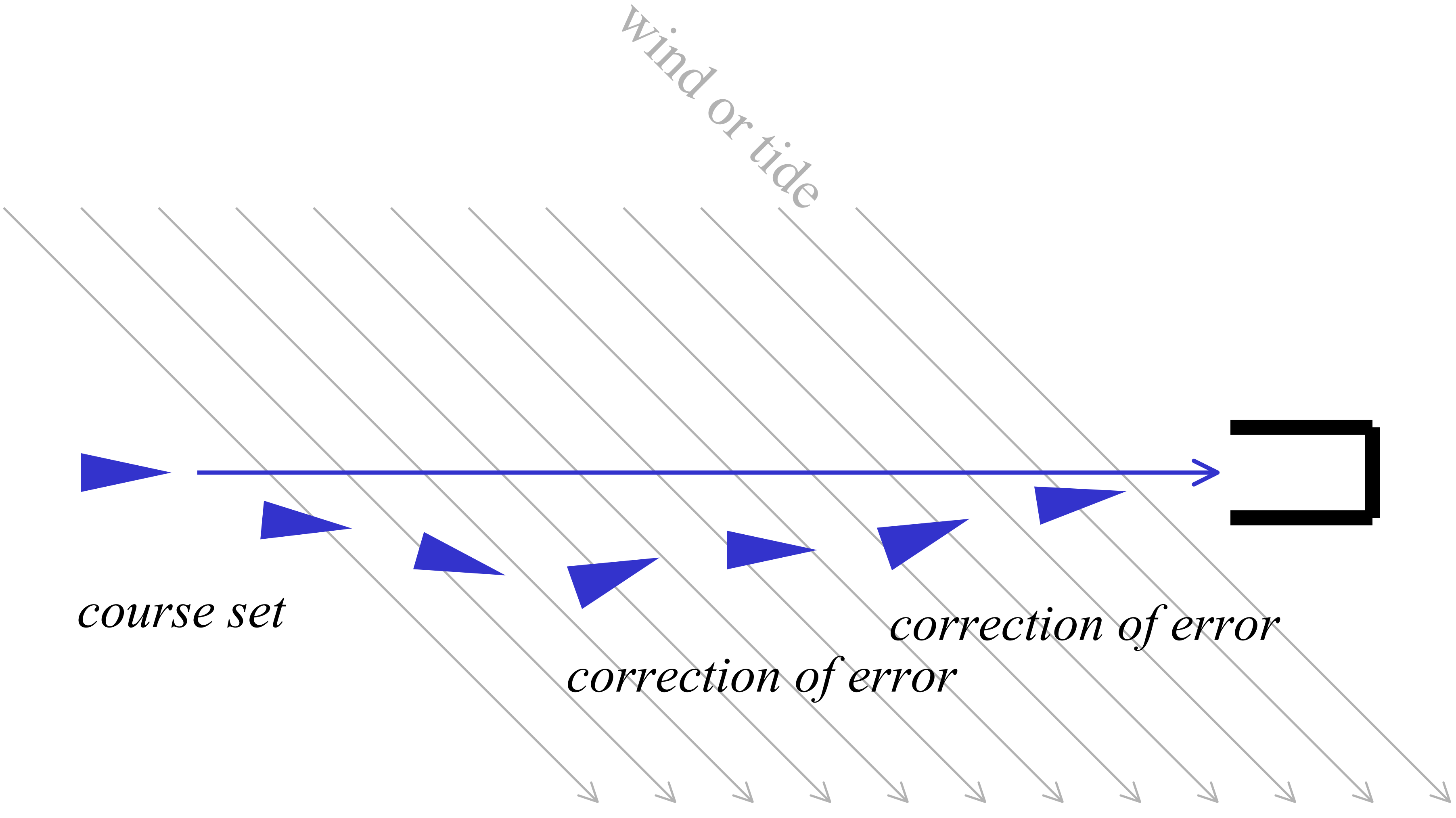
Steering



Steering


wind or tide
course set
correction of error
correction of error

Steering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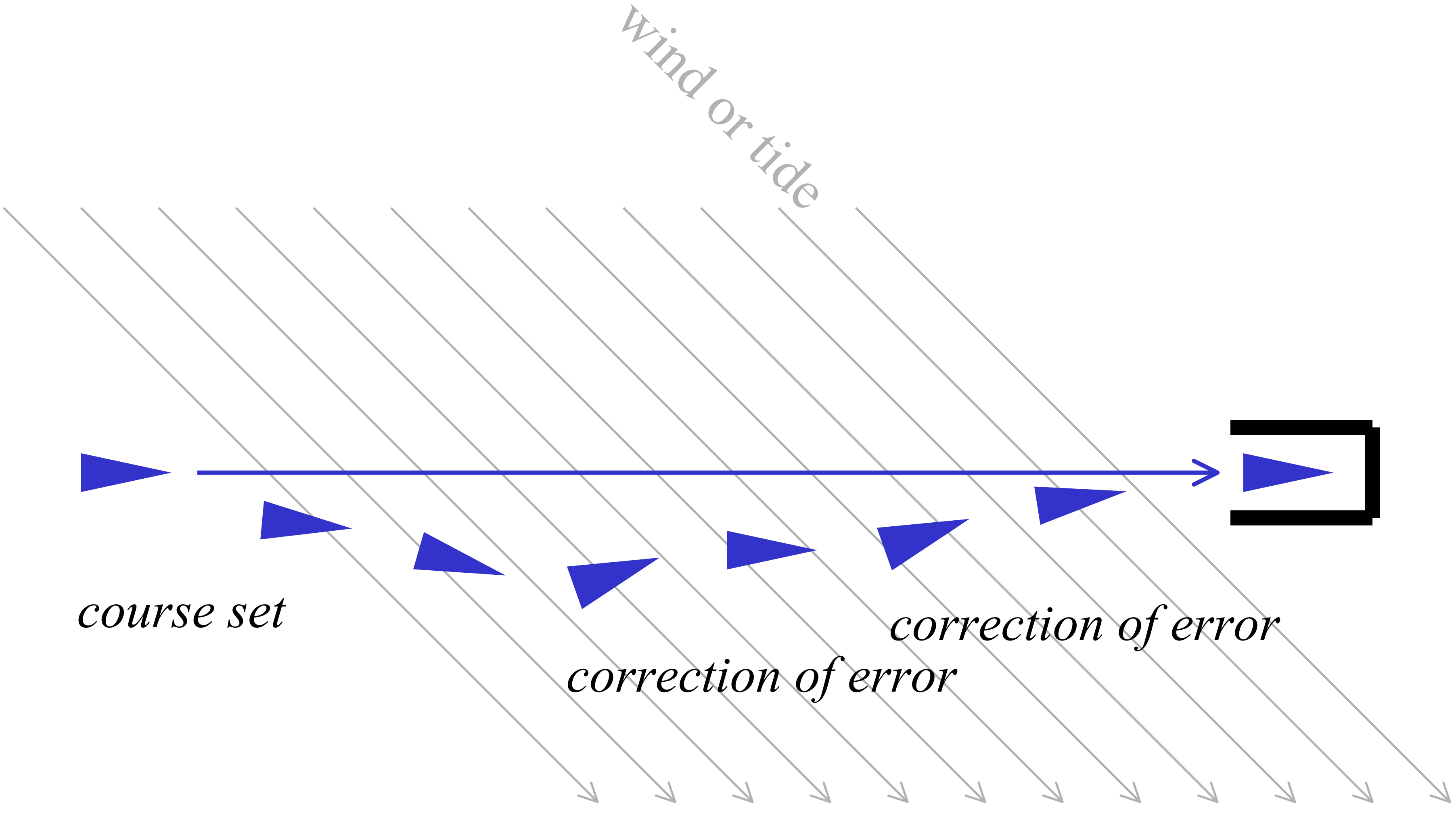
Steering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Cybernetics named

From Greek ‘kubernetes’
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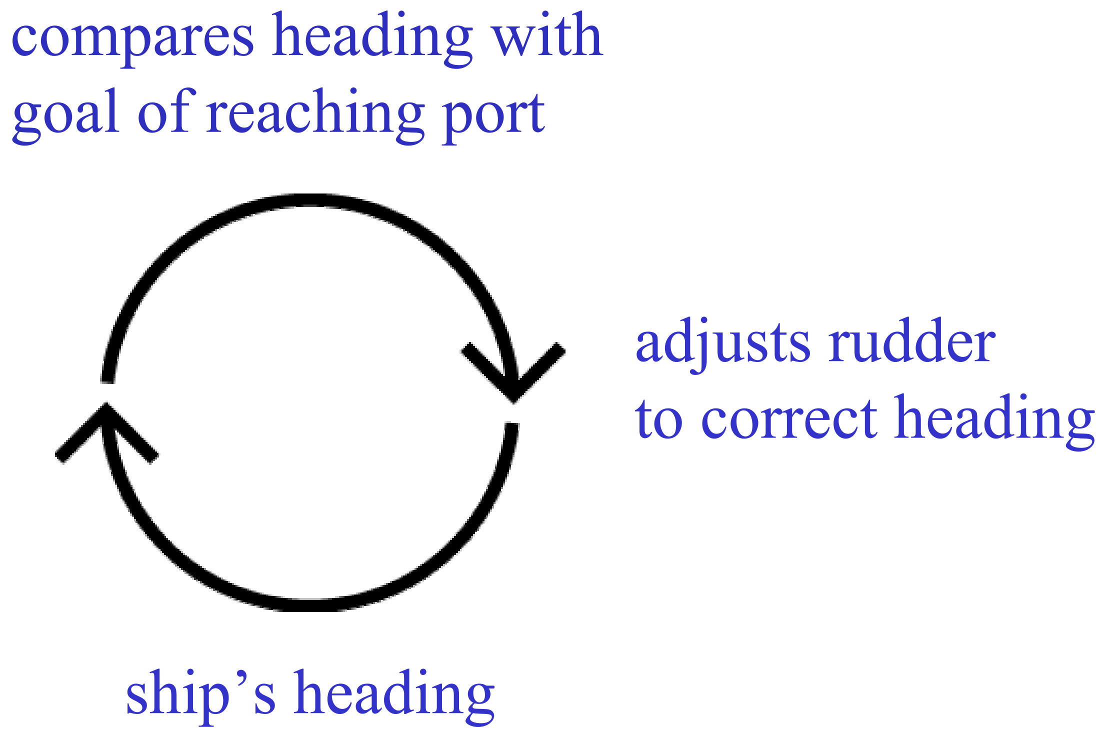
Cybernetic point-of-view
- system has goal
- system acts, aims toward the goal
- environment affects aim
- information returns to system — ‘feedback’
- system measures difference between state and goal
  — detects ‘error’
- system corrects action to aim toward goal
- repeat

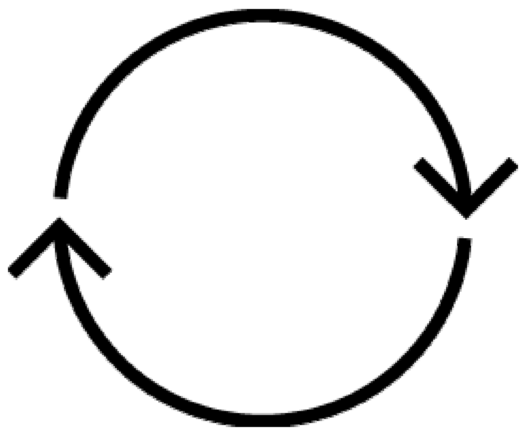
Steering as a feedback loop



Steering as a feedback loop

detection of error

compares heading with
goal of reaching port



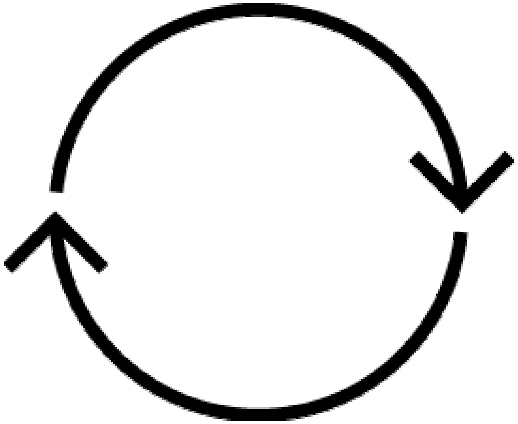
feedback

adjusts rudder
to correct heading

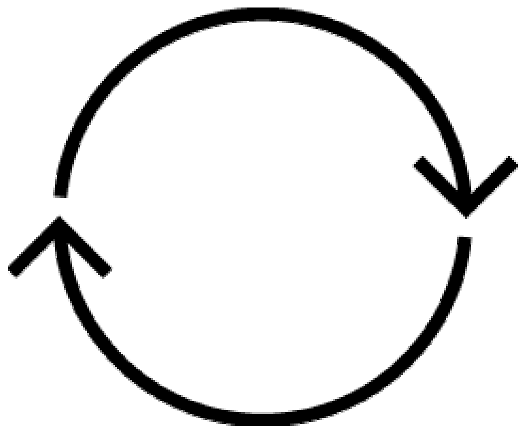
correction of error

ship’s heading

Automation of feedback

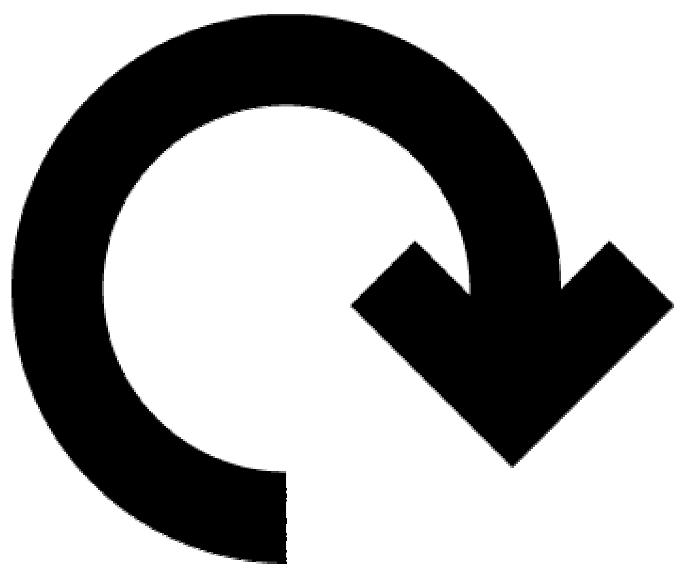


Automation of feedback

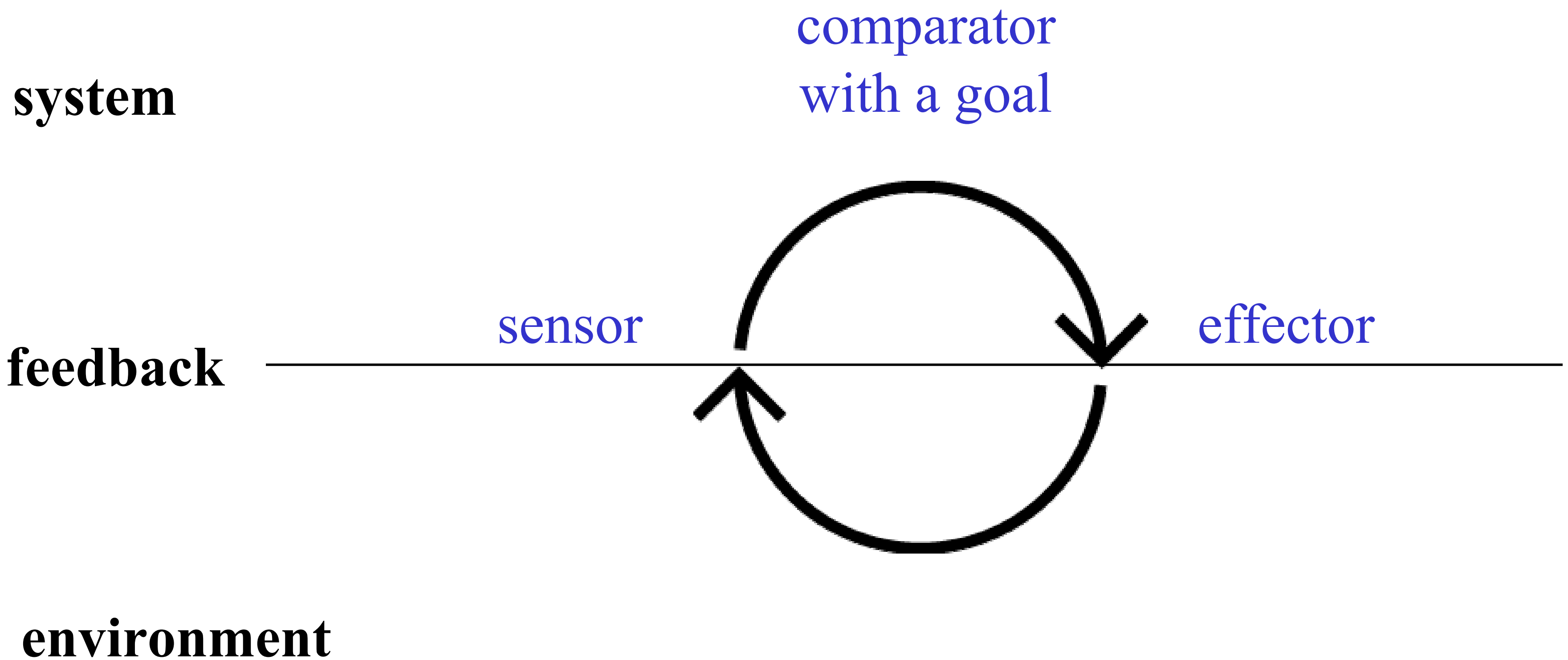


The feedback loop

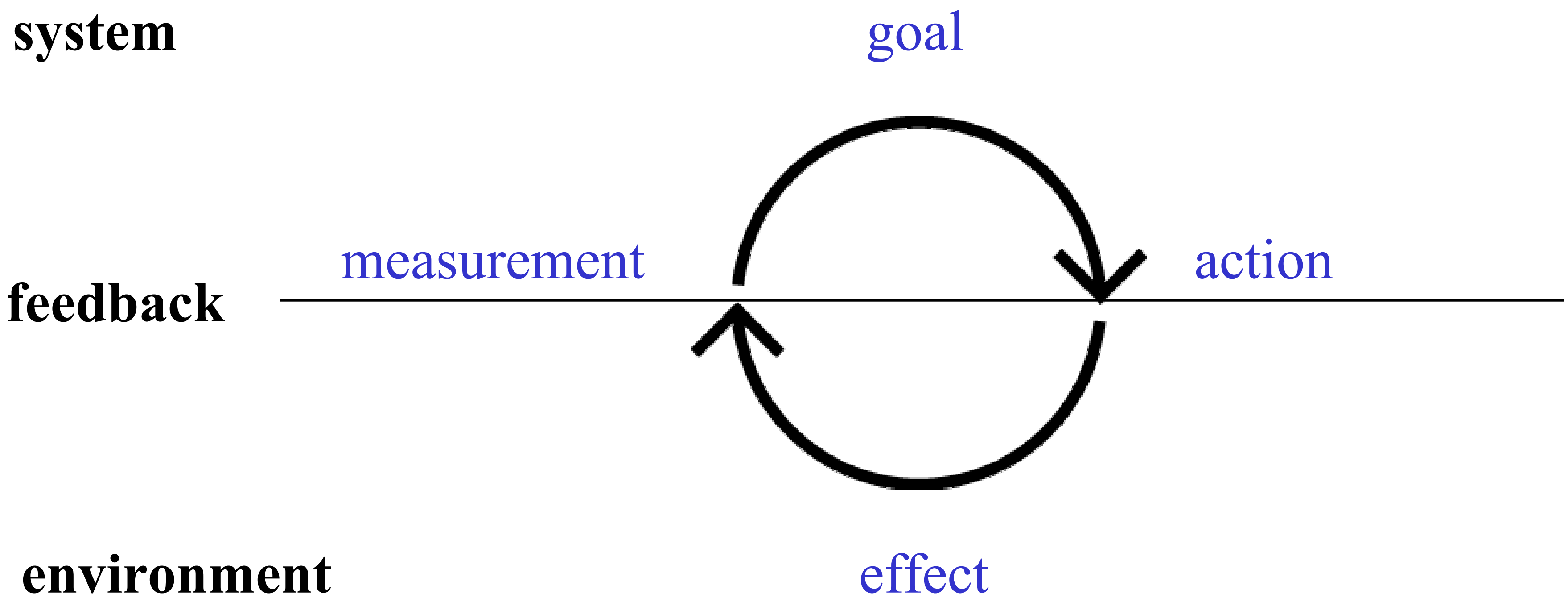
‘Cybernetics introduces for the first time —
and not only by saying it, but methodologically —
the notion of circularity, circular causal systems.’
— *Heinz von Foerster*



Cybernetic terms



Cybernetic modeling



'through-looping'

Cybernetics early uses

‘Cybernetics saves the souls, bodies, and material possessions from the gravest dangers.’

— *Socrates according to Plato*

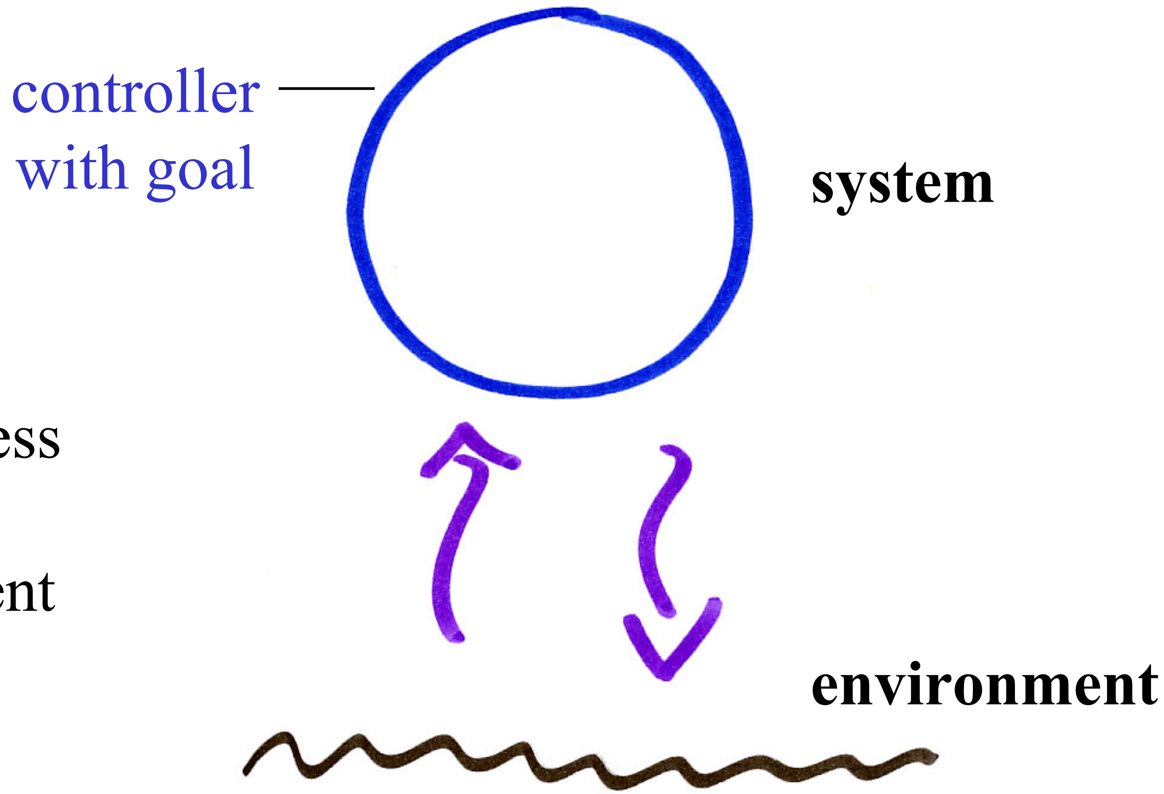
‘The future science of government should be called “la cybernetique.”’

— *André-Marie Ampere, 1843*

‘Until recently, there was no existing word for this complex of ideas, and…I felt constrained to invent one....’

— *Norbert Wiener*

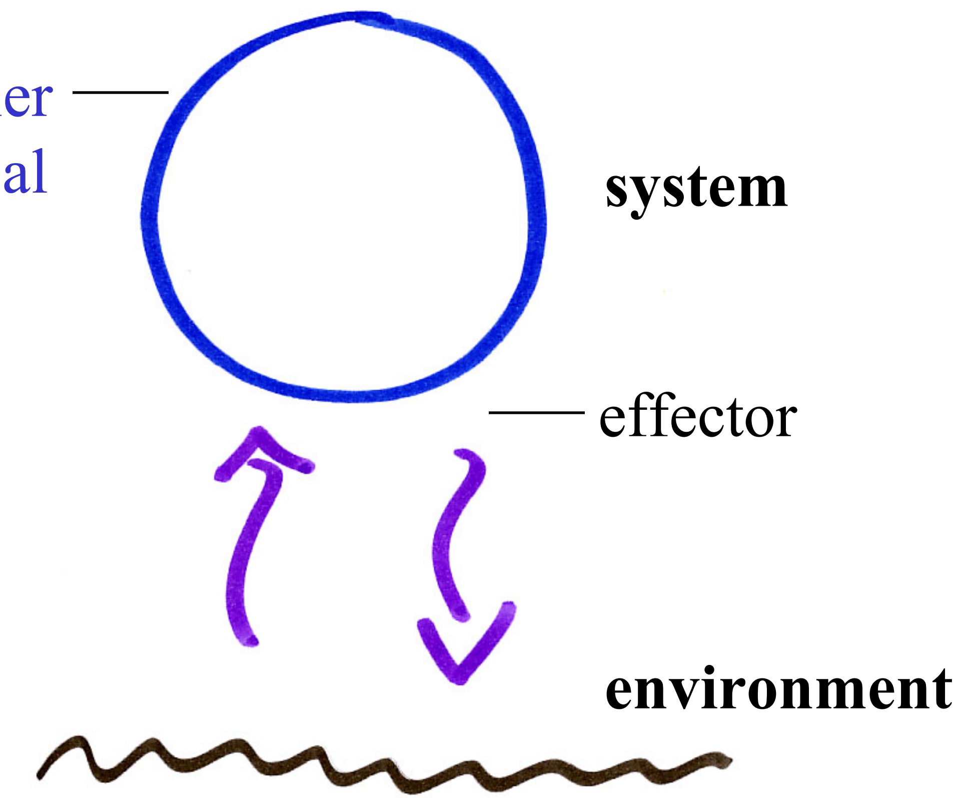
Requisite variety defined



Yes or No—

Does the system possess sufficient variety to regulate its environment and maintain its goal?

Requisite variety—effectors



Sufficient variety?

- What are the parameters in the environment that the system can effect?

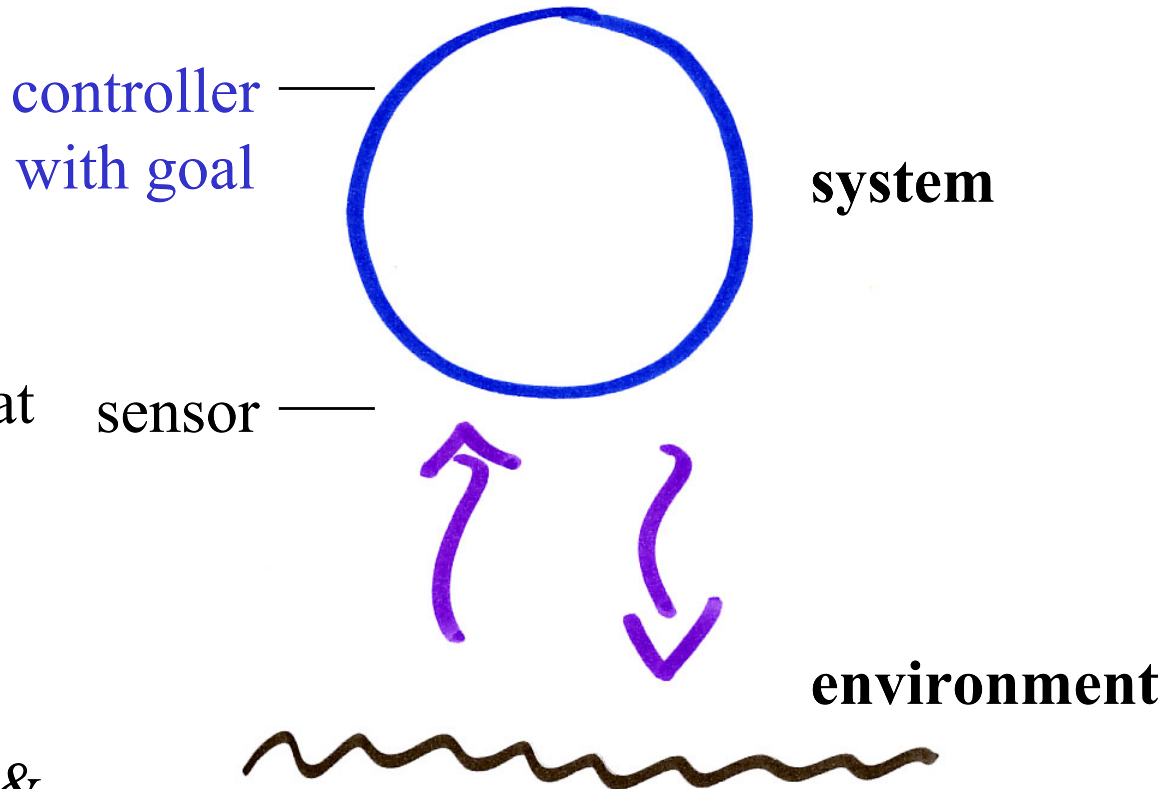
- Within what range of those parameters can the system maintain control?

Requisite variety—sensors

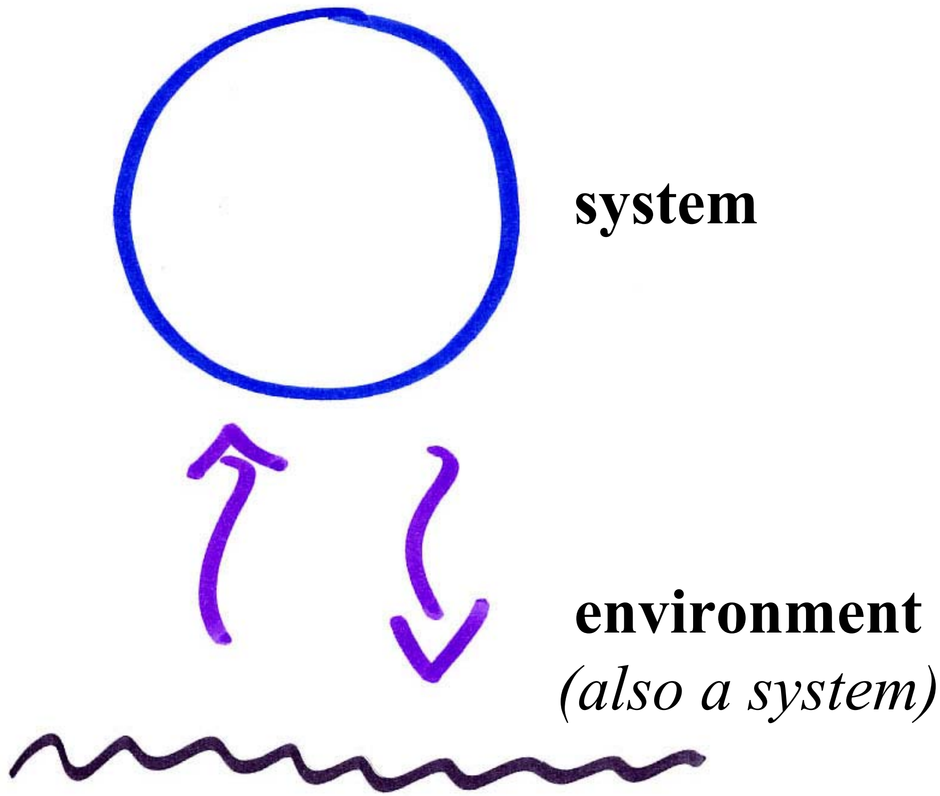
Sufficient variety?

- Is there sensing of environment such that deviations from goal can be detected?

- Do the sensors have sufficient resolution & speed so that the system can respond in time?



But who defines ‘system’?



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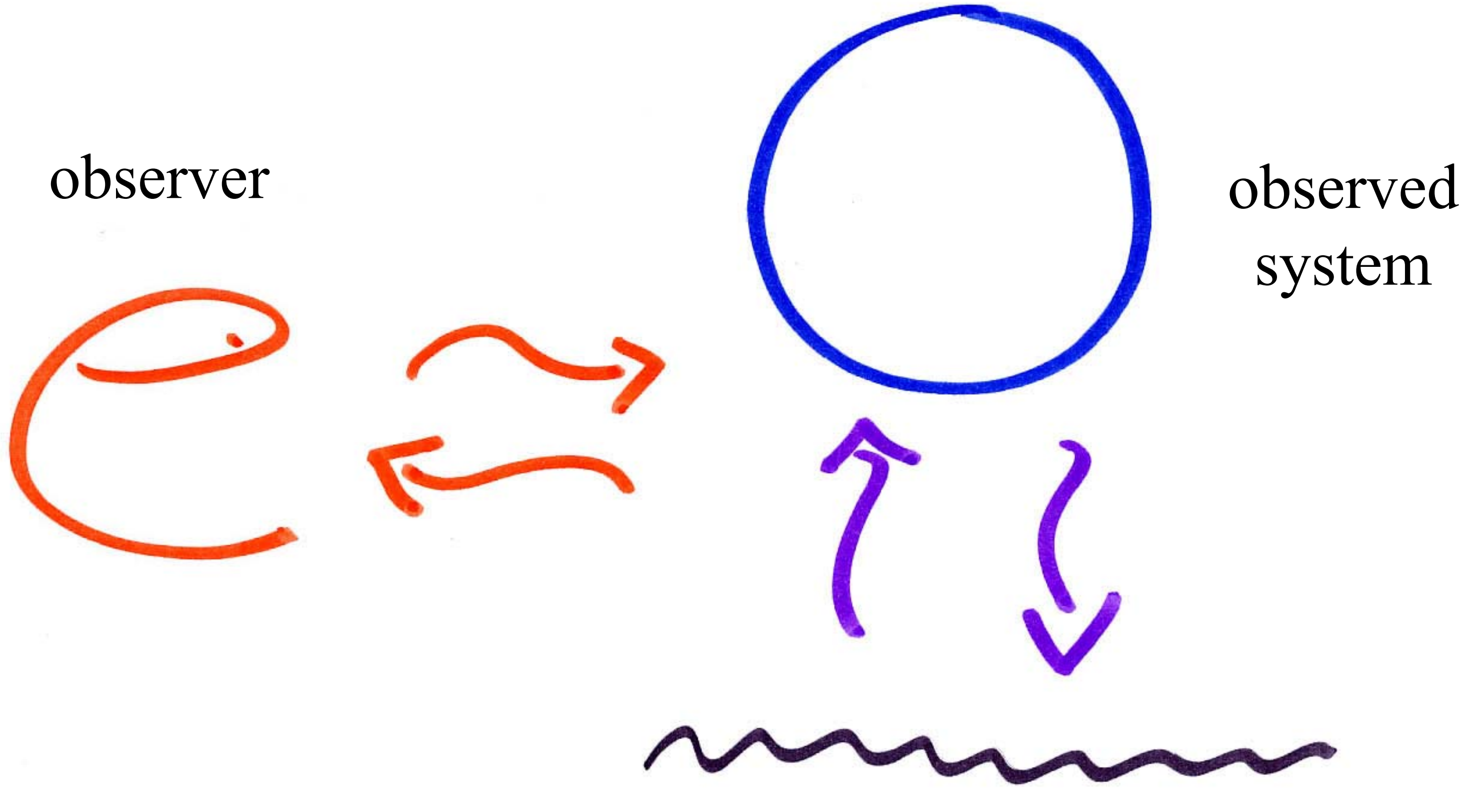
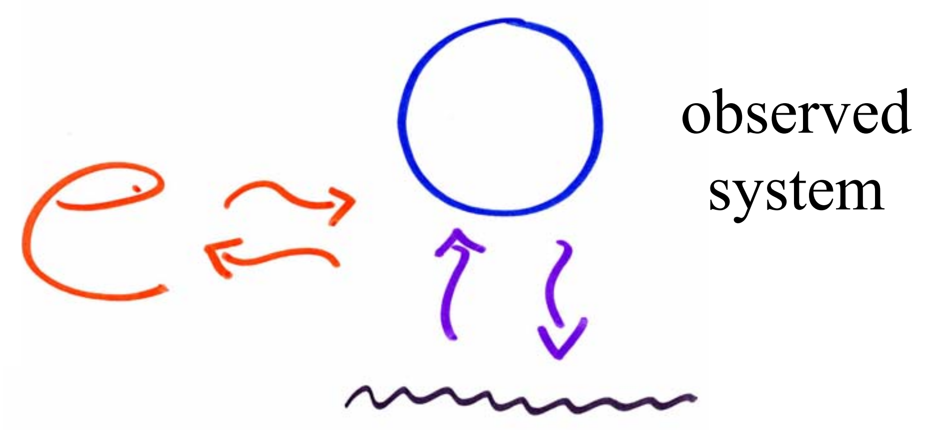


The introduction of subjectivity

1st-order cybernetics

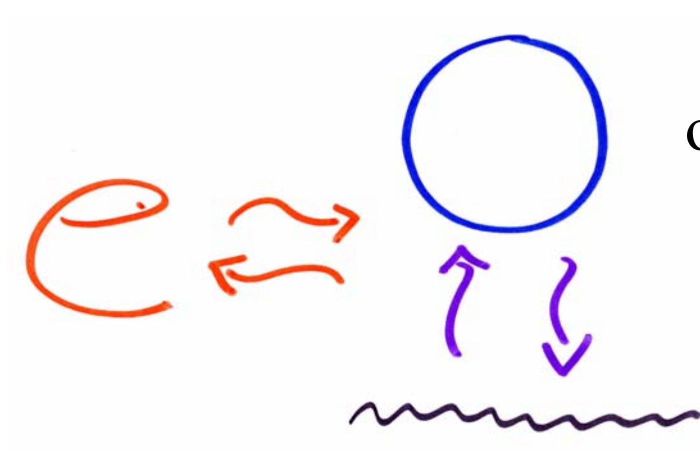


The introduction of subjectivity

2nd-order cybernetics

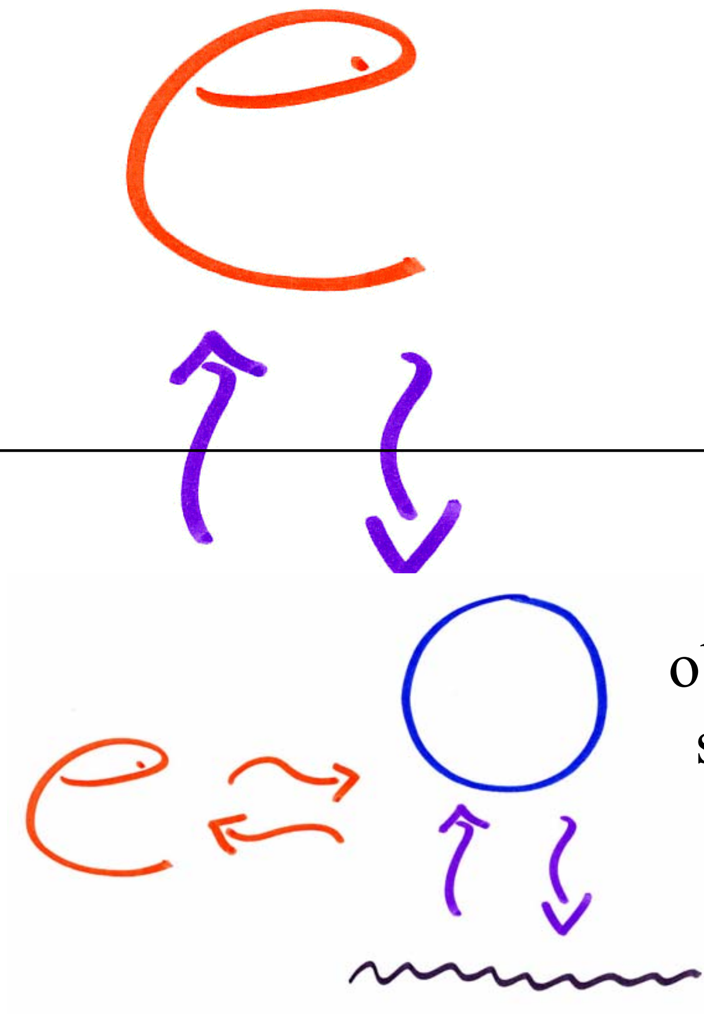
1st-order cybernetics

observing
system



observed
system

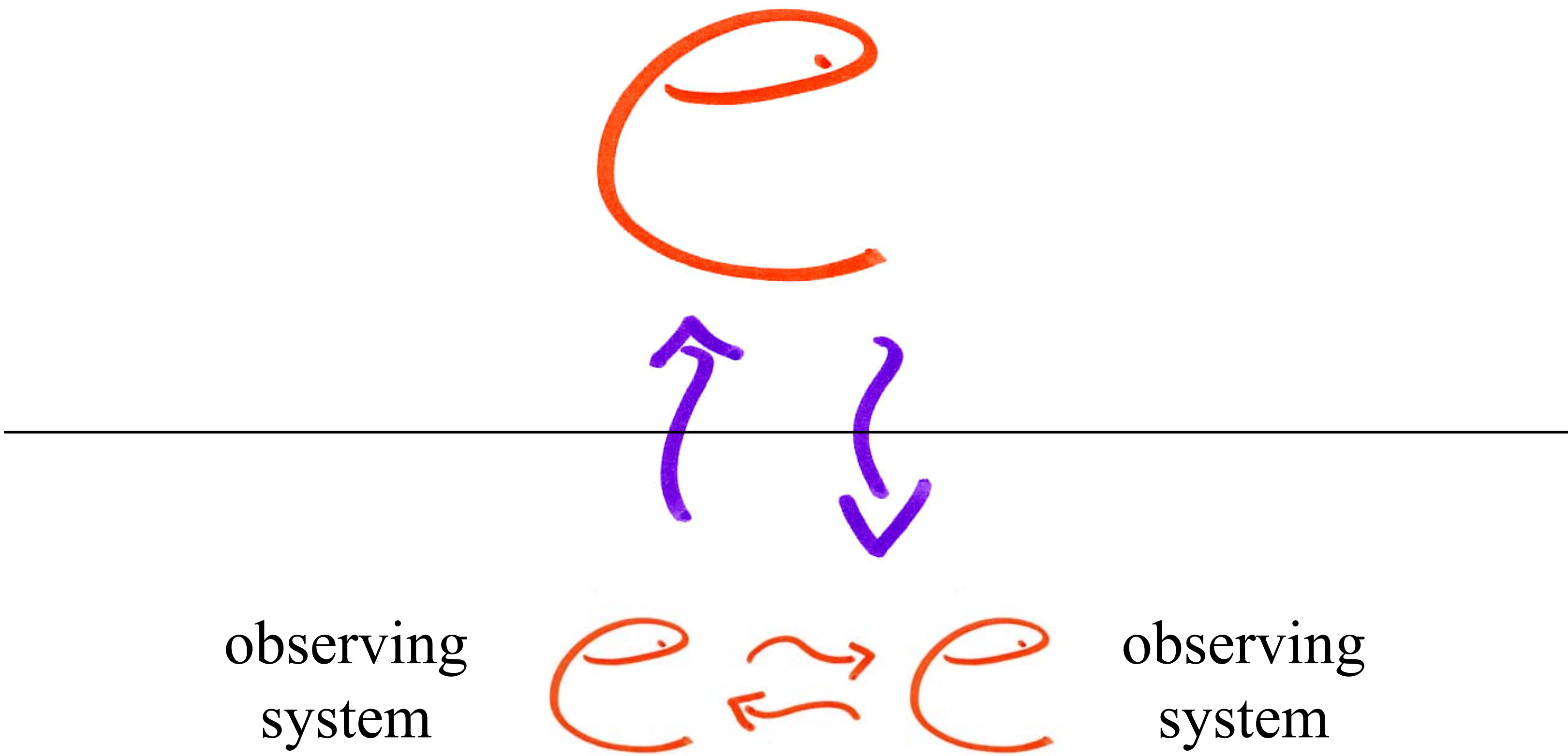
Observing the observer



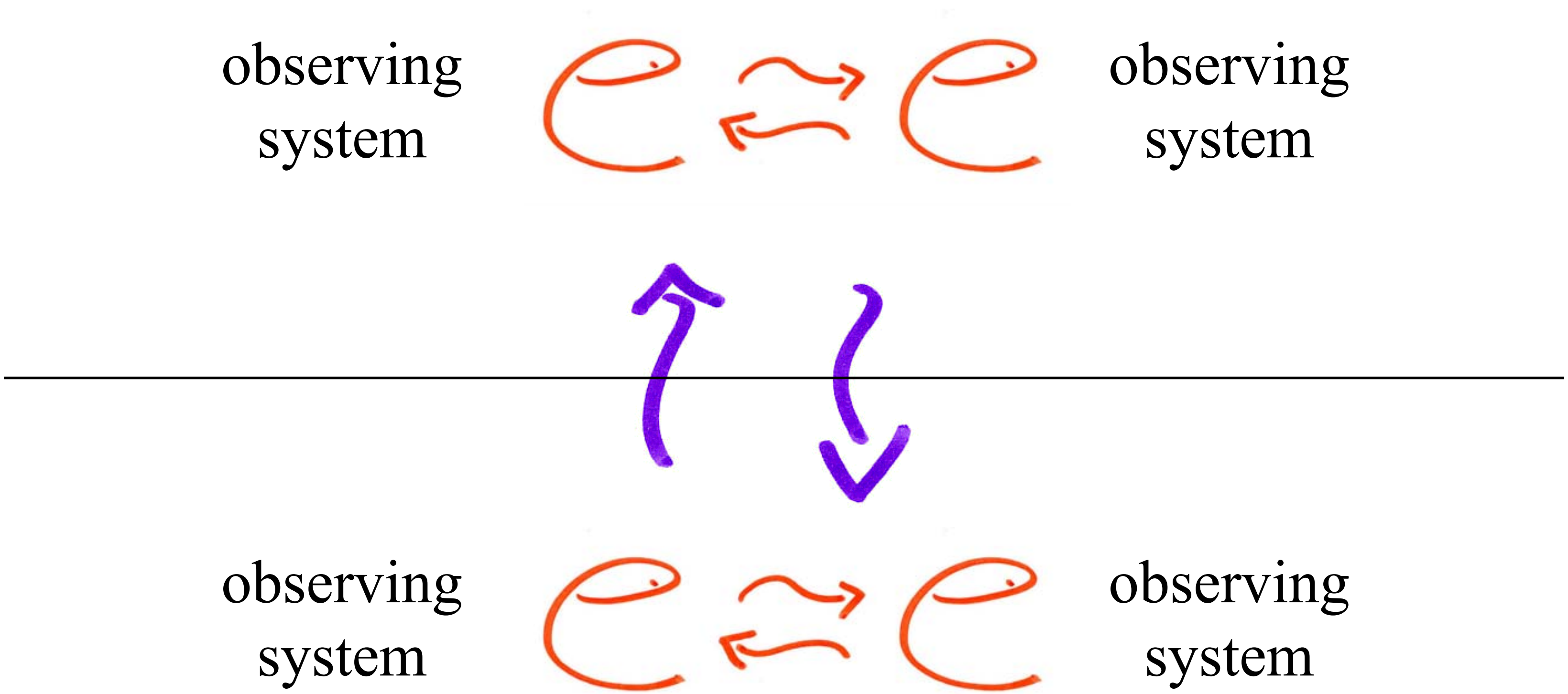
observing system

observed system

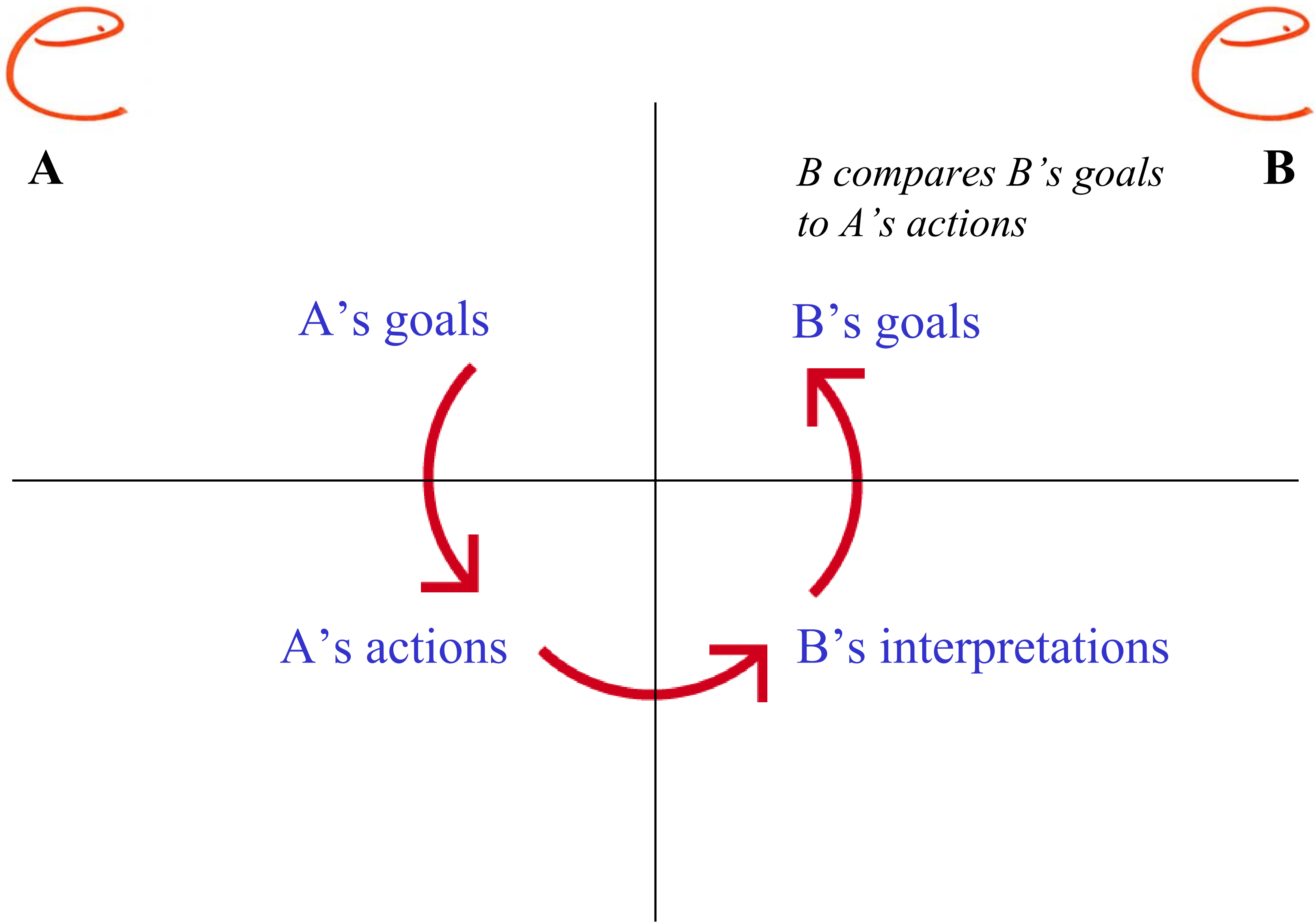
Observing conversations



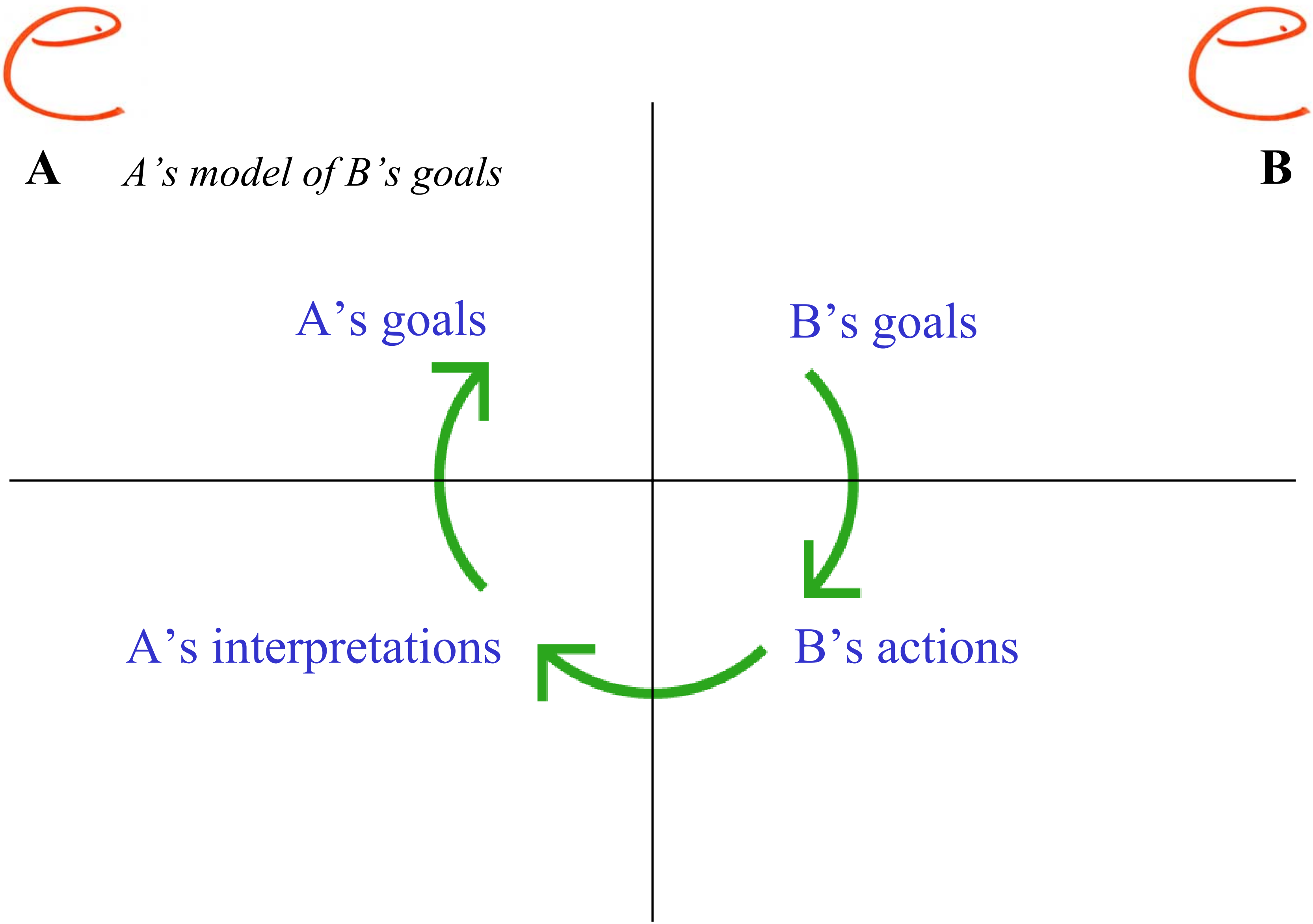
Conversations about conversations



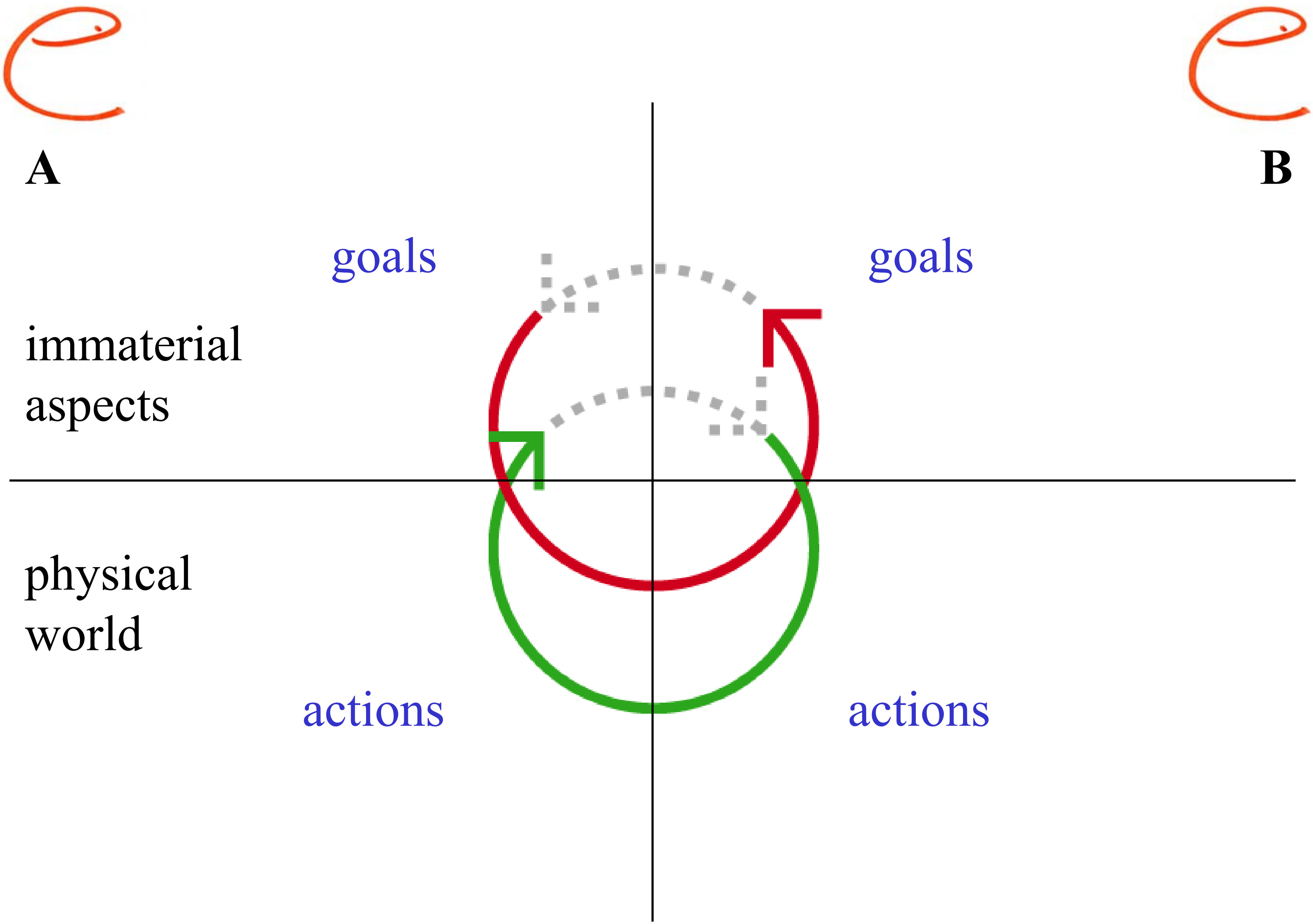
Defining ‘interaction’



Defining ‘relationship’



Defining ‘conversation’



Domain of cybernetic modeling

Includes goals — the ‘why’ of actions as well as ‘how’

- Systems are defined by boundaries
- Systems have goal(s)
- Information flow from the environment to the system relevant to achieving a goal defines ‘feedback’

Goals bound to actions, actions bound to goals

— *‘through-looping’*

Systems as abstractions

- Not about what a system is made of
- Not delimited by subject domain or discipline or distinctions such as biological, physical, ecological, psychological, or social

Goals of cybernetic modeling

See causality as a loop

- Shift from hierarchy of power to participation in shared goals

Place actions in the context of goals

Understand what is possible for a system

- Possibilities are defined by ‘requisite variety’ (RV)
- RV enables the design of changes to the system to improve it

Measure the degree of mutual understanding

- Define ‘conversation’, ‘agreement’

Define and realize ‘intelligent systems’

Discuss participation, choice, ethics

Scope of cybernetics

Explanation of communication = *psychology*
Modeling of learning = *cognitive science*
Limits of knowing = *epistemology*
Hearer makes the meaning = *post-modernism*
Reality as social construction = *constructivism*
Reliable methodologies of describing = *science*

Measuring understanding & agreement
= *science of subjectivity*
= *second-order cybernetics*

Cybernetics quoted

‘…communication and control in animal and machine’
— *Norbert Wiener*

‘… the science of observing systems’
— *Heinz von Foerster*

‘… the art of defensible metaphors’
— *Gordon Pask*

‘… the study of the immaterial aspects of systems’
— *W. Ross Ashby*

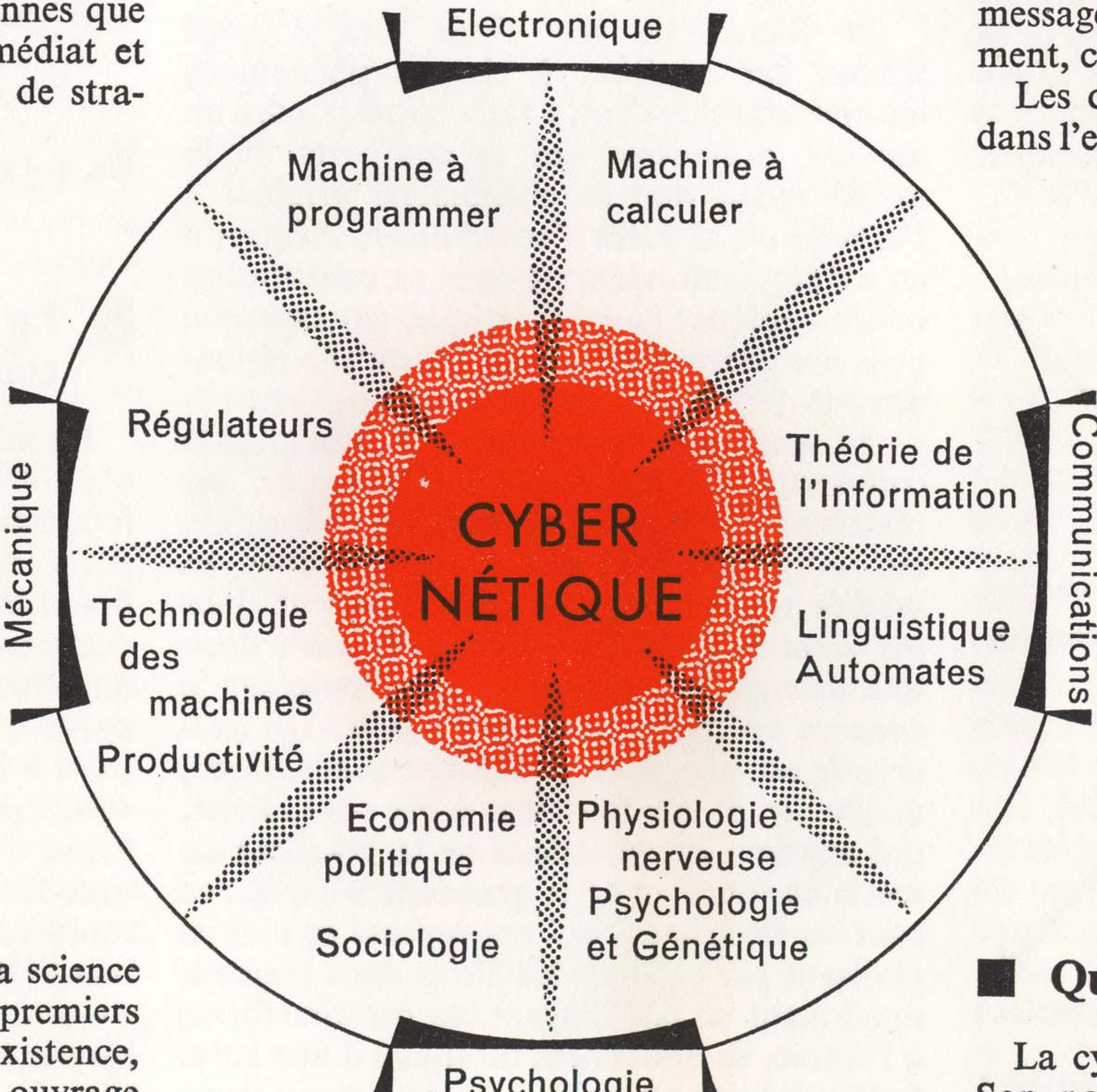
‘… only practiced in Russia and other under-developed countries’
— *Marvin Minsky*

de dormir, de travail-
lite artificiel est plus
ons quotidiennes que
concret, immédiat et
es centaines de stra-

ntôt qua-
it imbiber
oins spec-
nédiats: la
ro, l'auto-
ninoir, le
radio sont
révolution
lle phéno-
ue le flux
à notre
is en mou-
nucléaire
n'influera
qu'au jour
ure d'élec-
ème de ce
car nous
guer.

aspects de la science
ii ont les premiers
n de notre existence,
me de cet ouvrage

Fig. 2. Cybernétique, science-carrefour.

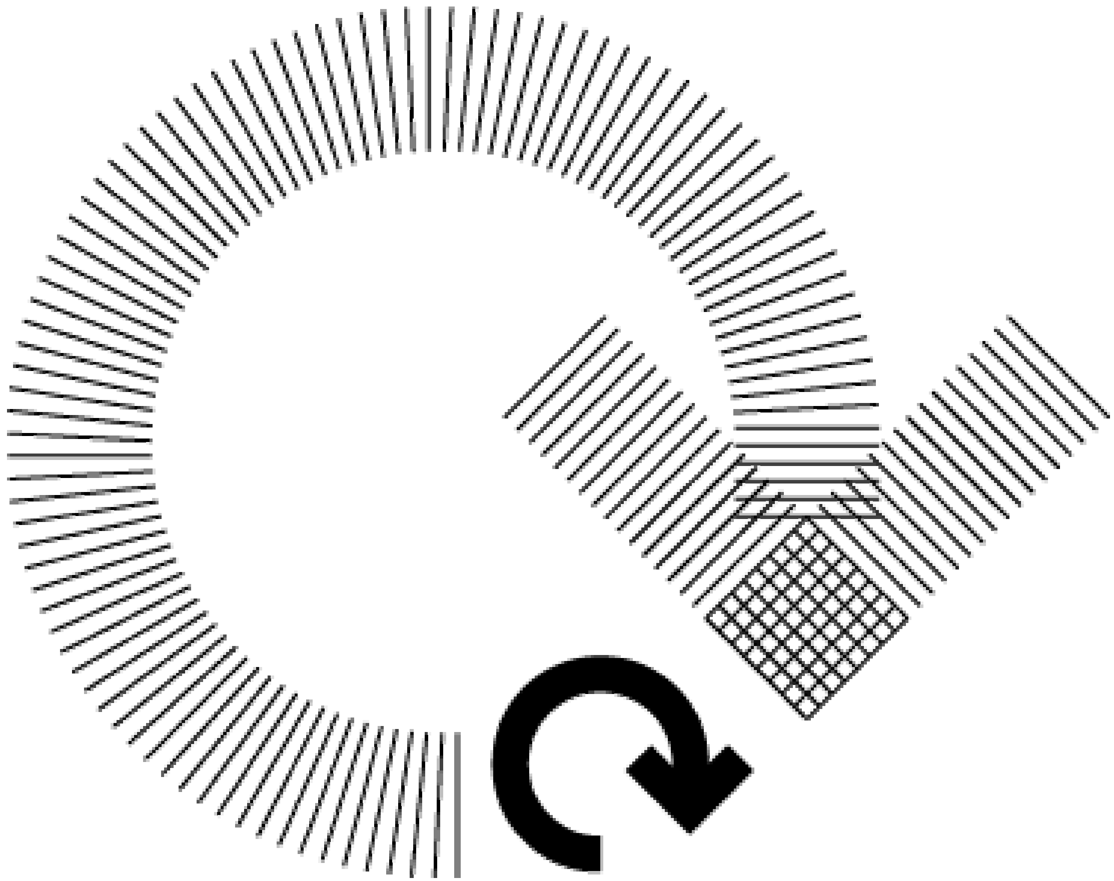


du *pouvoir* de l'hon
teur et sa *complexit*
messages qui mettent
ment, constitue une
Les découvertes s
dans l'esprit des hom
des vieux
la physiq
sionne pa
Prométhé
qu'il app
science, l
trouve sa
mythes ét
celui de
Frankenst
son œuvre
et van Ker
quelquefo
nouvelle s
à la puiss
l'on peut
de la cybe

■ Qu'est-ce que

La cybernétique e
Son nom platonicie

Cybernetics summarized



Appendix

A brief history of Cybernetics and Systems Design

Early self-regulating systems (non-biological)

~300 BC, Ktesibios, Alexandria credited with inventing a water clock with a self-regulating water supply

~200 BC, Heron, Alexandria invented an inexhaustible goblet, wrote *The Pneumatica*

~1588, Mill-hopper, UK, regulated flow of grain

~1620, Cornelis Drebbel, Holland, invented a float-based thermostat

~1745, E. Lee, fantail pointed windmill into wind

Modern self-regulating systems

1788, James Watt patented the fly-ball governor

1868, James C Maxwell paper: *On Governors*

1883, Warren Johnson, Milwaukee, patented thermostat (company became Johnson Controls)

1885, Albert Butz patented "damper flapper" (company became Honeywell)

1922, Nicholas Minorsky: *Directional Stability of Automatically Steered Bodies*

GE and Sperry Gyroscope built auto-pilots

1934, Harold Hazen: *Theory of Servo-Mechanisms*

Systems design has its origins right before and during WWII

Cybernetics

- Neuro-systems research
- Anti-aircraft fire control

Operations Research (OR)

- Radar and air force fighter system integration
- Submarine air-patrol resource allocation
- Representation of real-world systems by mathematical models with a view to optimizing outcomes

After the war, OR leads to Systems Analysis

- Later, management science; also management cybernetics

Post-war development

1946, RAND founded in Santa Monica

1951, MIT founds Lincoln Lab to develop SAGE air defense system; MITRE founded to run project

1952, Herbert Simon spends summer at RAND

1955, Ramo-Woolridge (later TRW) awarded contract as overall systems manager for Atlas and Titan missile projects

1969, Ramo: *Cure of Chaos: Fresh Solutions to Social Problems through the Systems Approach*

MIT

- McCulloch, Pitts, Shannon, and Wiener on faculty
- Vannevar Bush, Dean of Engineering, was also President Roosevelt’s Science Advisor
- Servo Lab
- Radiation Lab
- George Valley, Air Defense System Engineering Committee, Project SAGE
- Lincoln Lab
- Negroponte, Architecture Machine Group
- MITRE Corporation (MIT Research & Engineering)

Trans-disciplinary conversation Macy meetings 1946-1953

Wiener & von Neumann . . .	mathematics
Bateson & Mead . . .	anthropology
Warren McCulloch . . .	neurophysiology
Conrad Lorenz . . .	psychology
Heinz von Foerster . . .	physics
. . .	. . .

Conference Subtitle —
'Circular Causal and Feedback Mechanisms
in Biological and Social Systems'

Related publications (selected)

1943, Bigelow, Rosenbleuth, & Wiener: *Behavior, Purpose, and Teleology*

1943, McCulloch & Pitts: *A Logical Calculus of the Ideas in Nervous Activity*

1948, Wiener: *Cybernetics*

1949, Shannon & Weaver: *Mathematical Model of Communications*

1952, Ashby: *Design for the Brain*

1956, Ashby: *An Introduction to Cybernetics*

1961, Pask: *An Approach to Cybernetics*

Cybernetics construed — Norbert Wiener's 1948 subtitle

communication and control

in

animal and machine

1st-order cybernetics

Cybernetics intended

~~communication and control~~ → communication and regulation

in → in

~~animal and machine~~ → goal-directed systems, whether organic or constructed

1st-order cybernetics

Cybernetics evolved —
Heinz von Foerster, Gordon Pask, c.1960s

~~communication and regulation~~ → language and agreement

in → in

~~goal-directed systems,~~ whether organic or constructed → linguistic, goal-directed systems whether organic or constructed

science of observed systems → **2nd-order cybernetics** → *science of observing systems*

HfG Ulm

1953 to 1968, Hochschule für Gestaltung

Wiener, Heidegger, visit and lecture

Fuller, Eames, Bayer, et al. visit

Archer, Rittel on faculty

1962, American design school leaders visit

1966, British design school leaders visit

Classes offered in operations research, cybernetics, and semiotics

Design Methods Movement

1962, conference in London
1962, Rittel leaves Ulm for UC Berkeley
1965, conference in Birmingham
1966, Design Methods group formed at Waterloo
1968, conference in Cambridge, Mass
1971, conference at CalTech
1974, conference at Columbia

Related publications (selected)

1962, Alexander: *Notes on the Synthesis of Form*
1962, Englebart: *Augmenting Human Intellect*
1964, Rittel: *Universe of Design*
1964, Archer: *Systematic Methods for Designers*
1967, Papanek: *Design for the Real World*
1968, Brand: *Whole Earth Catalog*
1970, Jones: *Design Methods*
1972, Negroponte: *Soft Architecture Machine*
1973, Koberg & Bagnal: *Universal Traveler*

Reactions (selected)

1968, City government forces HfG Ulm to close

1972, Churchman and Hoos: *Critiques*

1972, Rittel: *Dilemmas*

1973, Venturi et al.: *Learning from Las Vegas*

Alexander and Jones express concerns

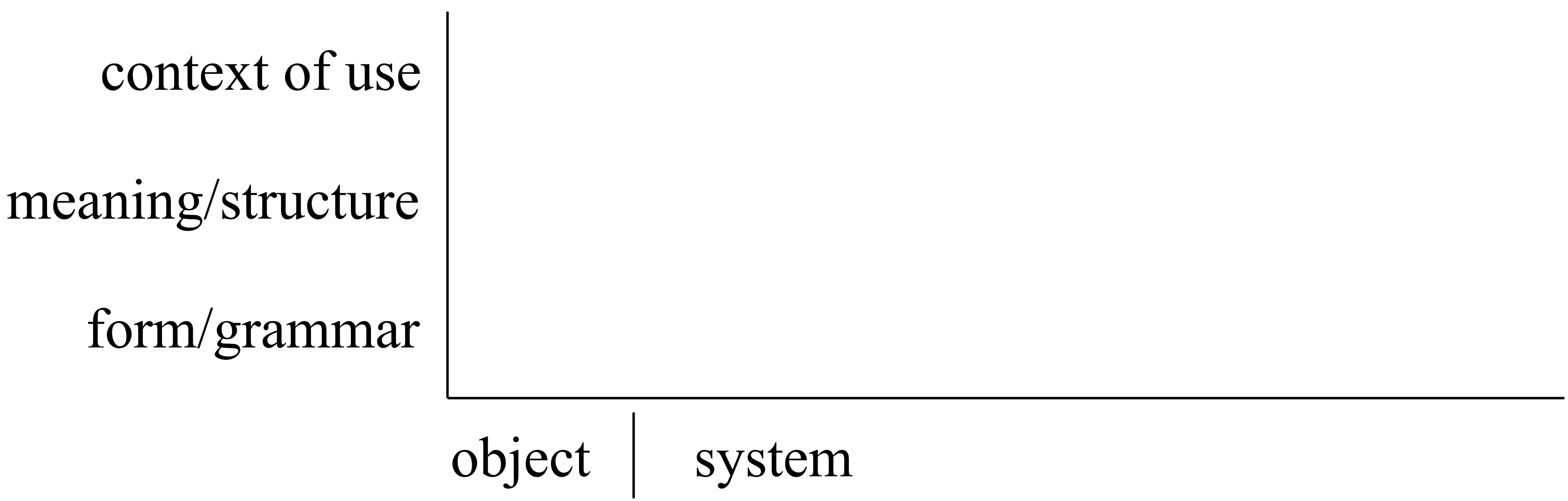
Analogs to cybernetics

Disciplines relying on feedback processes:
Refining and clarifying goals = *design*

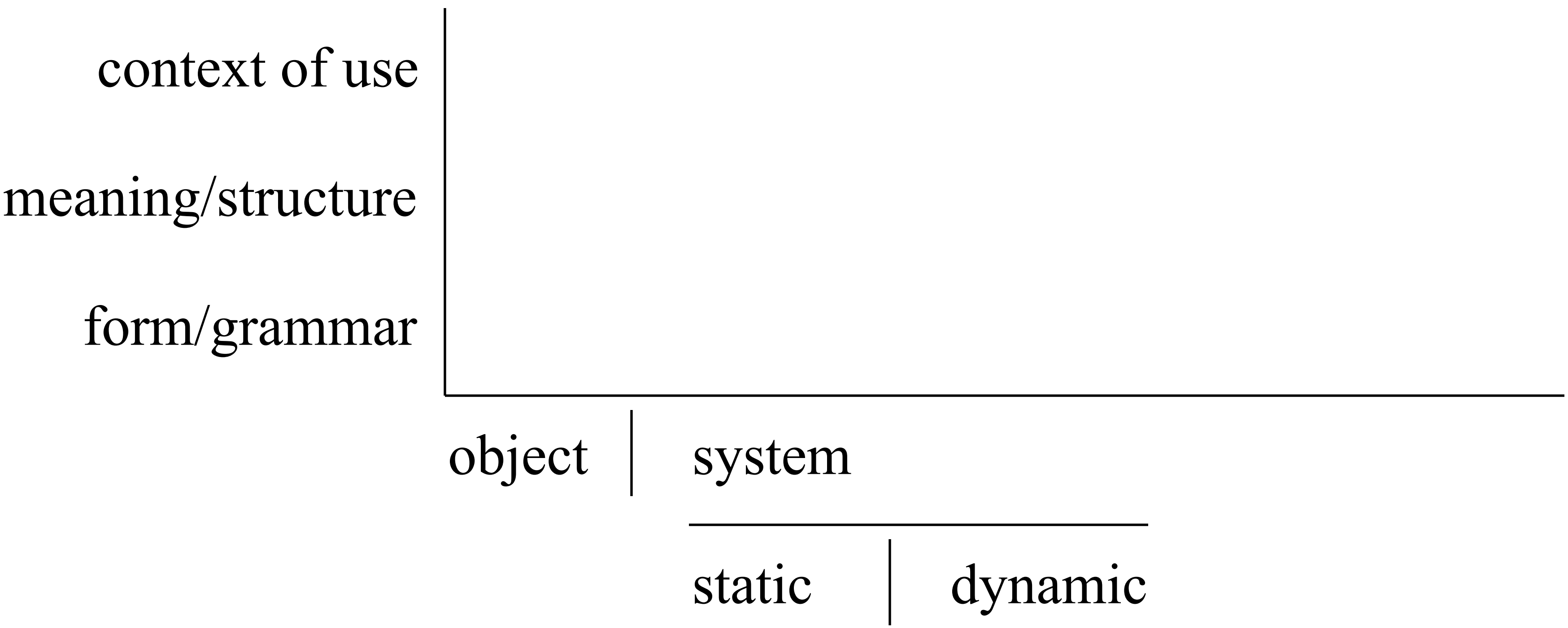
Understanding customer needs = *consultative selling*
Organizing evidence to support conclusions = *law*
Directing and measuring work = *management*
Diagnosing treatments based on symptoms = *medicine*
Specifying appropriate physical systems = *engineering*

When a cybernetic framework is appropriate for design

When a cybernetic framework is appropriate for design



When a cybernetic framework is appropriate for design



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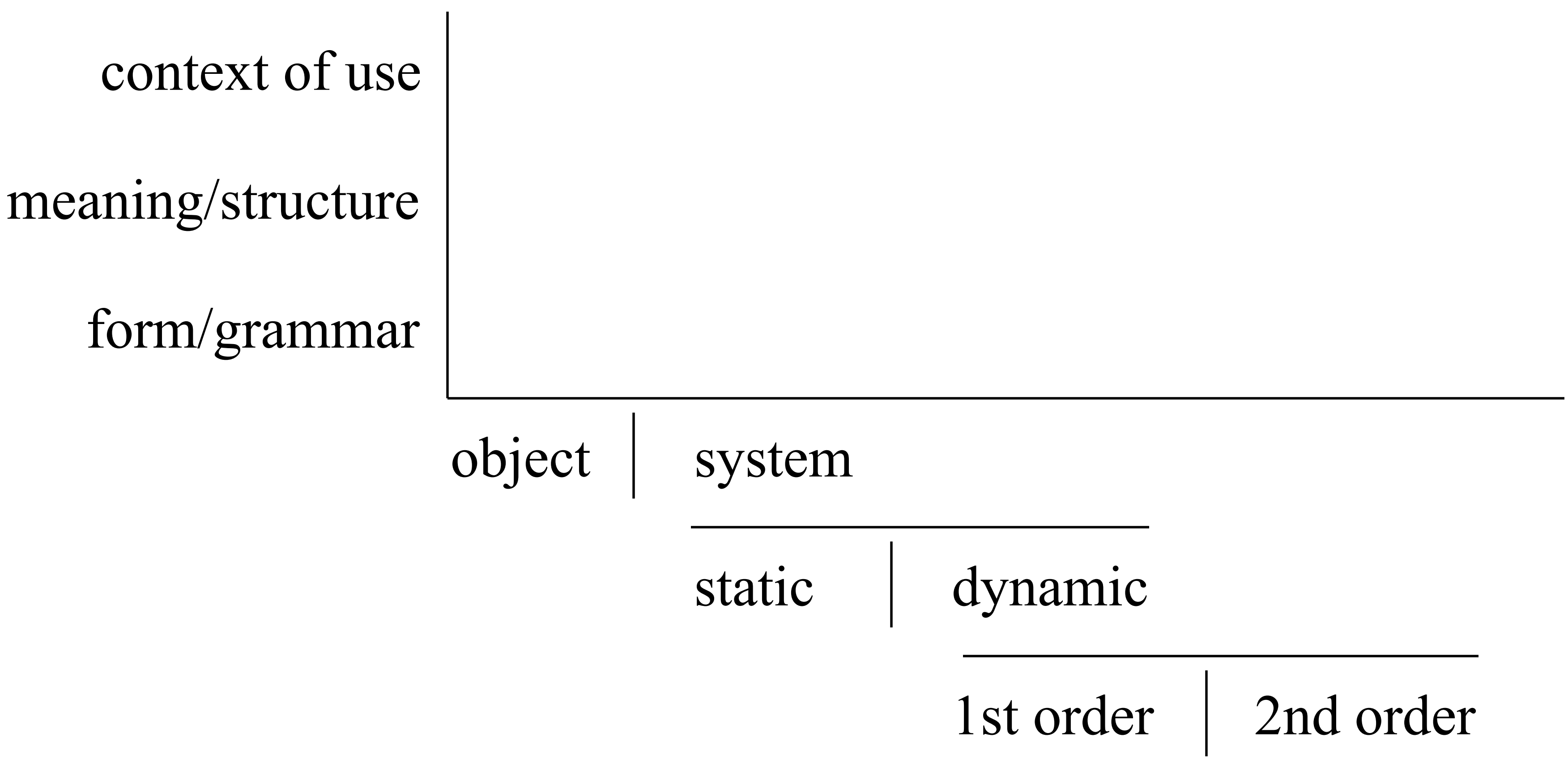
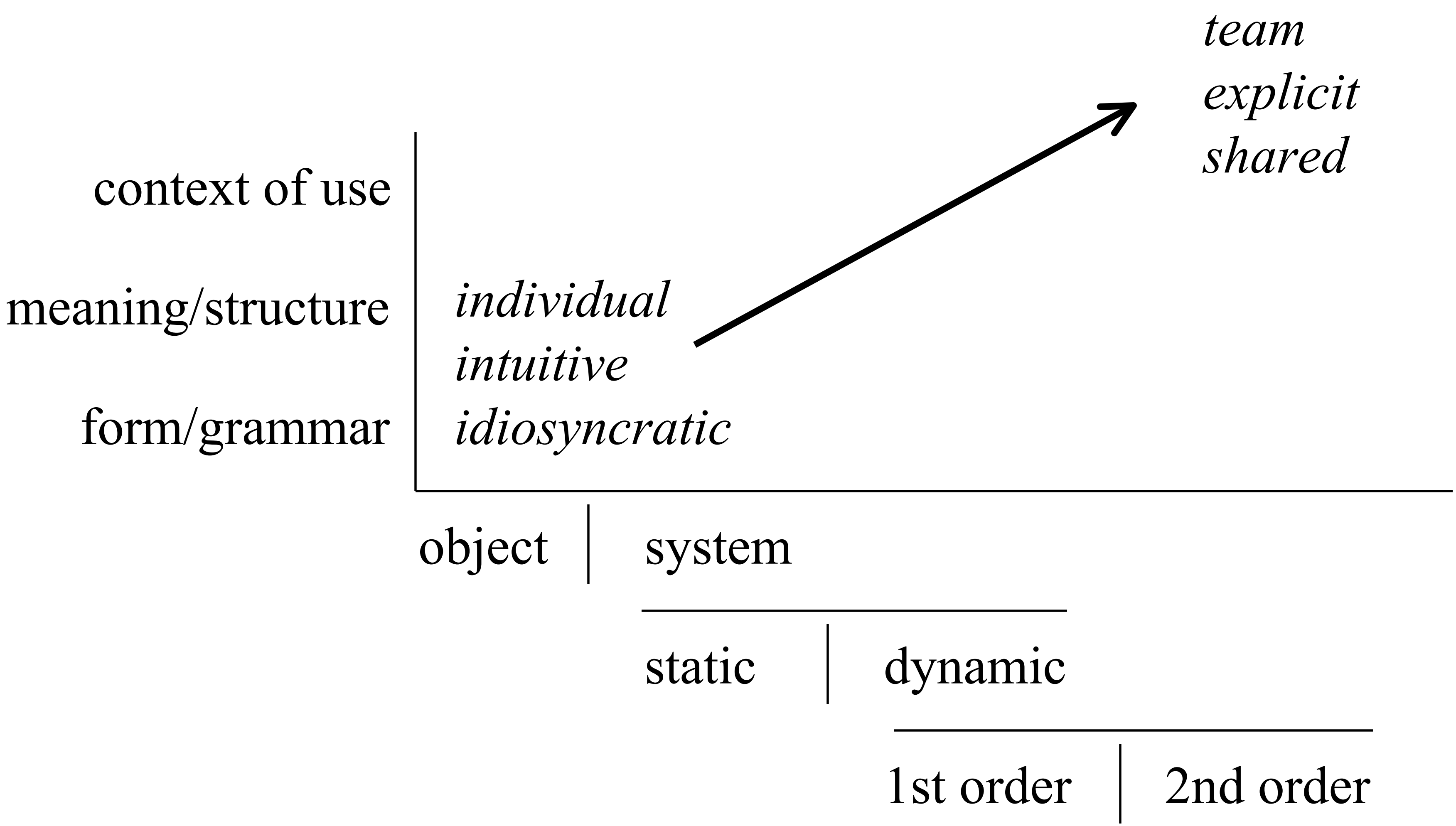


When a cybernetic framework is appropriate for design



The design of goals: ‘how’ problems and ‘what’ problems

In maximization problems . . .

one is attempting to optimize a clearly definable objective function; the solution is embodied in the available data, if they are used correctly.

In choice-of-objectives problems . . .

the fundamental question is the selection of the appropriate mix of goals. The data suggest no solution in themselves.

– *James Schlesinger*