DES203T:
Designing Intelligent Systems

Session 4 (Module-2)

INDIAN INSTITUTE OF INFORMATION TECHNOLOGY,
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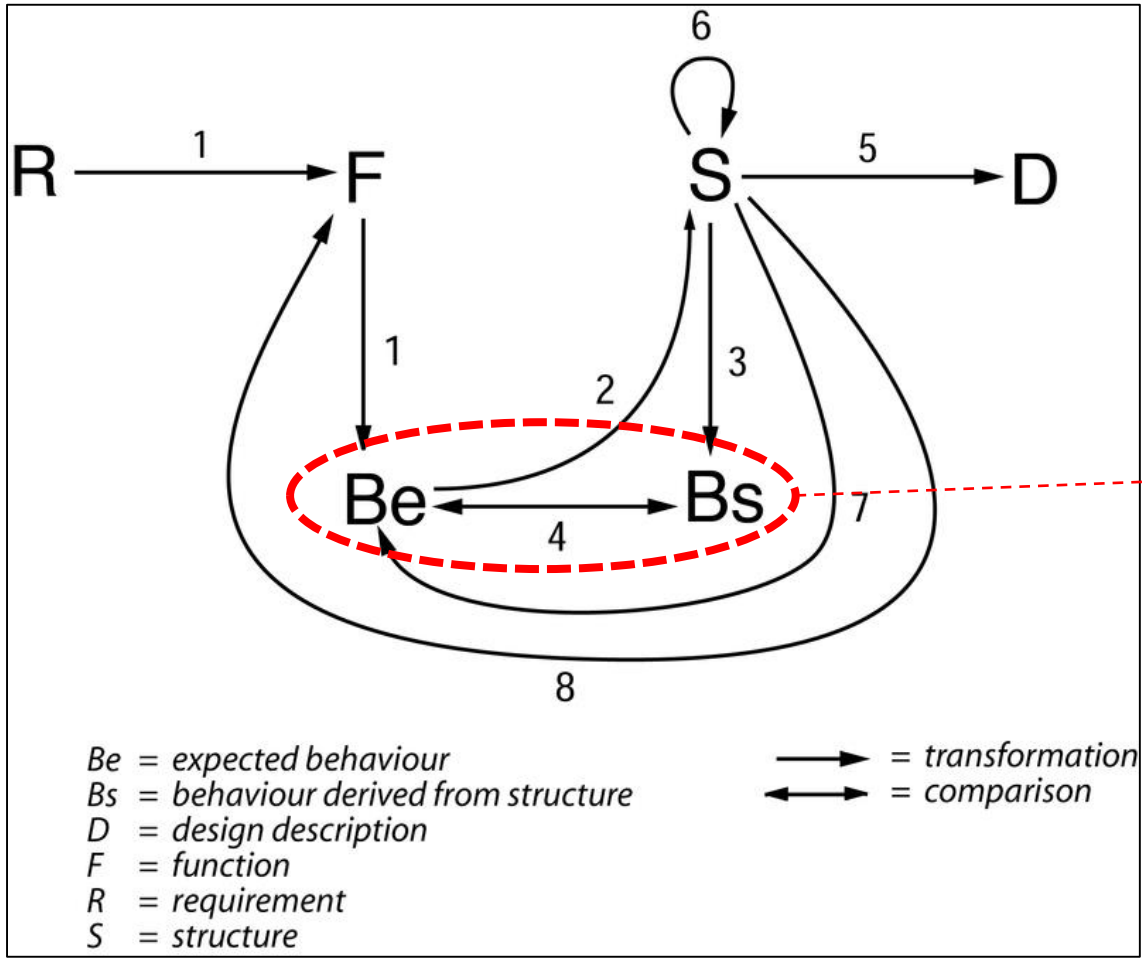
SESSION OUTLINE

- Designing for Intelligent Behavior – What is missing?
- Use of metaphors / analogies: Model Based Systems Design
- Architecture for Intelligent Behavior based on complexity principles

Designing for Intelligent Behavior



Intelligent behavior like any other behavior depends on function and structure

The definitions of intelligence guide us to use metaphors / analogies of human / living / natural systems for designing intelligent systems … But, what do we hope to extract from the metaphors / analogies and how do we do it? Can they say something about F/S?

And, what is the connection between information intensity and intelligence?

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Use of Analogy in Design Literature

Charles Pierce (Semiotics)

Rule

Cause Effect

Generic ↕ Particular

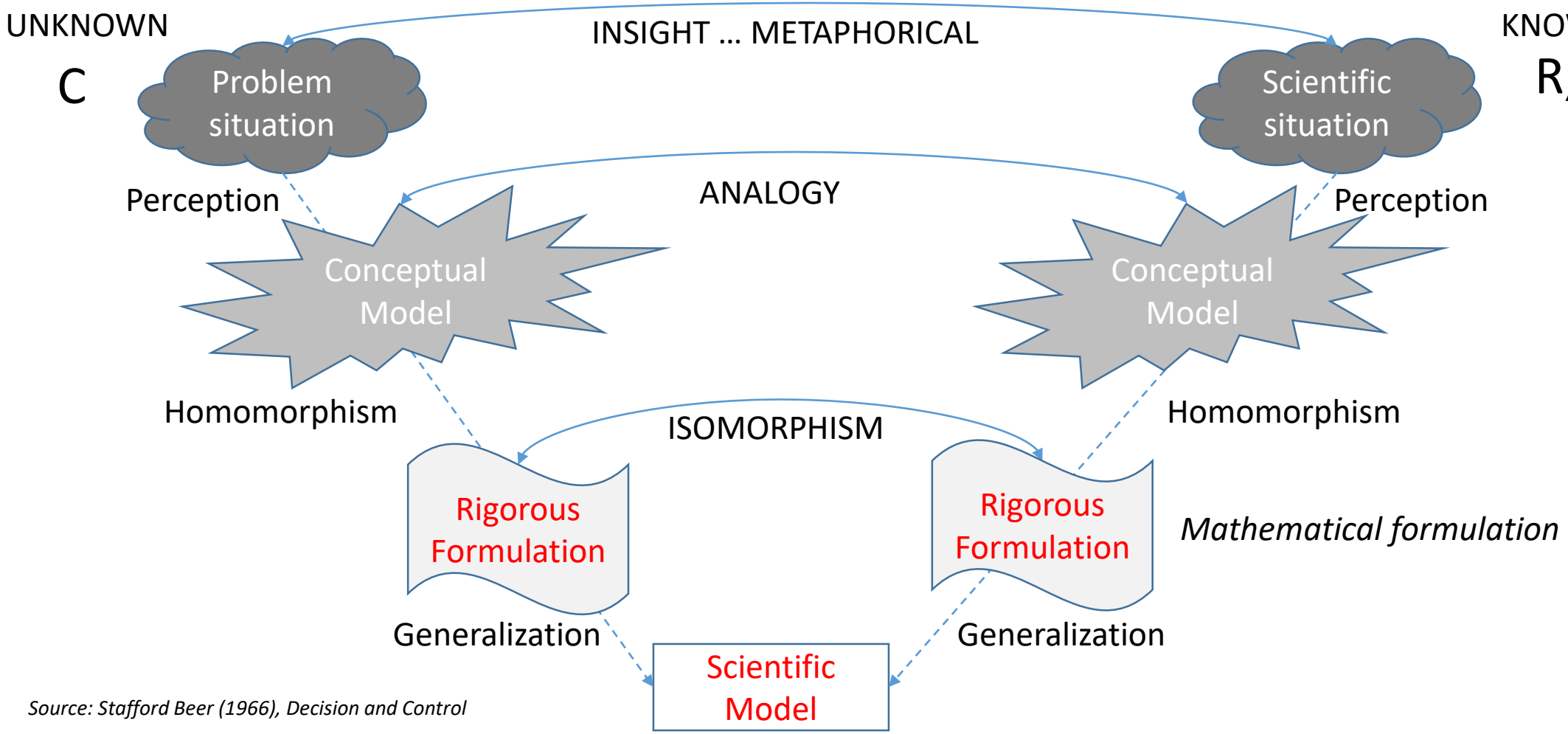
Find C, given E and R — **Abduction** (Particular to Particular) — *Mainly used in Concept Design / Design Synthesis*

Example: If the purpose is to Design for Intelligence, and we know that Feedback principle is key to intelligent behavior, then find a concept that has appropriate feedback loops

Find R, given C and E — Induction (Particular to Generic) — *Mainly used in Concept Evaluation*

Find E, given C and R — Deduction (Generic to Particular) — *Mainly used for Detail Design*

Analogical Reasoning in Science & Engineering



Source: Stafford Beer (1966), Decision and Control

In the early 1950s researchers used humans as an analogy to conceptualize intelligent machines

- One of them reversed the analogy … it opened a whole new set of possibilities and paved the way for a holistic view of machine intelligence (including AI & embodied intelligence)

How Ross Ashby approached intelligence

- Among the numerous scientists who pursued mechanistic theories of intelligence in the last century, W. Ross Ashby (1903–1972) stands out as a particularly unique and interesting figure

- A medical doctor and psychiatrist by training, Ashby approached the brain as being first and foremost an organ of the body. Like other organs the brain had specific biological functions to perform

- Ashby further believed that through a thoughtful analysis of those functions, a quantitatively rigorous analysis of the brain's mechanisms could be devised

Using mechanical concepts to understand intelligence

- It is unique in the way that Ashby used rather sophisticated mechanical concepts, such as equilibrium and amplification, which were not particularly favored by other researchers

- And moreover, he used these concepts not merely metaphorically, but also imported their associated mathematical formulations as a basis for quantifying intelligent behavior

Exploiting the mathematical formulations of "equilibrium"

- Animal and human behavior shows many features. Among them is the peculiar phenomenon of "adaptiveness." Although this fact is easily recognized in any given case, yet it is difficult to define with precision

- It is suggested here that adaptive behavior may be identical with the behavior of a system in stable equilibrium, and that this latter concept may, with advantage, be substituted for the former

- Stable equilibrium is necessary for existence, and that systems in unstable equilibrium inevitably destroy themselves… all dynamic systems change their internal organizations spontaneously until they arrive at some state of equilibrium

Leveraging the principle of amplification

- In resolving the problem of the mechanical chess player, Ashby had shown that a machine could output more information than was input through its design, by making use of other, random, information.

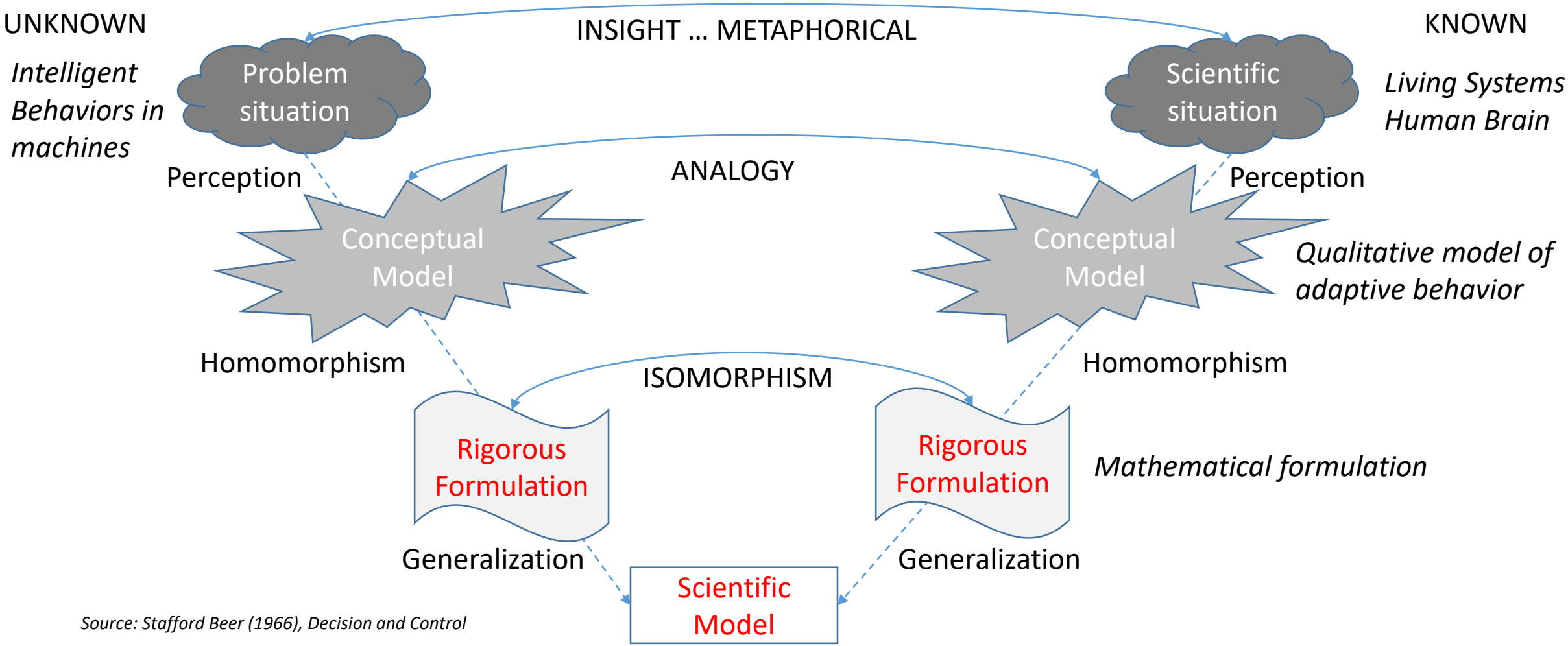
- This was a kind of amplification—information amplification—like the amplification of power that utilizes an input of power plus a source of free energy to output much more power than was originally supplied

A scientific approach to using metaphors in design: *Ashby on mechanisms of mind (1951)*

- Intelligence is understood as a combination of the abilities to produce a great many meaningless alternatives, and to eliminate by appropriate selection the incorrect choices among those—a two-stage process.

- All forms of intelligence depend necessarily on receiving information in order to achieve any appropriate selection that they make. And the greater the set of possibilities and complexity of the partitioning of alternatives, the more information will be required for the selection to be appropriate. … Increase in information intensity is a pre-requisite for intelligent behavior

An approach to using analogies for intelligent systems design



Source: Stafford Beer (1966), Decision and Control

How does Bio-mimetics work?

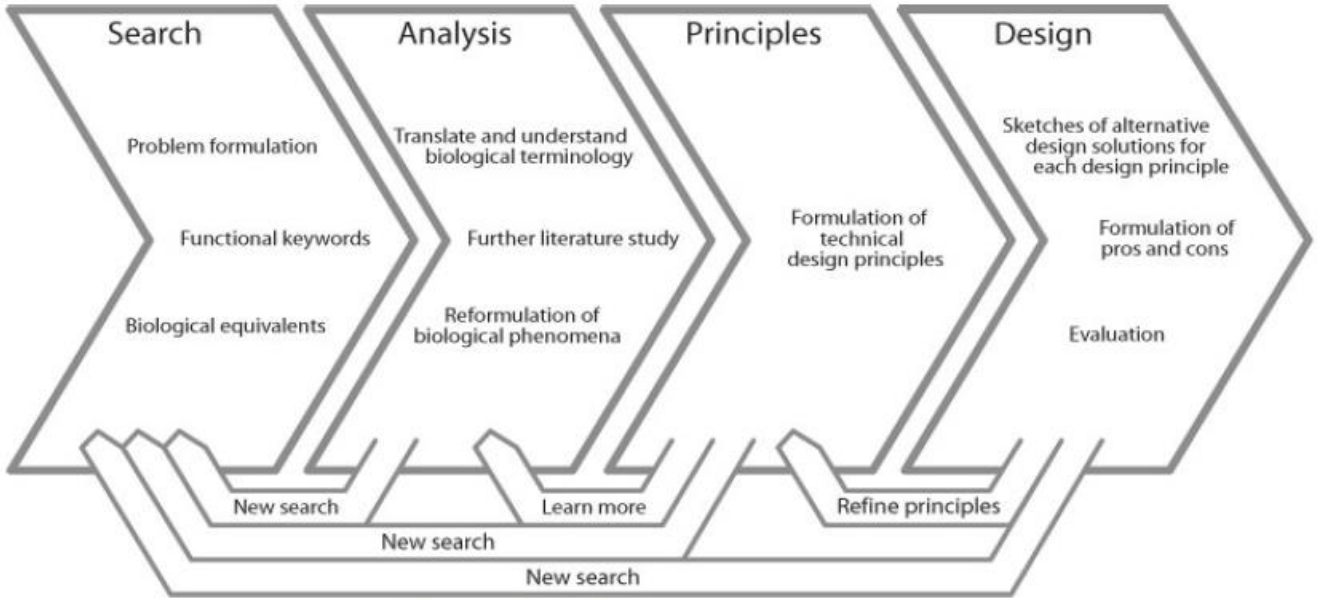


Figure 1. Biomimetic design methodology

*Table 1. Selected problem areas and primary search words. A * (asterisk) in the word find more versions of the word, e.g. sens* searches both sense and sensing.*

	Problem area	Search words
1.	Energy efficient movement on water (walk on water)	Locomotion, movement, water running, biomechanics, water surface
2.	Energy efficient movement in rugged terrain	Locomotion, energy, efficiency
3.	Mechanical energy storage, short duration high impact energy in/output <-> long lasting low impact energy in/output	Locomotion, energy, storage

Table 2. search strategy example 'walk on water'

animals	and	water interface	and	locomotion
or basilisk lizard		or water surface		or movement
or basiliscus plumifrons		or water running		or running
or basiliscus basiliscus				or biomechanics

Table 5. Examples on biological solutions for the 7 problem areas.

	Examples of biological phenomena	Behavior or biological function
1.	• Lizards • Water strider • Fisher spiders • Swimmers, e.g. penguins with reduced water resistance • Sharks with reduced water resistance	• The lizard runs on two legs on the water surface by continually and quickly striking the water surface with the hind legs in order to escape predators • Water striders and fisher spiders stay on top of the water surface thanks to the surface tension allowing them to live and hunt on water • Swimmers use hydrophobic surfaces to reduce drag • Sharks have small scales that reduces drag

Torben Lenau (2009), BIOMIMETICS AS A DESIGN METHODOLOGY – POSSIBILITIES AND CHALLENGES, INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, Stanford

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What pattern of P-F-S produces Intelligent Behavior for a given E?

(P)urpose
Goal

(F)unction
Abstraction/Modeling
Learn, Understand/Comprehend
Reason, Visualise, Interpret, Plan
Judge/Evaluate
Act

(S)tructure
Experience/Historical
Contextual/Social
Centralized/Distributed
Individual/Collective

A key Cybernetic Principle: Negative Feedback or Self-Regulation is critical for Goal Directed Behavior

Problems / Challenges to Goal Attainment

Survive? Adapt? Evolve? Advance?
Probability of success
Speed & Complexity
Profitable

(E)nvironment
Everyday, New, Hard, Uncertain, Variety
(*precise definition of environment / niche is required*)

In the next 3 sessions we will cover

Some functional architectures for intelligent behavior