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Agent-Based Modelling in Research

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Heuristic

A sustainable enterprise is a complex adaptive system that is able to self-organise in response to changes in its environment through innovation

Presentation Outline

- Introduction to Agent-Based Modelling
- Complex adaptive systems – a metaphor for organisations
- Using agent-based simulation to model strategic scenarios
- Integrating sustainability into core business strategy

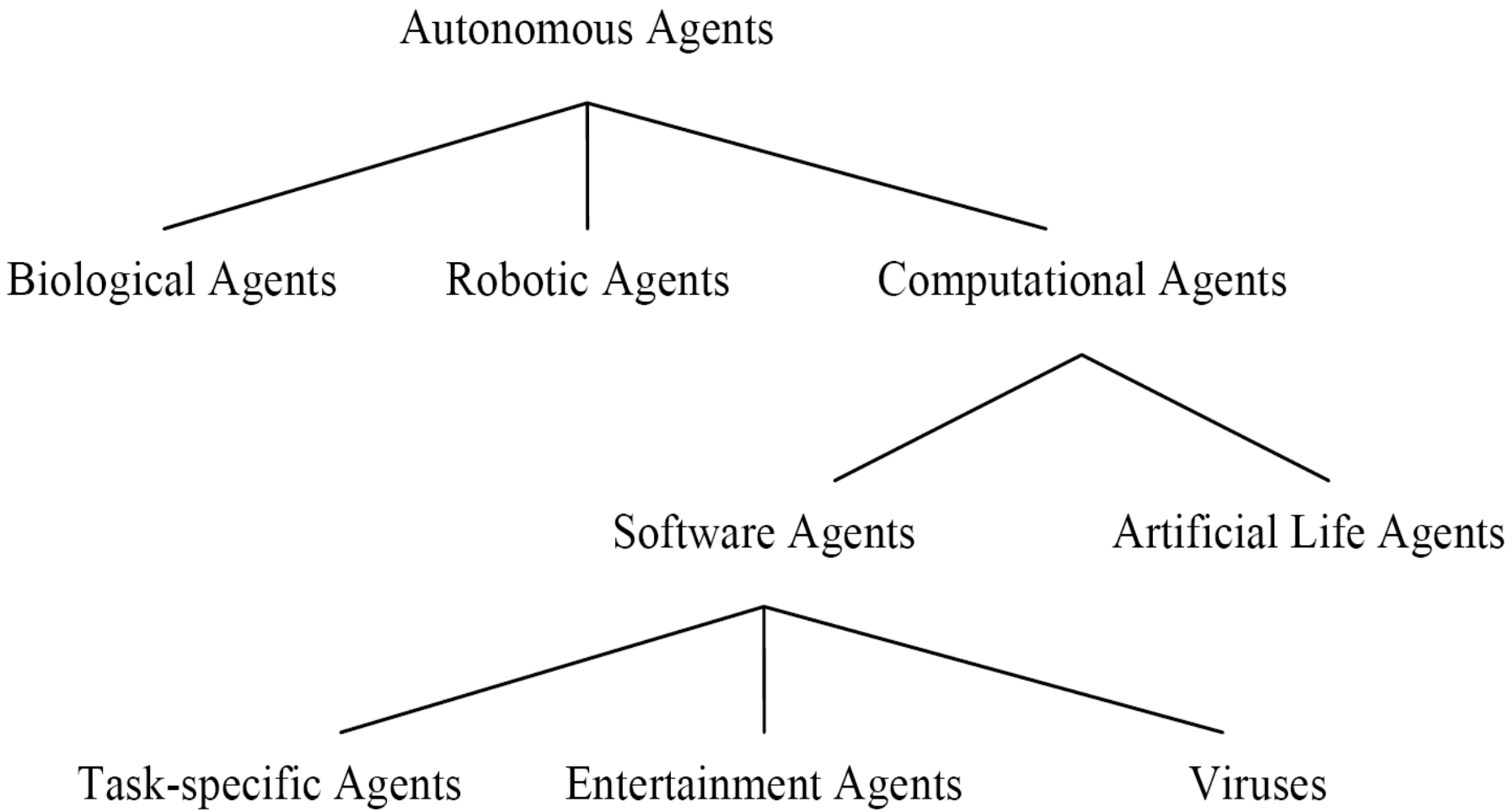
Agent-Based Modelling (ABM)

- In agent-based modelling, a system is modelled as a collection of autonomous decision-making entities called agents
- Each agent individually assess its situation and makes decisions on the basis of a set of rules

Definition of an Autonomous Agent

Autonomous agents are computational systems that **inhabit** some complex dynamic environment, **sense** and **act** autonomously in this environment, and by doing so, realise a set of **goals** and **tasks** for which they are designed

Agent Taxonomy



Why Use ABM?

- Represents a low-risk inexpensive laboratory for researching individual and organisational behaviour
- ABM captures emergent phenomena
- ABM provides a natural description of a system
- One can develop agent specifications to yield new classes of emergent phenomena

Emergence

- Emergence is the production of global patterns of behaviour by agents in a complex system interacting according to their own local rules of behaviour, without intending the global patterns of behaviour that come about
- Global patterns cannot be reduced to individual behaviour
- Emergence is a key property of complex systems and much research is being done to understand the nature of emergence and under what conditions it is likely to occur

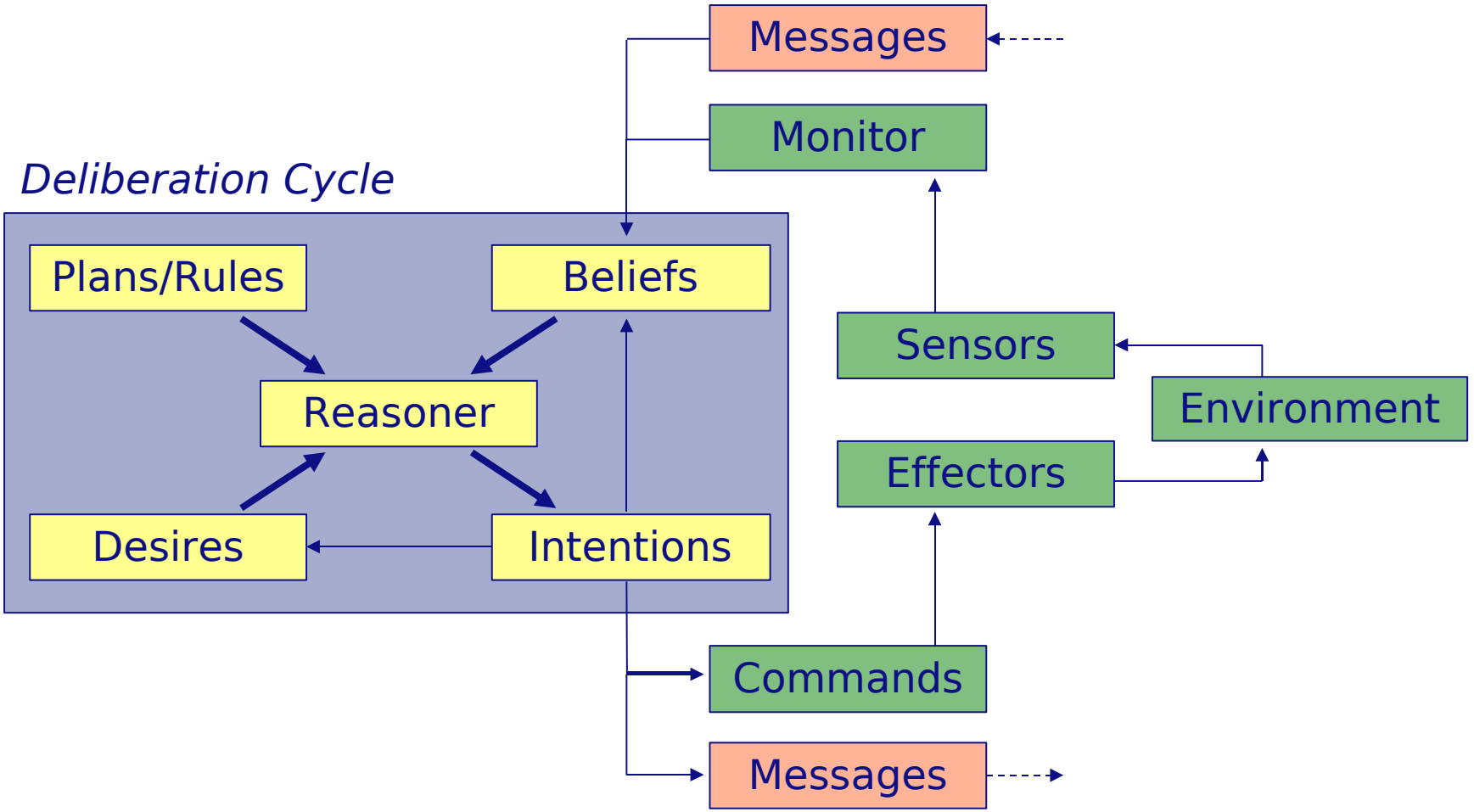
Modelling Behaviour

- Realistic behaviour is a function of
  - within-agent forces (decision rules, cognitive capabilities, and codes of behaviour)
  - agent-environment interactions (such as exploiting natural resources)
  - agent-agent interactions (such as trade and war)
  - environment-environment interactions (such as geographic location influencing natural resource availability)

BDI Agents

- The **beliefs** represent the informational state of the agent
- **Desires** (or goals) represent the motivational state of the agent
- The **intentions** represent the deliberative state of the agent, what the agent intends to do

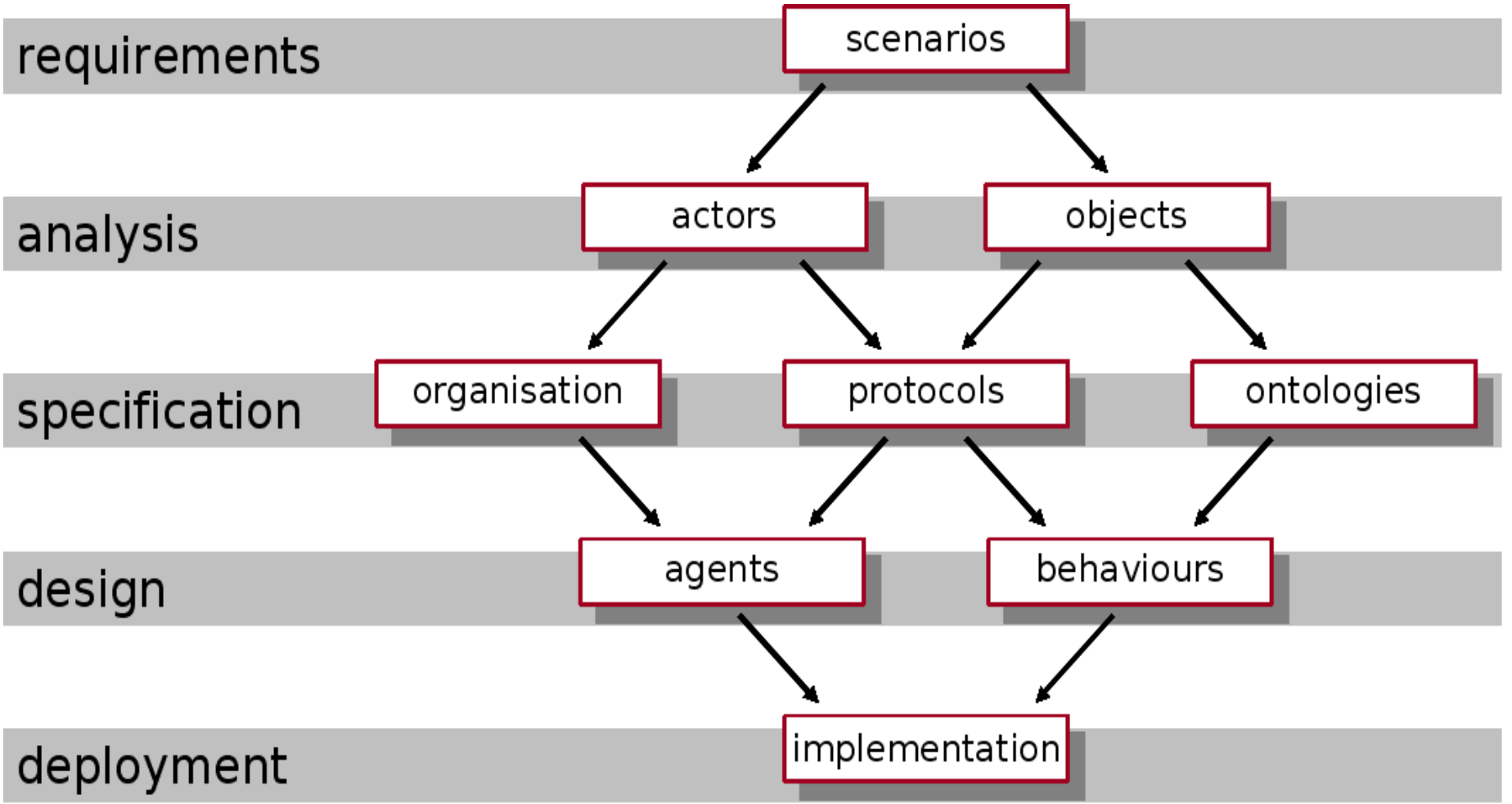
BDI Agent Architecture



ABM Areas of Application in Human Systems

- Flows - evacuation, flow management
- Markets - stock market, strategic simulation
- Organisations - operational risk and organisational design
- Diffusion - diffusion of innovation and adoption dynamics

Engineering Multi-Agent Systems



Complexity and Business Organisations

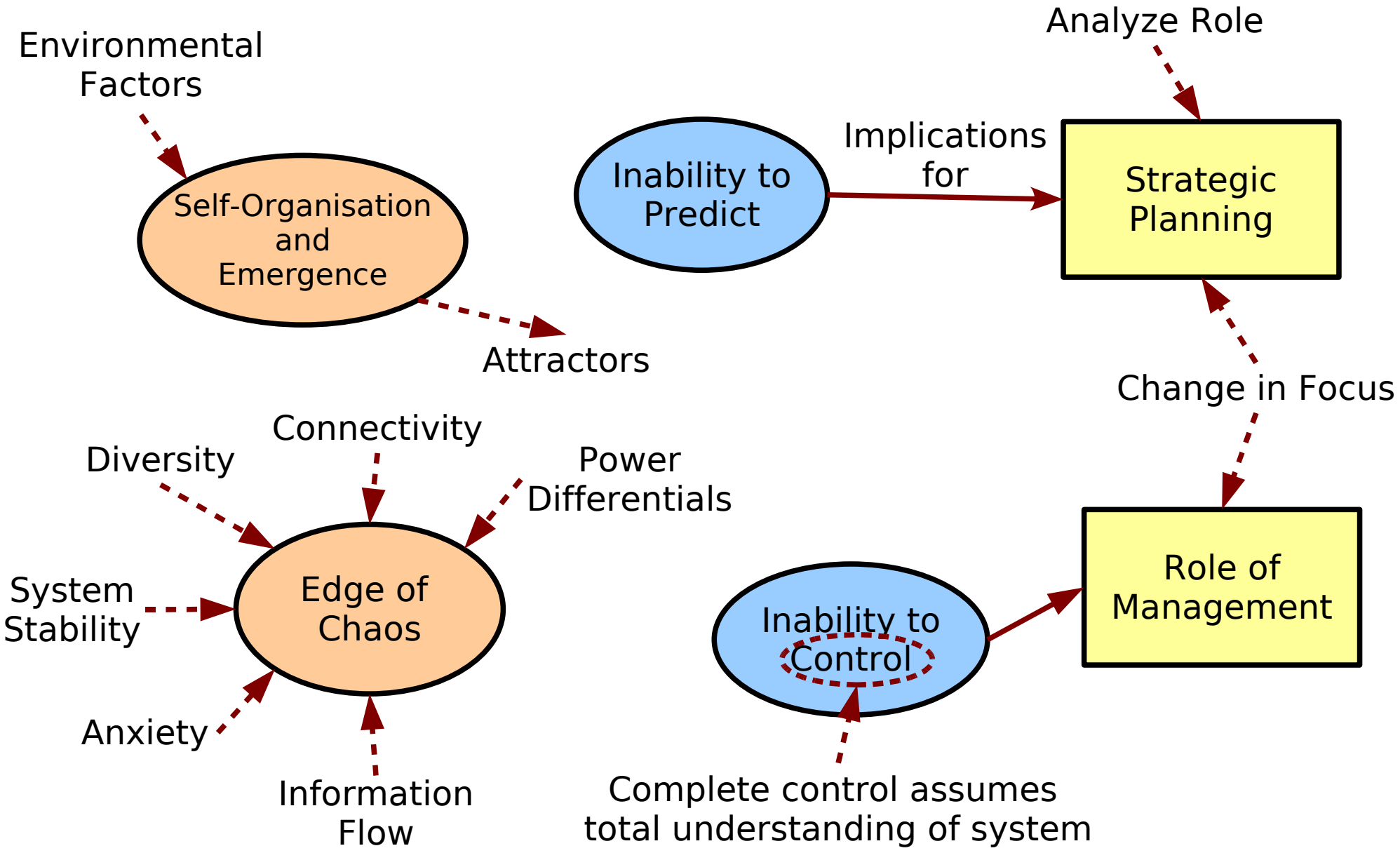
- The aim of using complexity theory to analyse a business organisation is to give a better insight into the nature of organisational behaviour
- Viewing a business organisation as a complex system has numerous implications for the way in which it is managed
- Nobody has real control over the system. Top-down approaches are inappropriate

Complex Adaptive Systems

- In a complex adaptive system, transformation is unlikely to happen if systems is in a steady state
- Neither will the system be able to form any coherent patterns if there is too much disorder
- Transformation is most likely to happen at the edge of chaos where self-organisation occurs around an attractor
- We cannot dictate the attractor, but may be able to influence the choice of attractor

Edge of Chaos

- Steady systems can move towards the edge of chaos if and when
  - their agents become better connected
  - there is more diversity either in the agents themselves or in the nature of the relationships between them
  - the amount of information transferred is increased
- Conversely, an unstable system needs to reduce some or all of these variables


Environmental Factors
Self-Organisation and Emergence
Attractors
Analyze Role
Inability to Predict
Implications for
Strategic Planning
Change in Focus
Connectivity
Diversity
Power Differentials
System Stability
Edge of Chaos
Anxiety
Information Flow
Role of Management
Inability to Control
Complete control assumes total understanding of system

Complexity and Business Strategy

- Viewing an organisation as a complex adaptive system has strategic implications
  - The non-linear nature of the system implies the future is unpredictable
  - Emphasis should be on understanding and facilitating relationships between agents to promote right kinds of behaviour

Key Variables for Effecting Change

- **Stability** – a system that has too much stability will be unable to change, it will need a certain amount of randomness
- **Connectivity** – a stable system can move towards the edge of chaos if its agents are better connected
- **Diversity** – this refers to the diversity in the agents themselves or the nature of the relationships between them
- **Information Flow** – if the amount of information transferred is increased the system moves towards the edge of chaos
- **Level of contained anxiety** - this is particularly relevant for human systems. The readiness for change and creativity are inhibited if the level of contained anxiety within an organisation is too contained
- **Power differentials** - If there is too much control due to power differentials within the organisation, then change is unlikely to occur.

Resilience Theory

- Engineering resilience – ability of system to return to steady state after a perturbation
- Ecological resilience – measured by the magnitude of disturbance that can be absorbed by a system before the system redefines it structure by changing the variables and processes that control behaviour

Action Research

- Action research amounts to creating a perturbation in a problematic system and observing its resulting behaviour
- Differences between observed and expected behaviour amount to a research question:
  - Why is the system behaving differently from what I expect?

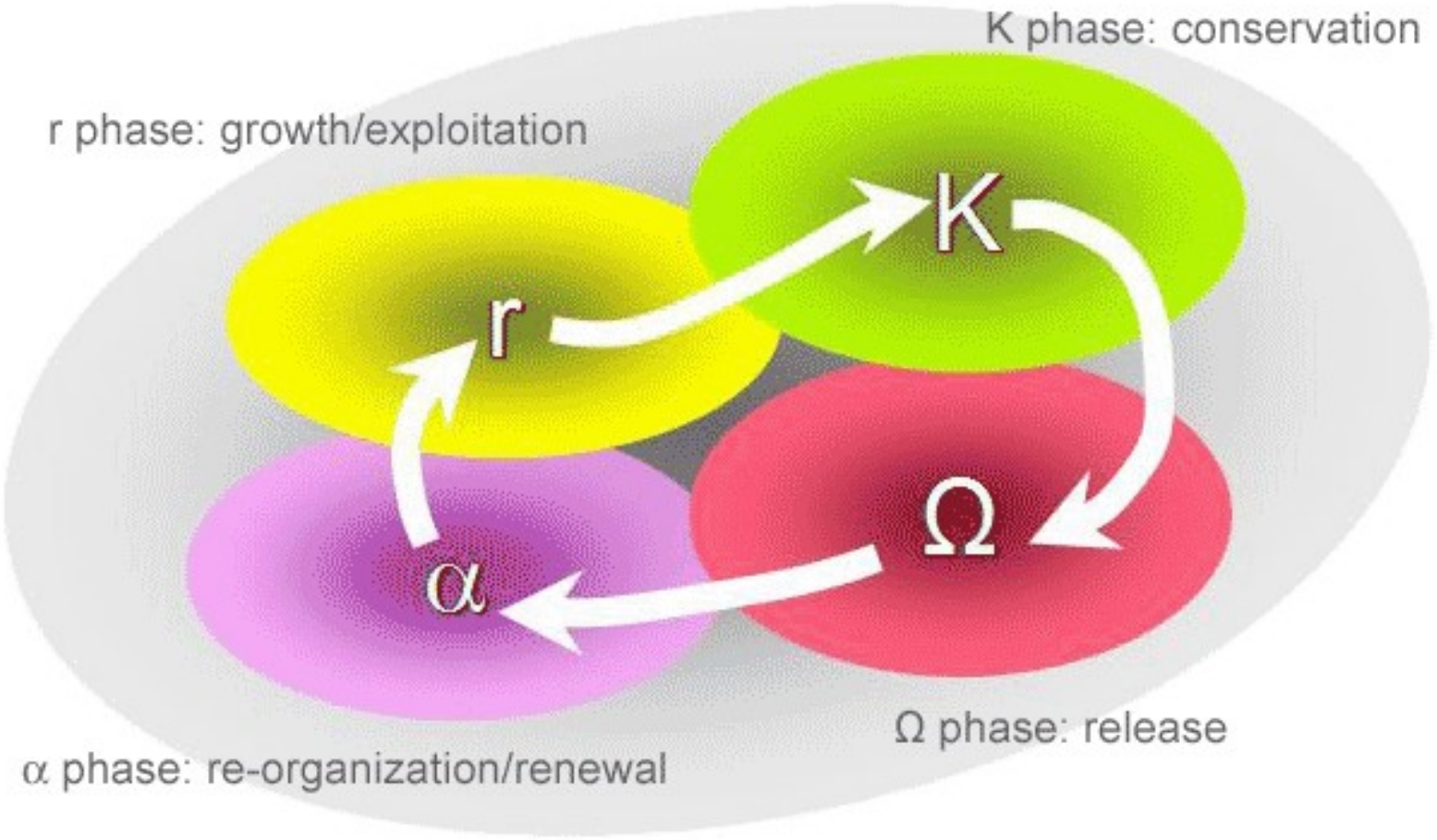
Adaptive Capacity

- Systems with high adaptive capacity are able to re-configure themselves without significant declines in crucial functions in relation to primary productivity, hydrological cycles, social relations and economic prosperity
- A consequence of a loss of resilience, and therefore of adaptive capacity, is loss of opportunity, constrained options during periods of re-organisation and renewal, an inability of the system to do different things. The effect of this is for the social-ecological system to emerge from such a period along an undesirable trajectory

Adaptive Cycle (1)

An adaptive cycle that alternates between long periods of aggregation and transformation of resources and shorter periods that create opportunities for innovation, is proposed as a fundamental unit for understanding complex systems from cells to ecosystems to societies

Adaptive Cycle (2)



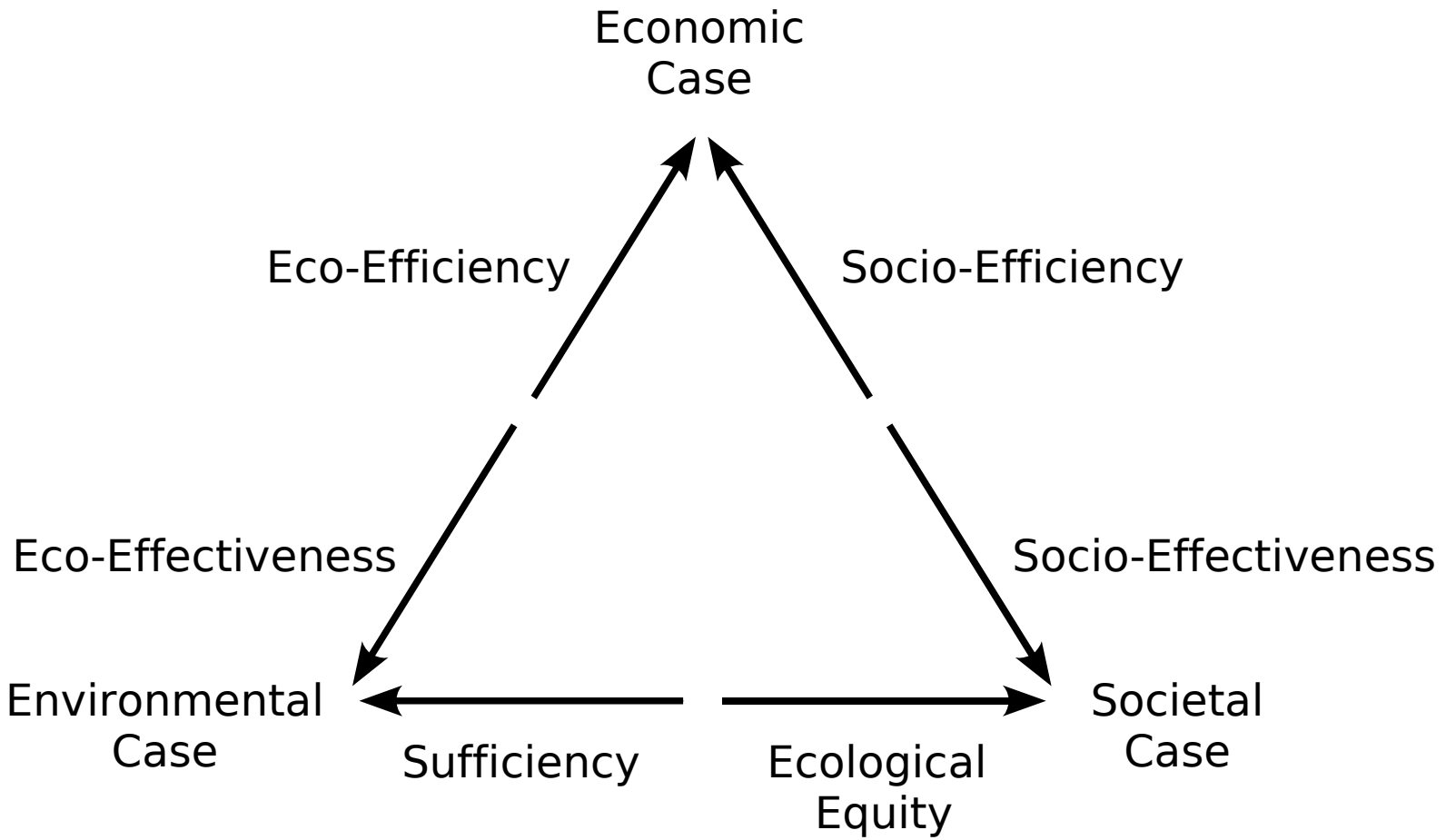
Adaptive Cycle (3)

- The adaptive cycle exhibits two major phases (or transitions)
  - The fore loop, from r to K, is the slow, incremental phase of growth and accumulation
  - The back loop, from Omega to Alpha, is the rapid phase of reorganization leading to renewal
- Focus is on processes of destruction and reorganisation, which are often neglected in favour of growth and conservation

Business Drivers for Sustainability

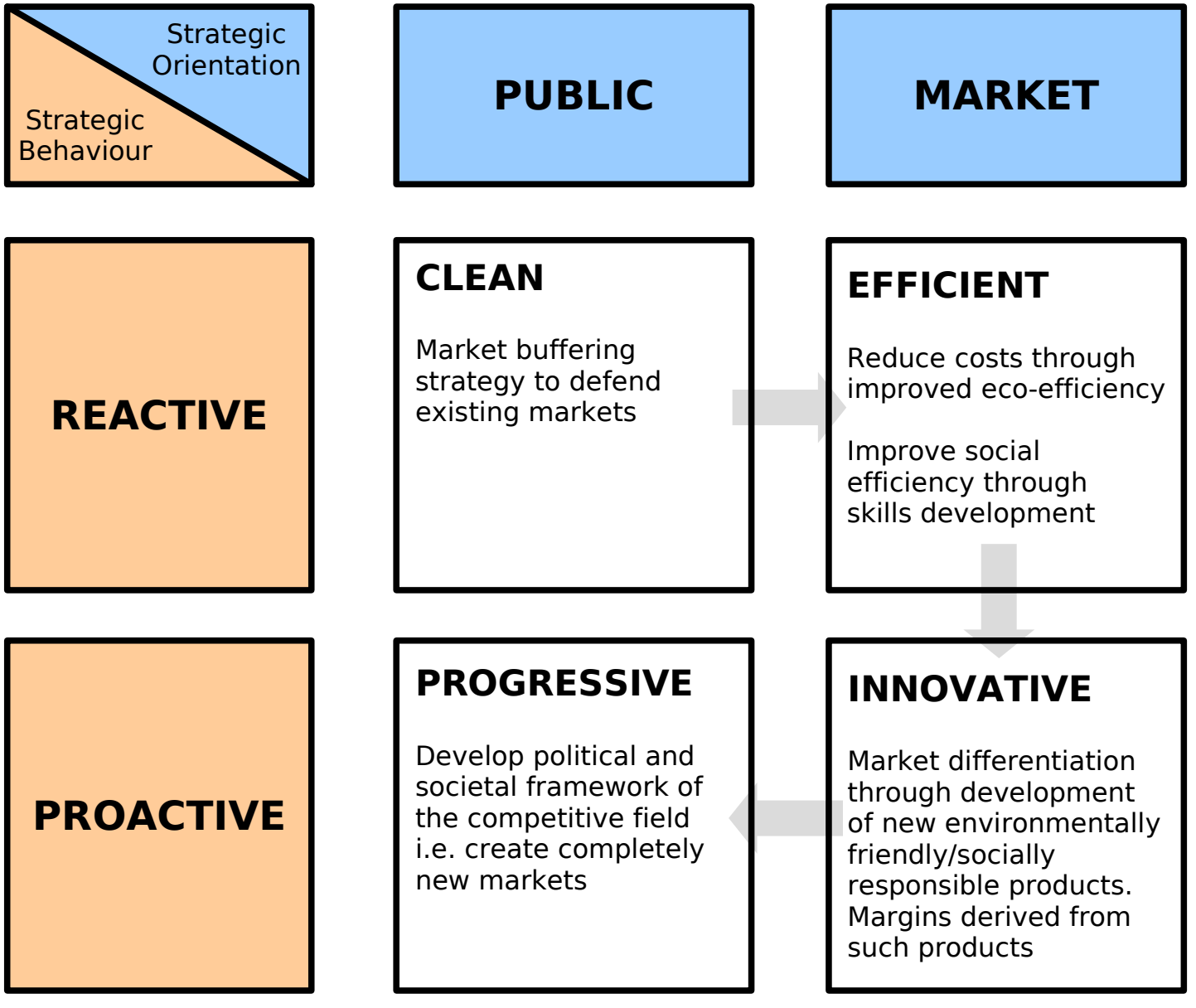
- Environmental and social impacts
- Stakeholder perceptions and demands
- The competitive field

Business Case for Sustainability



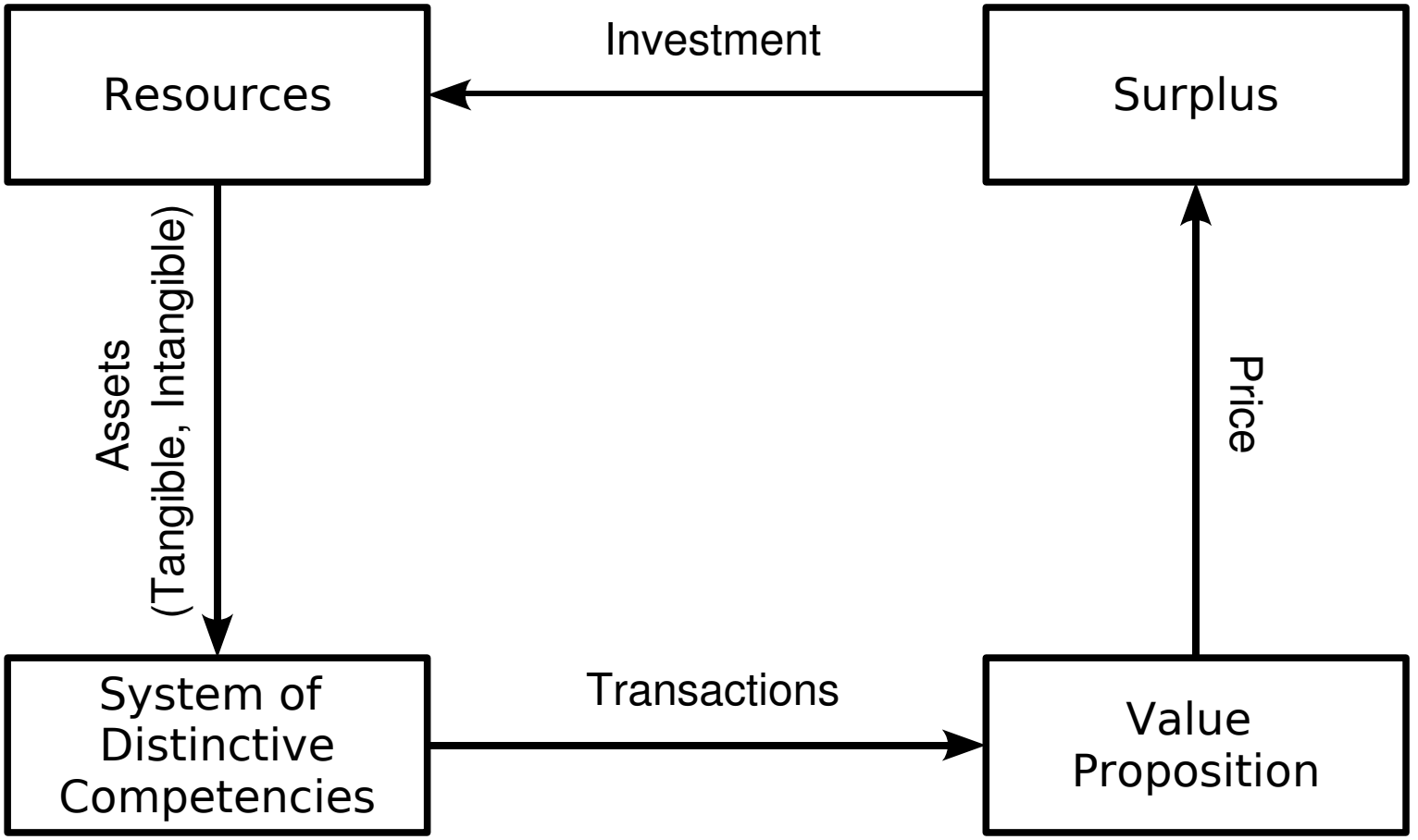
After Dyllick and Hockerts (2002)

Strategic Posture



After Bieker and Gminder (2001)

The Business Idea

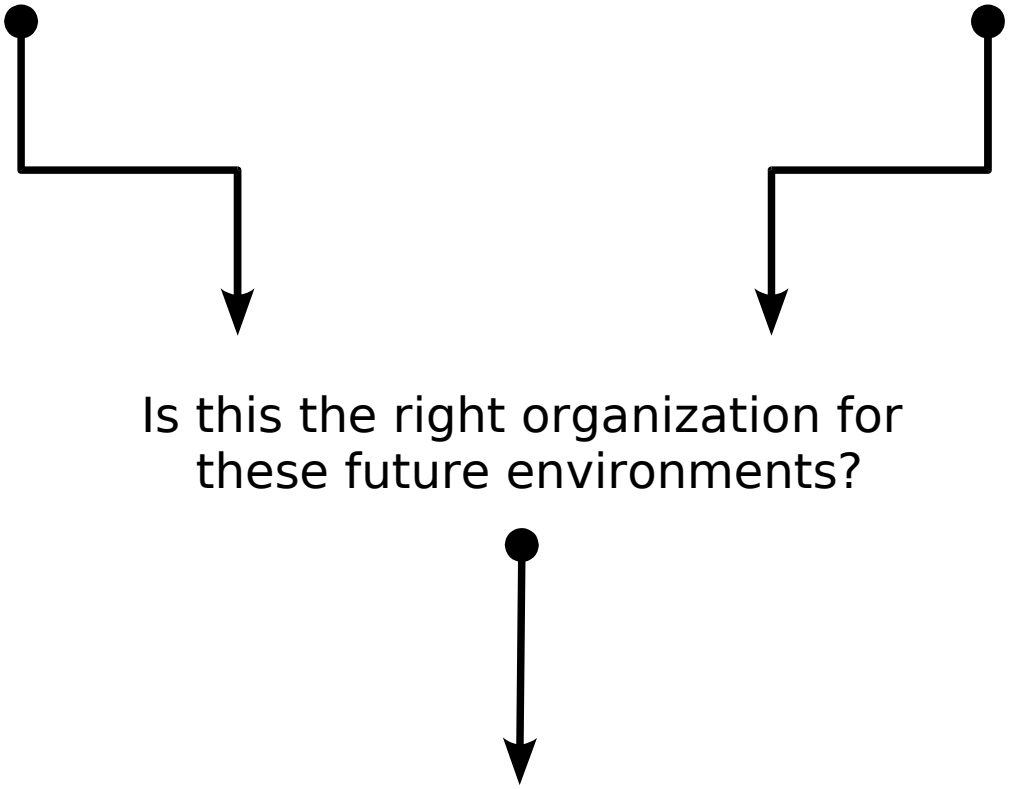


After van der Heijden (1997)

Strategic Choices

Understanding the environment
(scenarios)

Understanding the organization
(business idea)

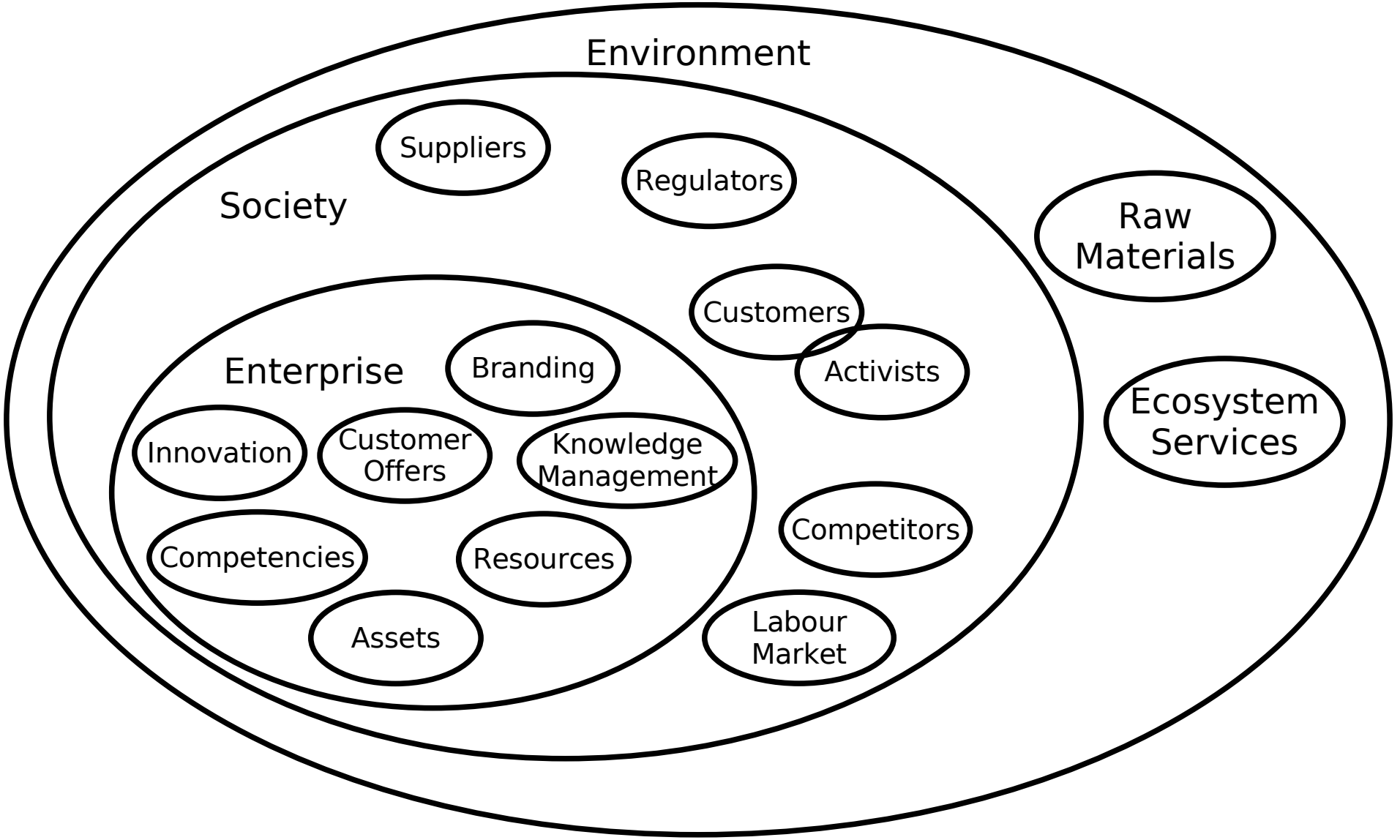


Is this the right organization for
these future environments?

No? Address competencies
Yes! Address business choices

After van der Heijden (1997)

Agent Landscape



Research Questions

- The aim is to employ ABM as an action research tool to refine research questions
- Initial questions include:
  - What behaviours contribute to sustainability?
  - What level of abstraction is required in the agent landscape?