SYSTEM THINKING DAN SYSTEM DYNAMIC

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Sesi 3
Systems Thinking Dan System Dynamics

Outcomes

Pada akhir sesi ini, peserta dapat:

- mengenali hubungan sebab akibat;
- memahami metodologi pemodelan *system dynamics*.

Systems Thinking


SYSTEMS THINKING
understanding the complex

3.5 Systems Thinking

(Anderson, Virginia and Lauren Johnson, 1997: *Systems Thinking Basics: From Concepts to Causal Loops*, Pegasus Communications, Inc. MA USA)

In general, systems thinking is characterized by these principles:

(1) thinking of the "big picture";

(2) balancing short-term and long-term perspective;

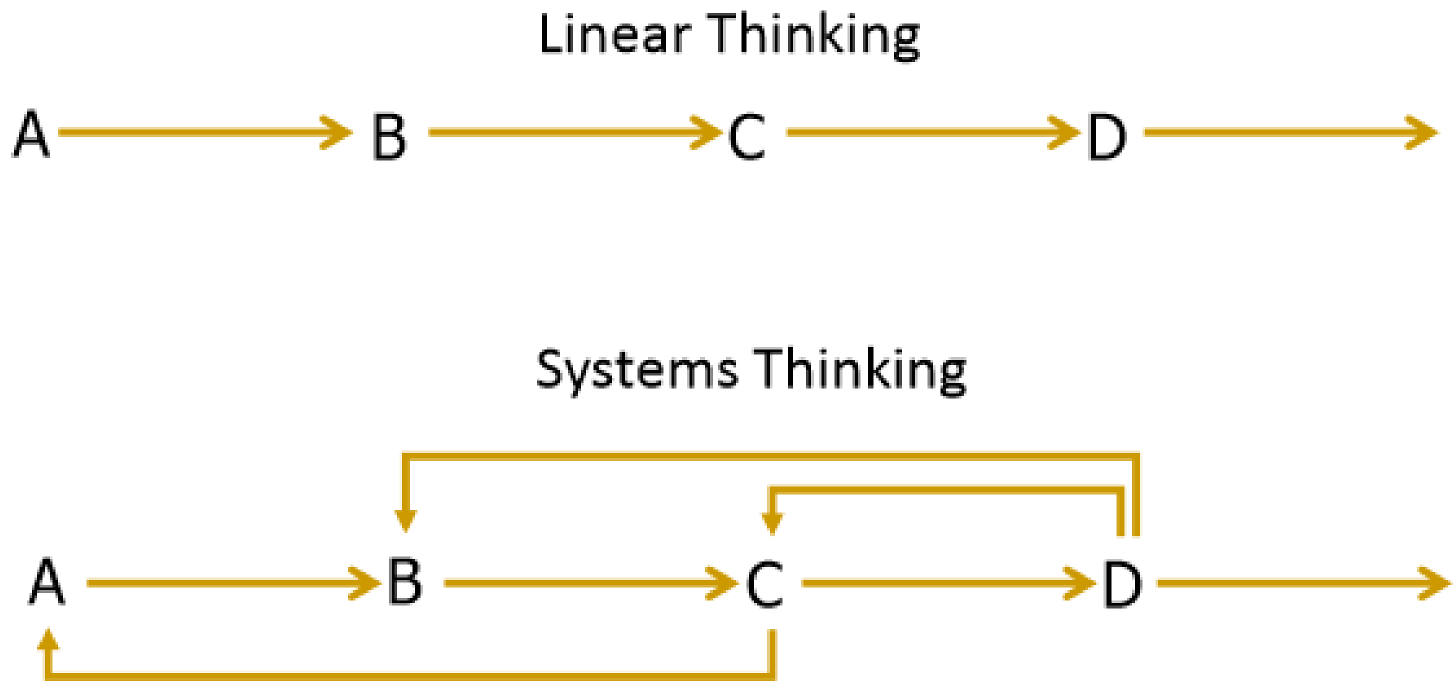
(3) recognizing the dynamic, complex, and interdependent nature of system;

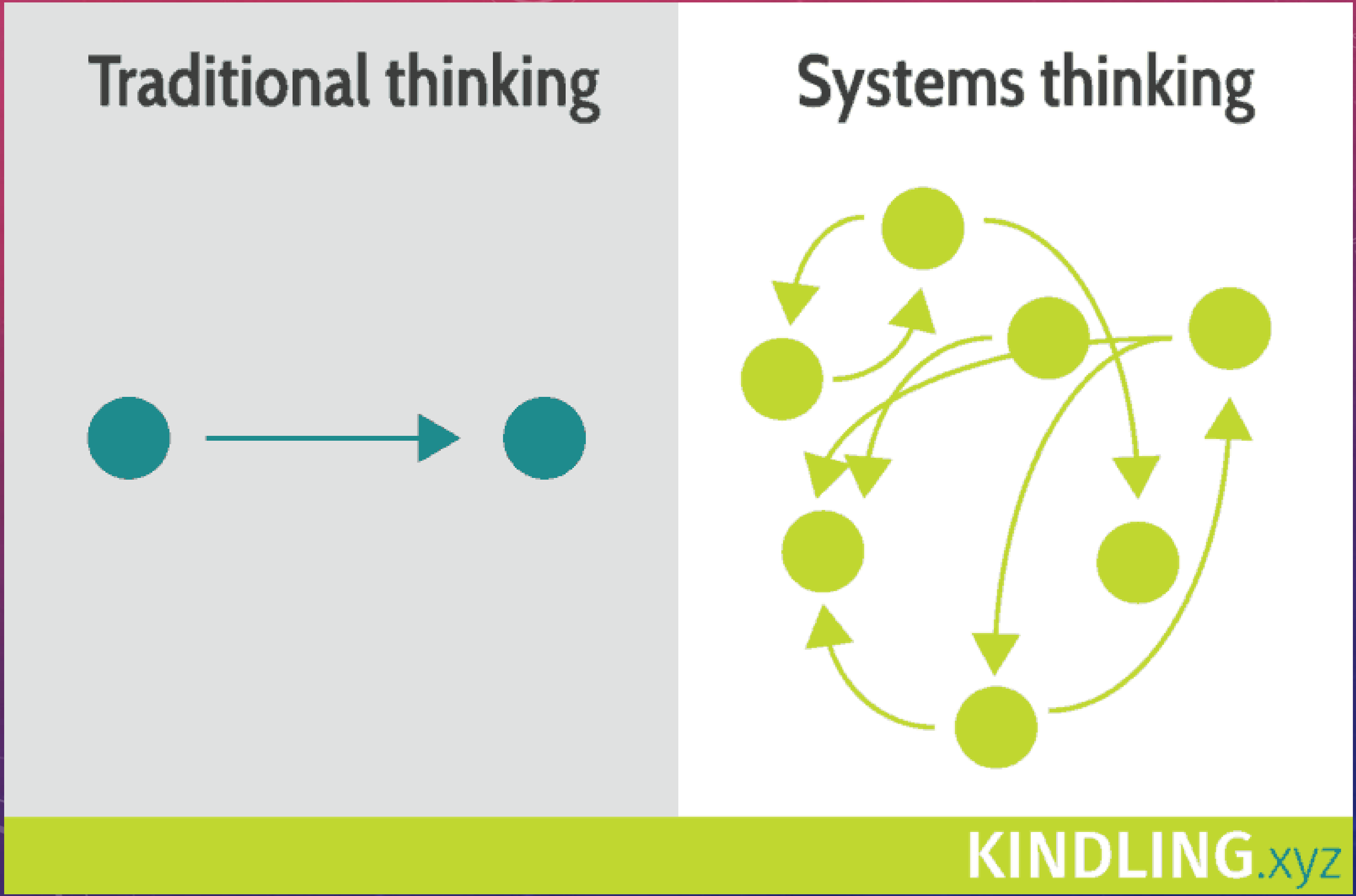
(4) taking into account both measurable and non measurable factors; and

(5) remembering that we are all part of the systems in which we function, and that we each influence those systems even as we are being influenced by them.

Linear Thinking vs Systems Thinking

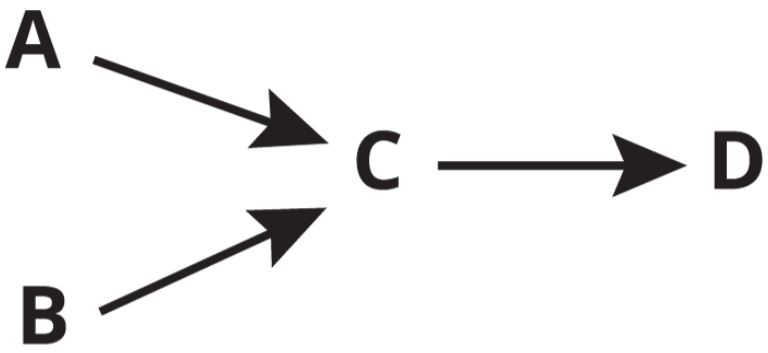
(Kim, Daniel H., 1997: *Introduction to Systems Thinking*, Pegasus Communications, Inc. MA USA)




Traditional thinking
Systems thinking
KINDLING.xyz

Event Oriented Thinking

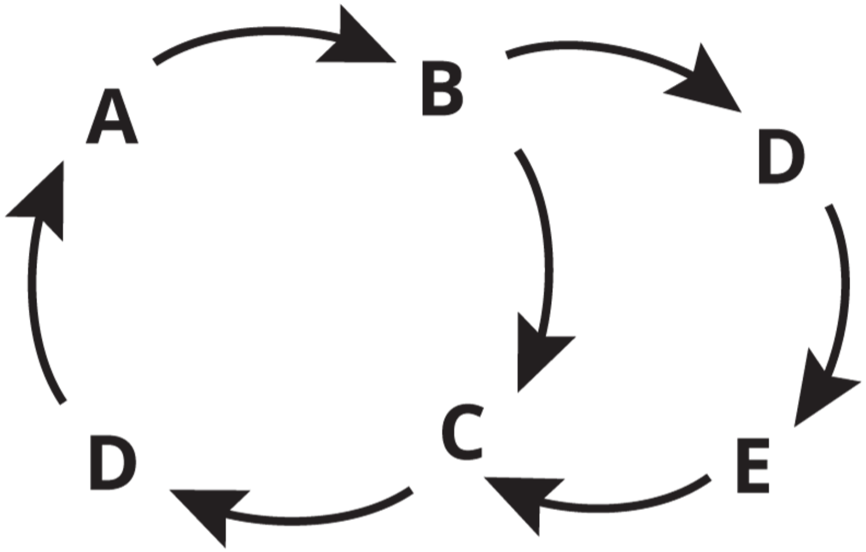
Thinks in straight lines



In event oriented thinking everything can be explained by causal chains of events. From this perspective the **root causes** are the events starting the chains of cause and effect, such as A and B.

Systems Thinking

Thinks in loop structure

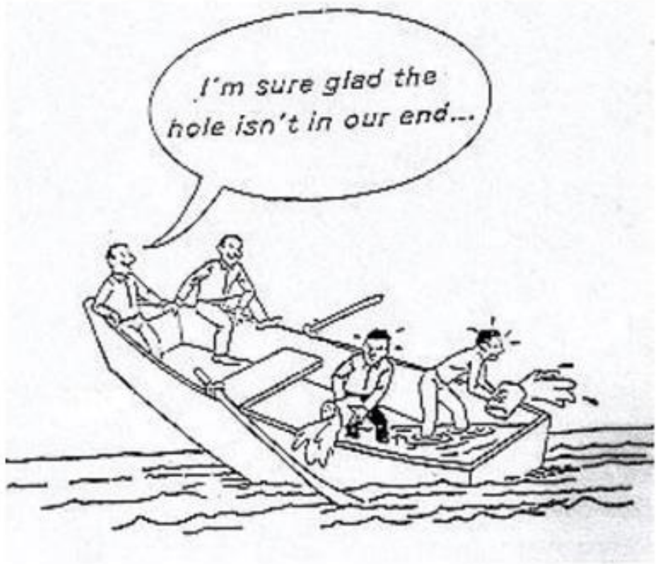


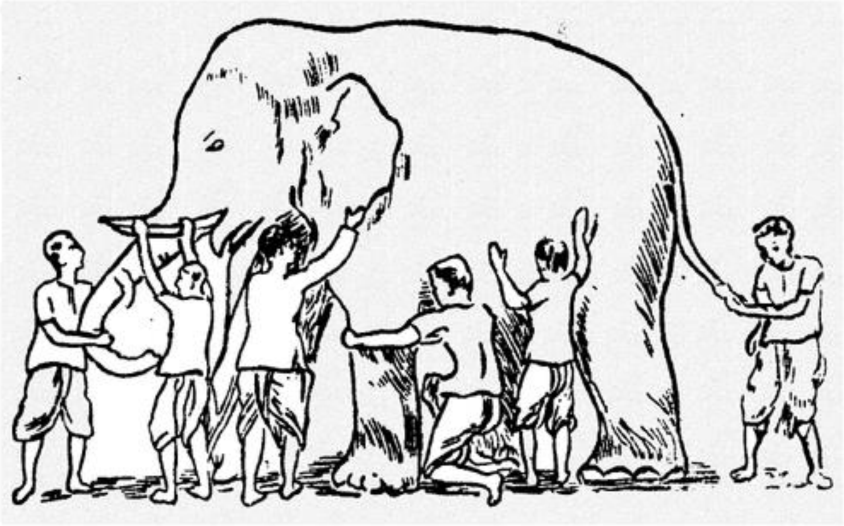
In systems thinking a system's behavior emerges from the structure of its feedback loops. **Root causes** are not individual nodes. They are the forces emerging from particular feedback loops.

Created by Thwink.org

Systems Thinking

in sustainability, projects and communication





Sustainable Development: Project Management & Communication
September 12, 2012

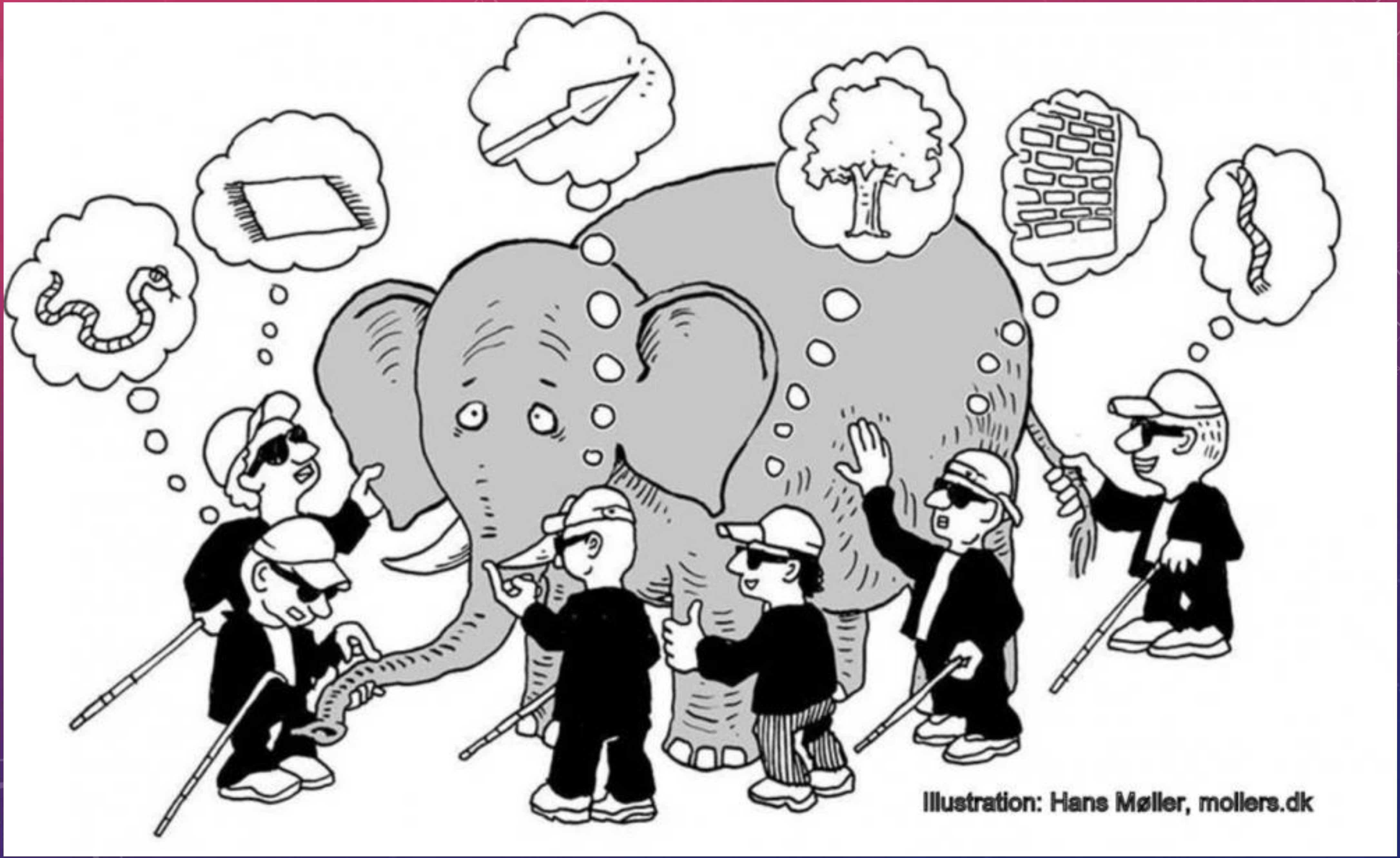
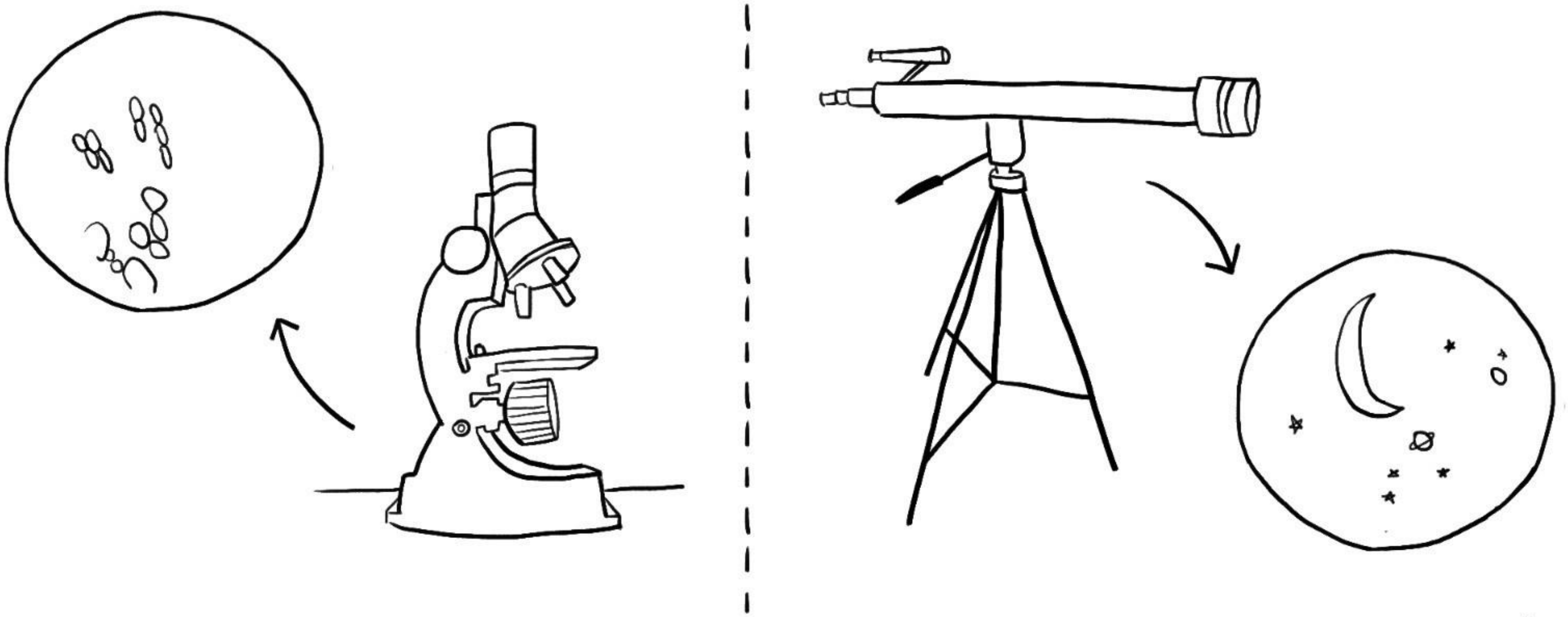
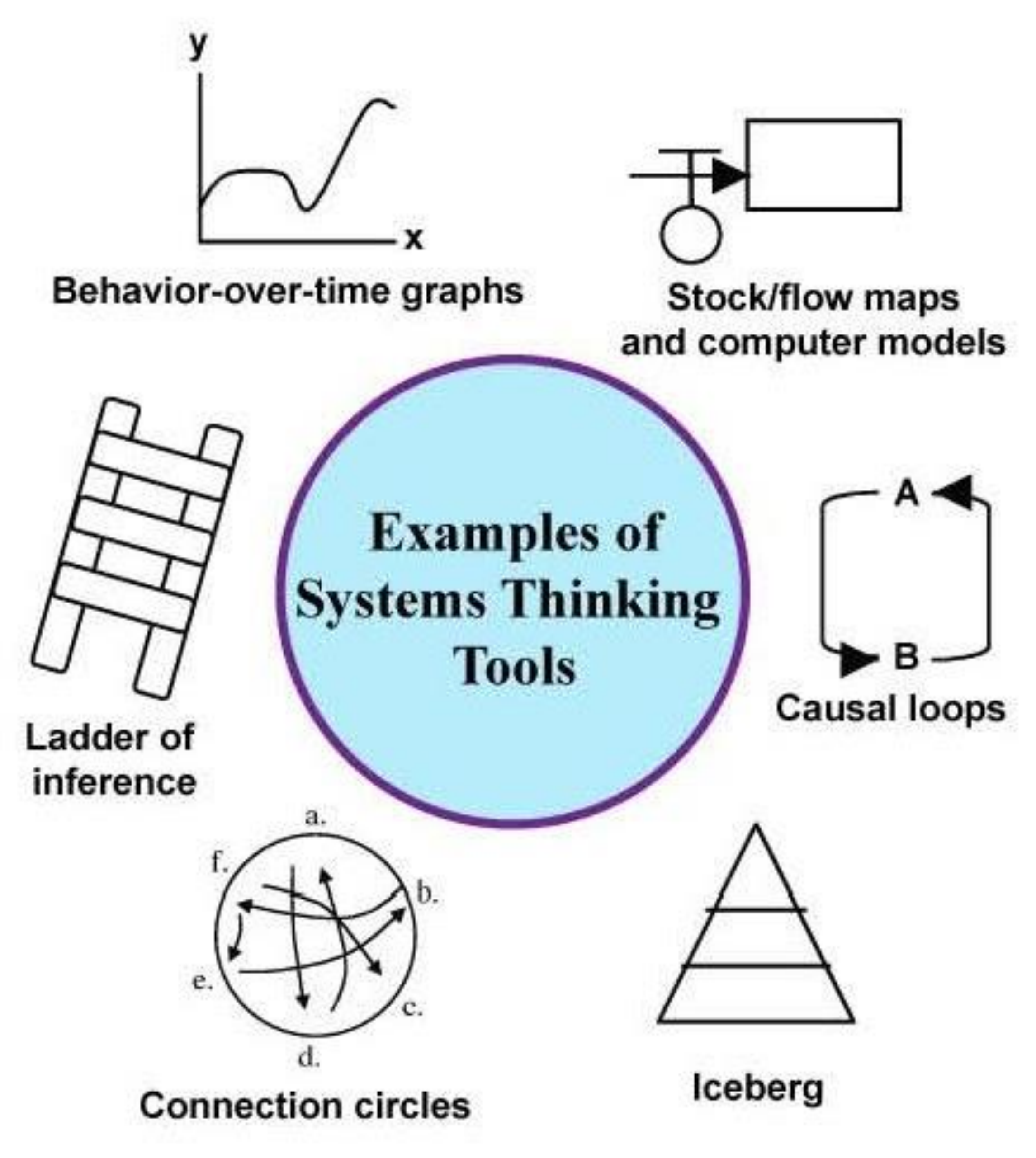


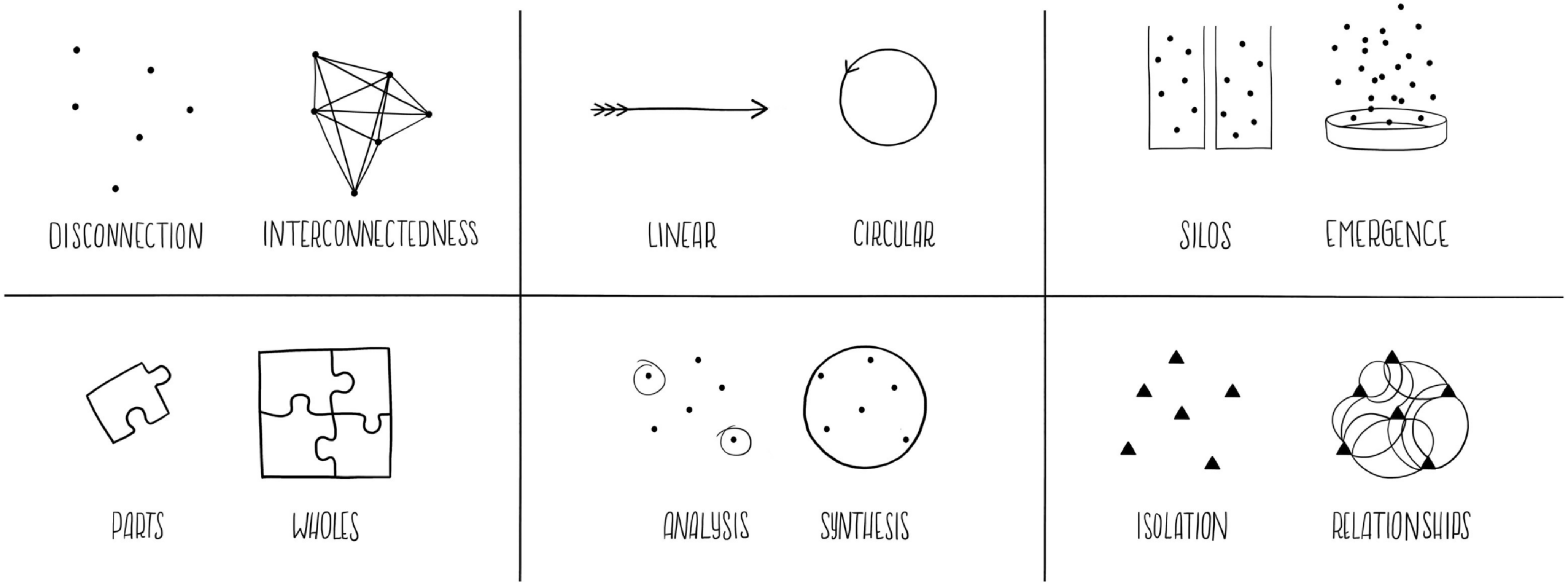
Illustration: Hans Møller, mollers.dk

SYSTEMS THINKING SCALES

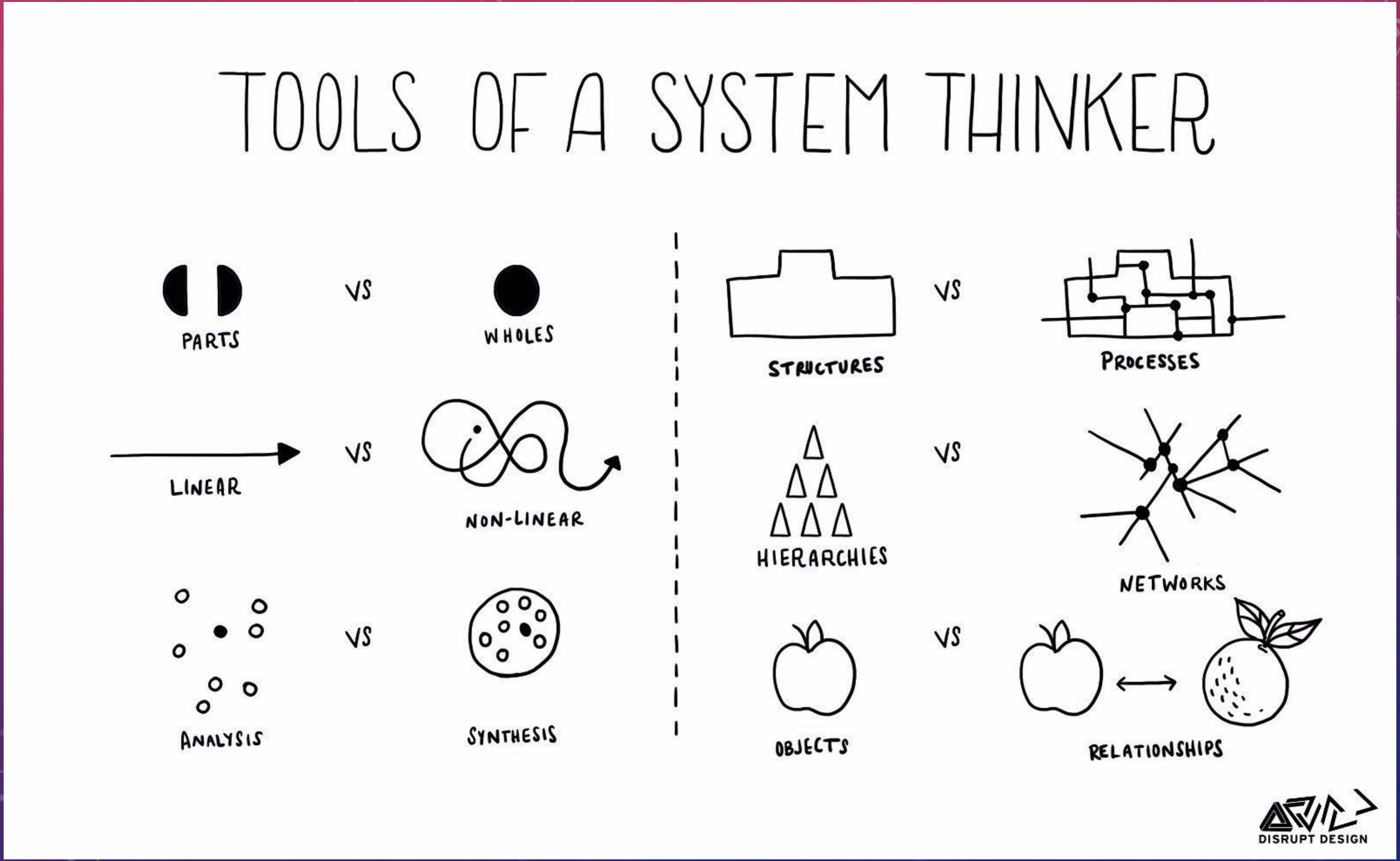


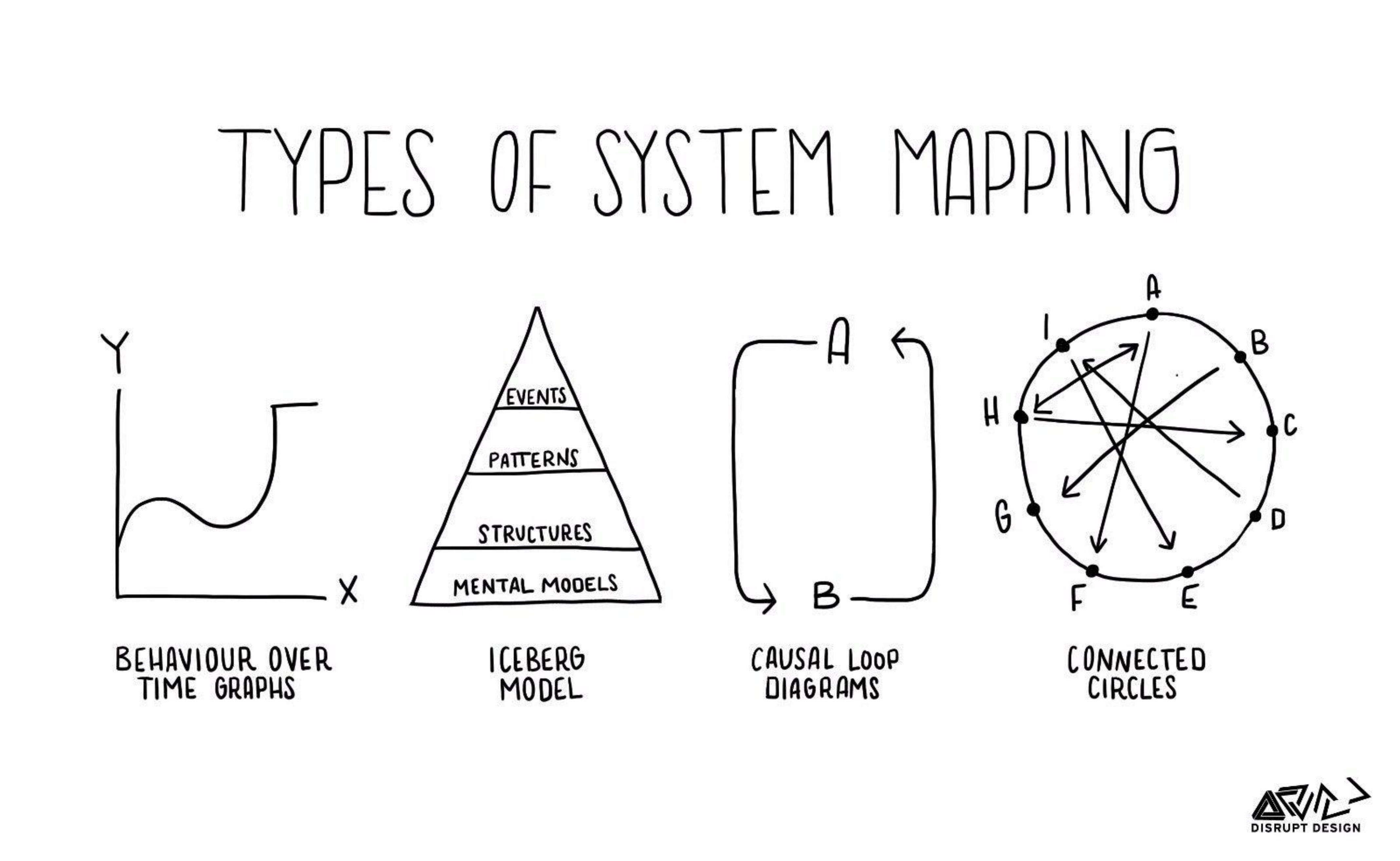

Examples of Systems Thinking Tools
y
x
Behavior-over-time graphs
Stock/flow maps and computer models
Ladder of inference
A
B
Causal loops
a.
b.
c.
d.
e.
f.
Connection circles
Iceberg

TOOLS OF A SYSTEM THINKER



DISRUPT DESIGN

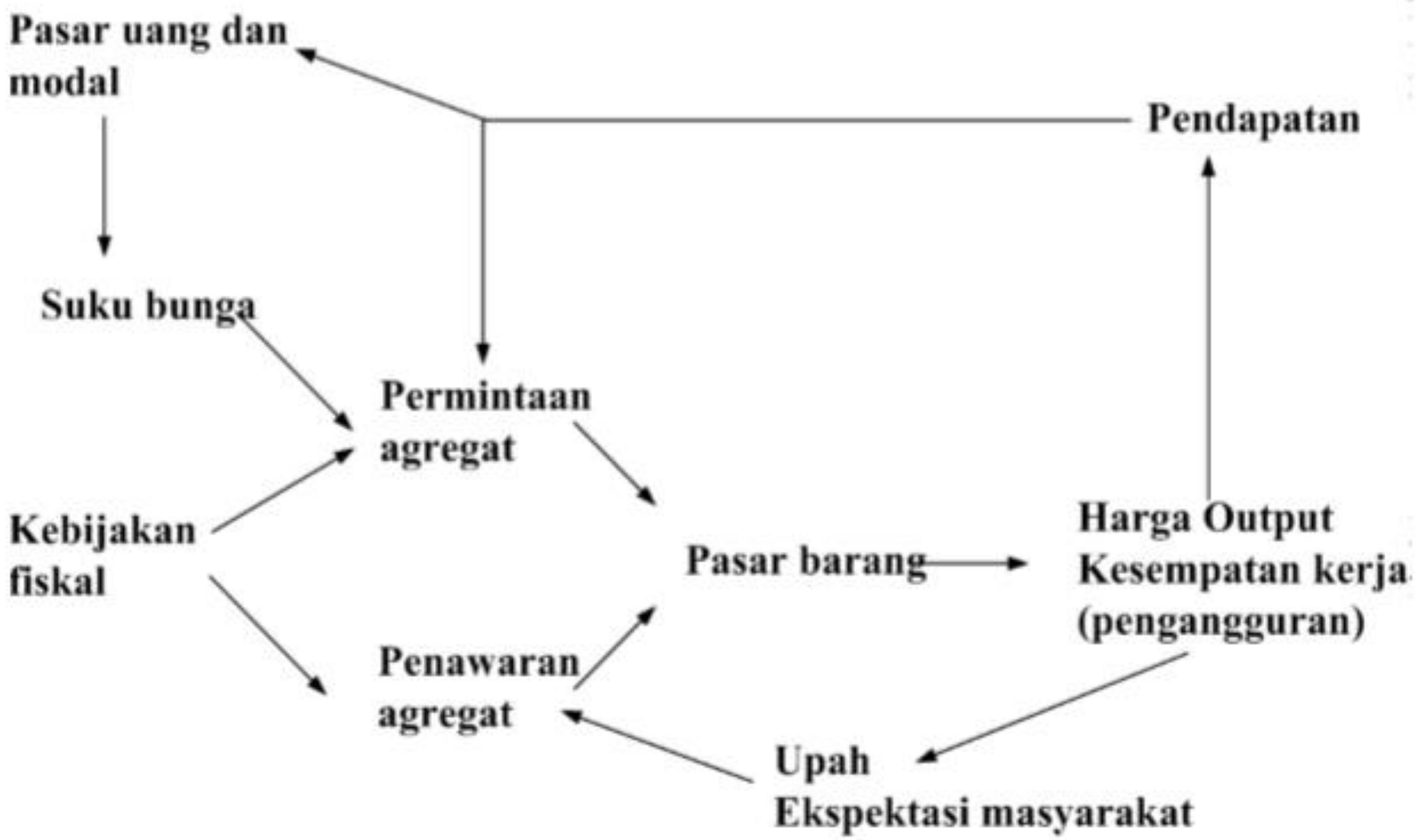

TOOLS OF A SYSTEM THINKER
PARTS
VS
WHOLES
STRUCTURES
VS
PROCESSES
LINEAR
VS
NON-LINEAR
HIERARCHIES
VS
NETWORKS
ANALYSIS
VS
SYNTHESIS
OBJECTS
VS
RELATIONSHIPS
DISRUPT DESIGN


TYPES OF SYSTEM MAPPING
Y
X
BEHAVIOUR OVER TIME GRAPHS
EVENTS
PATTERNS
STRUCTURES
MENTAL MODELS
ICEBERG MODEL
A
B
CAUSAL LOOP DIAGRAMS
A
B
C
D
E
F
G
H
I
CONNECTED CIRCLES
DISRUPT DESIGN

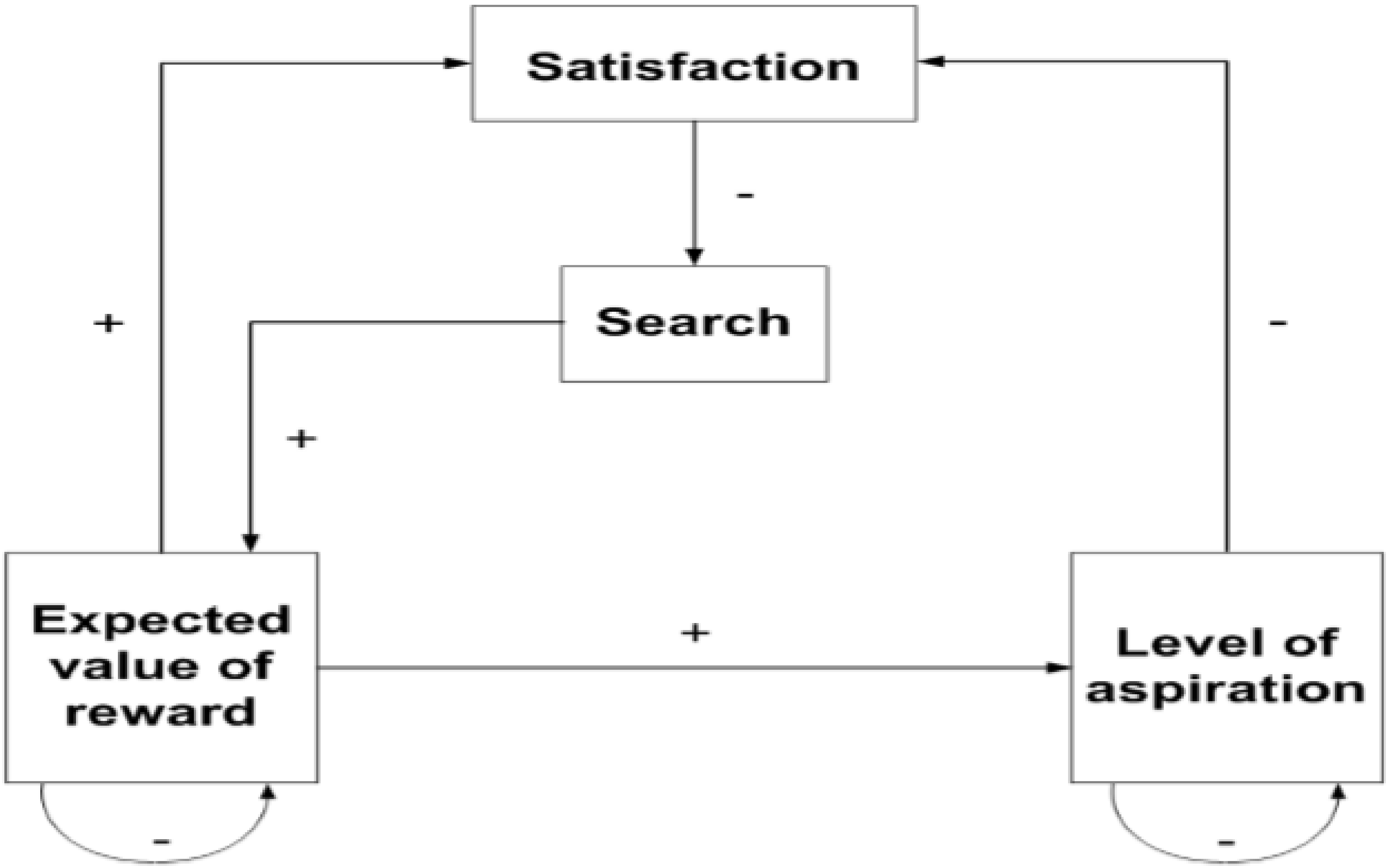
Prinsip **systems thinking** (Senge, 1990) :

- To observe the interdependent relationship (influenced and influence or feedback or interdependent), not a direct cause-effect relationships;
- To observe the processes of change (the process continues, ongoing processes), not just portraits.

- Model yang dibangun melalui suatu analisis struktural (*structural analysis*), berdasarkan pendekatan *systems thinking*, dimungkinkan untuk mempunyai titik kontak yang banyak.
- Dalam paradigma *systems thinking*, struktur fisik ataupun struktur pengambilan keputusan diyakini dibangun oleh unsur-unsur yang saling-bergantung (*interdependent*) dan membentuk suatu lingkar tertutup (*closed-loop* atau *feedback loop*).
- Hubungan unsur-unsur yang saling bergantung itu merupakan hubungan sebab-akibat umpan-balik dan bukan hubungan sebab-akibat searah (Senge, 1990). Lingkar umpan-balik ini merupakan blok pembangun (*building block*) model yang utama.



PENDEKATAN DASAR TERHADAP MAKROEKONOMI



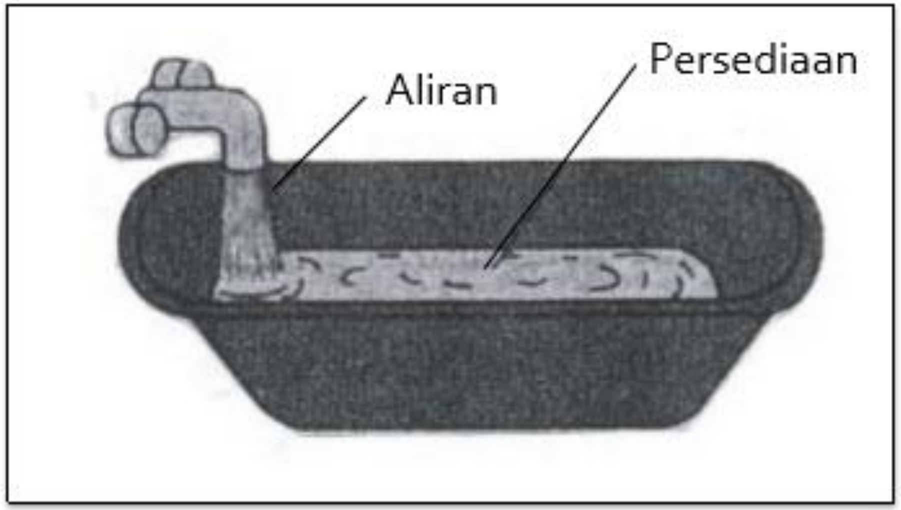
General model of adaptive motivated behavior
Source: March and Simon (1958, p. 49).

Persediaan Dan Aliran

(Teori makroekonomi – edisi ke 5 oleh N. Gegori Mankiw, Harvard University – Penerbit Erlangga 2003, hal 18)

- Banyak variabel ekonomi mengukur jumlah sesuatu– jumlah uang, jumlah barang, dan seterusnya. Para ahli ekonomi membedakan antara dua jenis variabel jumlah: persediaan *(stocks)* dan aliran *(flows)*. ***Persediaan (stocks)*** adalah jumlah yang diukur pada titik waktu tertentu, sedangkan ***aliran (flow)*** adalah jumlah yang diukur per unit waktu.
- Bak mandi, ditunjukkan pada Gambar 5-1, adalah contoh klasik yang digunakan untuk menggambarkan persediaan dan aliran. Jumlah air di dalam bak adalah persediaan: yaitu jumlah air di bak mandi pada titik waktu tertentu . Jumlah air yang keluar dari kran adalah aliran: yaitu jumlah air yang sedang ditambahkan ke bak per unit waktu. Catat bahwa kita mengukur persediaan dan aliran dalam unit yang berbeda. Kita berkata bahwa bak mandi berisi 50 *galon* air, tetapi air yang keluar dari kran adalah 5 *galon per menit.*

Gambar 3-4



Persediaan dan Aliran
Jumlah air di bak mandi adalah persediaan: jumlahnya diukur pada titik waktu tertentu. Jumlah air yang keluar dari kran adalah aliran: jumlahnya diukur per unit waktu.

- GDP mungkin adalah variabel aliran paling penting dalam perekonomian: GDP menyatakan berapa banyak uang yang mengalir mengelilingi aliran sirkuler perekonomian per unit waktu. Ketika Anda mendengar seseorang berkata GDP AS adalah $10 triliun, Anda seharusnya mengerti, ini berarti bahwa GDP adalah $10 triliun *per tahun*. (Demikian pula, kita bisa mengatakan bahwa GDP AS adalah $17.000 per detik.)
- Persediaan dan aliran seringkali berkaitan. Dalam contoh bak mandi, hubungan ini jelas. Persediaan air di bak menunjukkan akumulasi dari aliran yang keluar dari kran, dan aliran air menunjukkan perubahan dalam persediaan. Ketika membangun teori untuk menjelaskan variabel-variabel ekonomi, seringkali berguna untuk menentukan apakah variabel-variabel itu adalah persediaan atau aliran dan apakah ada hubungan di antara keduanya.
- Inilah beberapa contoh persediaan dan aliran yang akan kita pelajari dalam bab-bab berikutnya:

➢ Kekayaan seseorang adalah persediaan; pendapatan dan pengeluarannya adalah aliran.

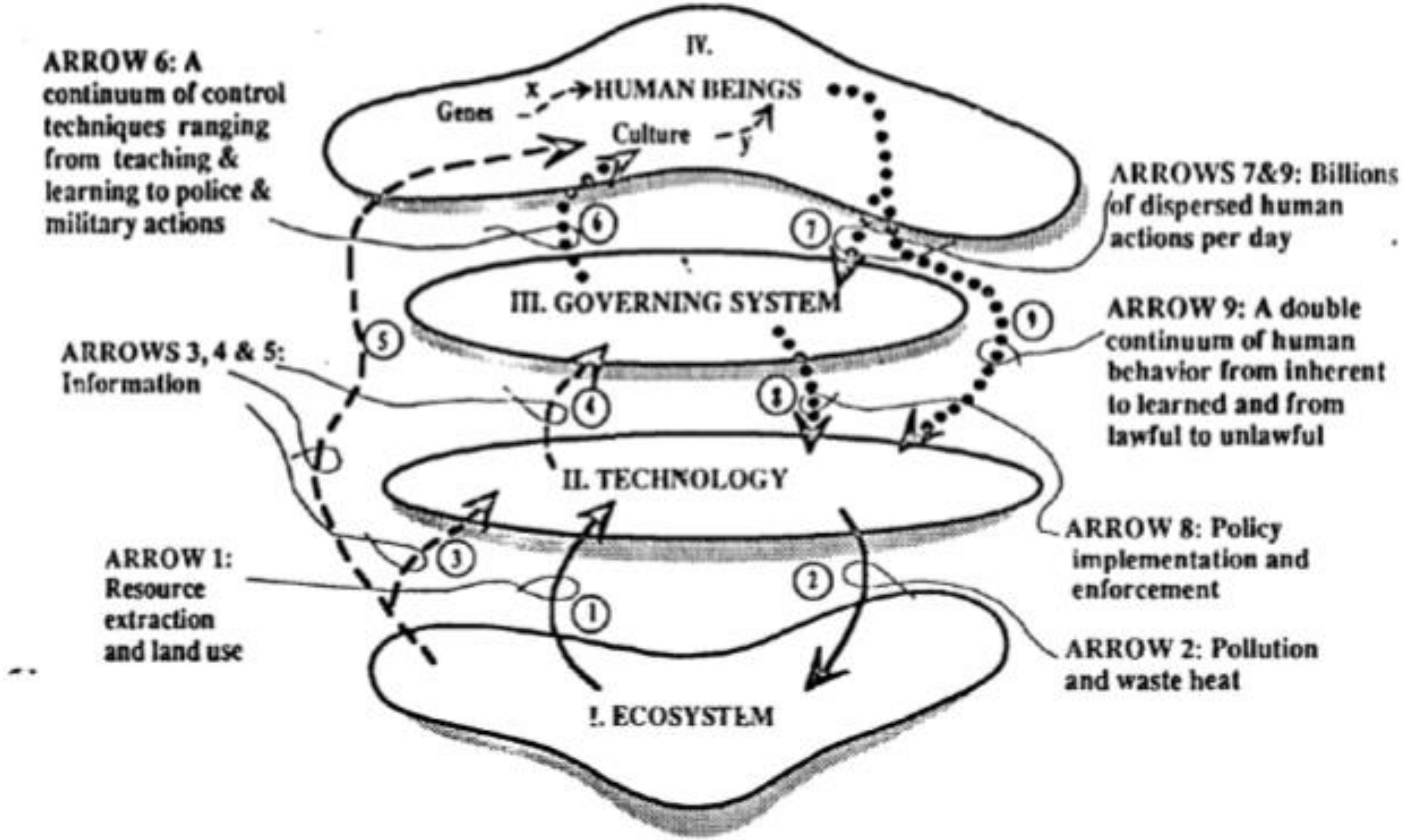
➢ Jumlah orang yang menganggur adalah persediaan; jumlah orang yang kehilangan pekerjaan mereka adalah aliran.

➢ Jumlah modal dalam perekonomian adalah persediaan; jumlah investasi adalah aliran.

➢ Utang pemerintah adalah persediaan; defisit anggaran pemerintah adalah aliran.

FOUR-SECTOR FEEDBACK MODEL OF HUMAN LIFE-SUPPORT SYSTEM

(Duncan, 1991)



- SECTOR I. ECOSYSTEM
  This is the earth's natural environment comprising all land, water, air, energy & material resources, plants and animals.

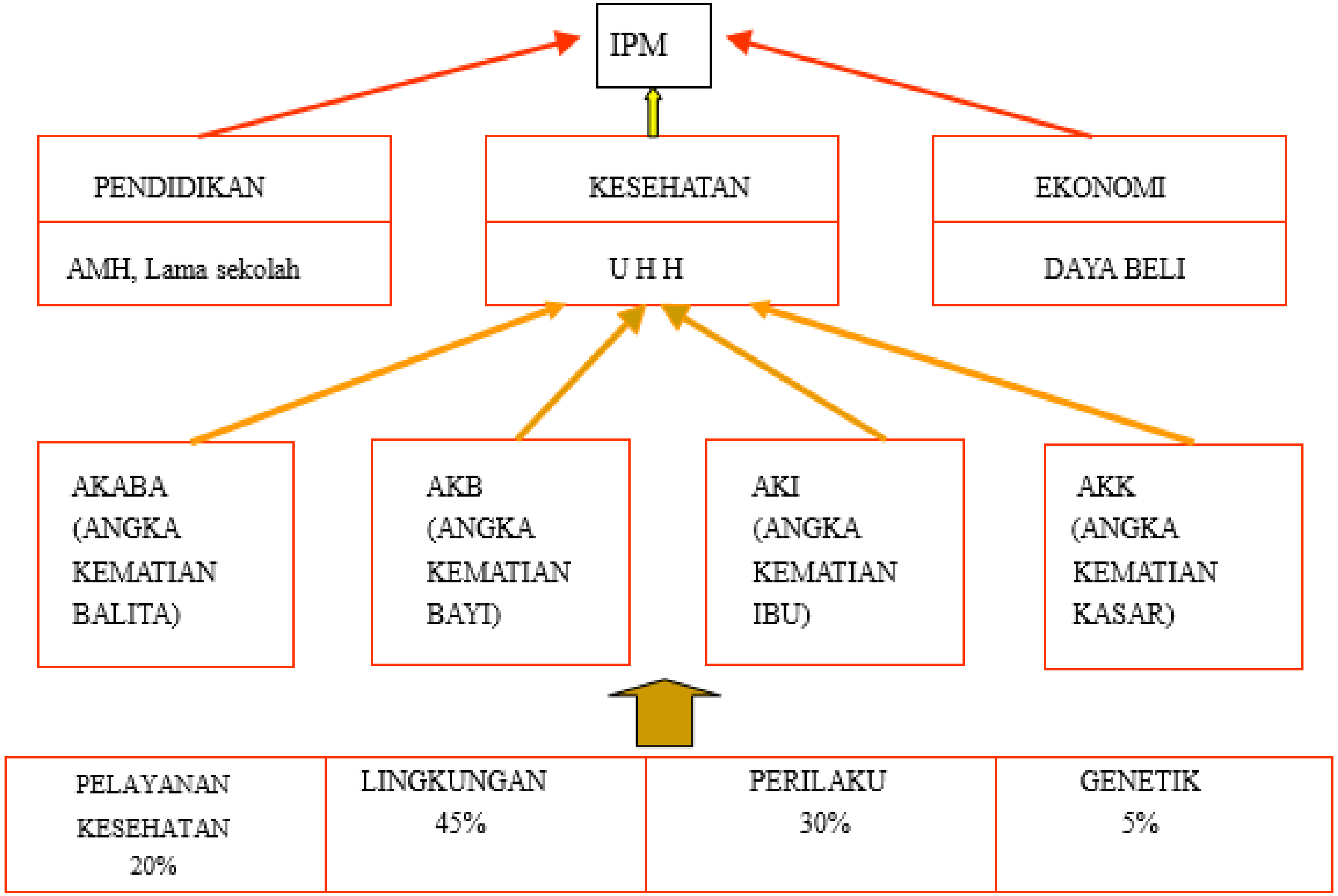
- SECTOR II. TECHNOLOGY
  This is the human industrial and consumption system comprising all technology used for agriculture, physical production, transportation, et cetera.

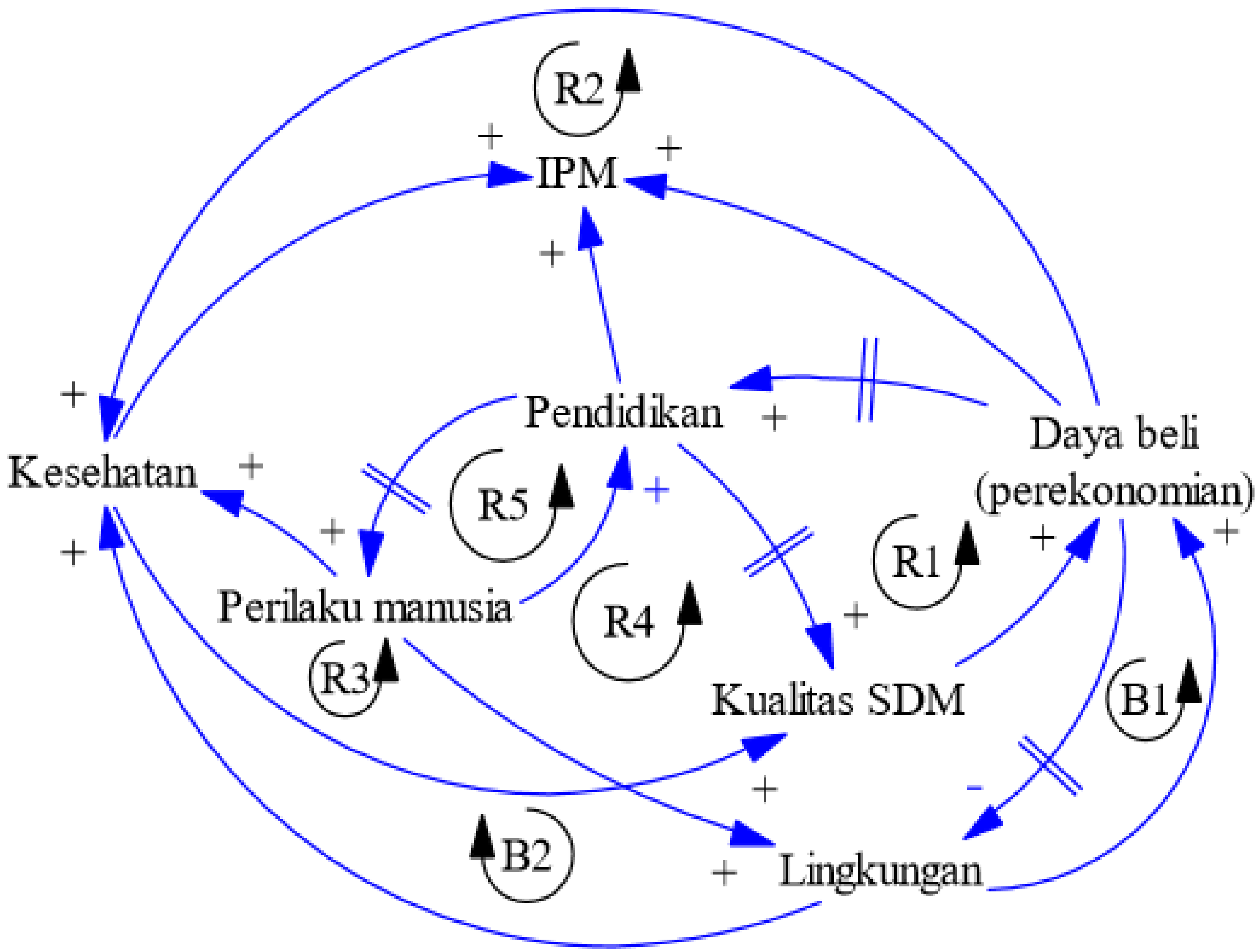
- SECTOR III. GOVERNING SYSTEM
  This is the social regulatory system comprising all human institutions and processes: economic, financial, governmental, judicial, military, educational, religious, et cetera.

- SECTOR IV. HUMAN BEINGS
  This is the global population comprising billions of individual human beings. Genes process hereditary information. Brains process cultural information.

- SOLID ARROW : Materials & energy flow
- DASHED ARROW : Information flow
- DOTTED ARROW : Human behavior or institutional action
- ARROW x : Genetic Influence
- ARROW y : Cultural Influence

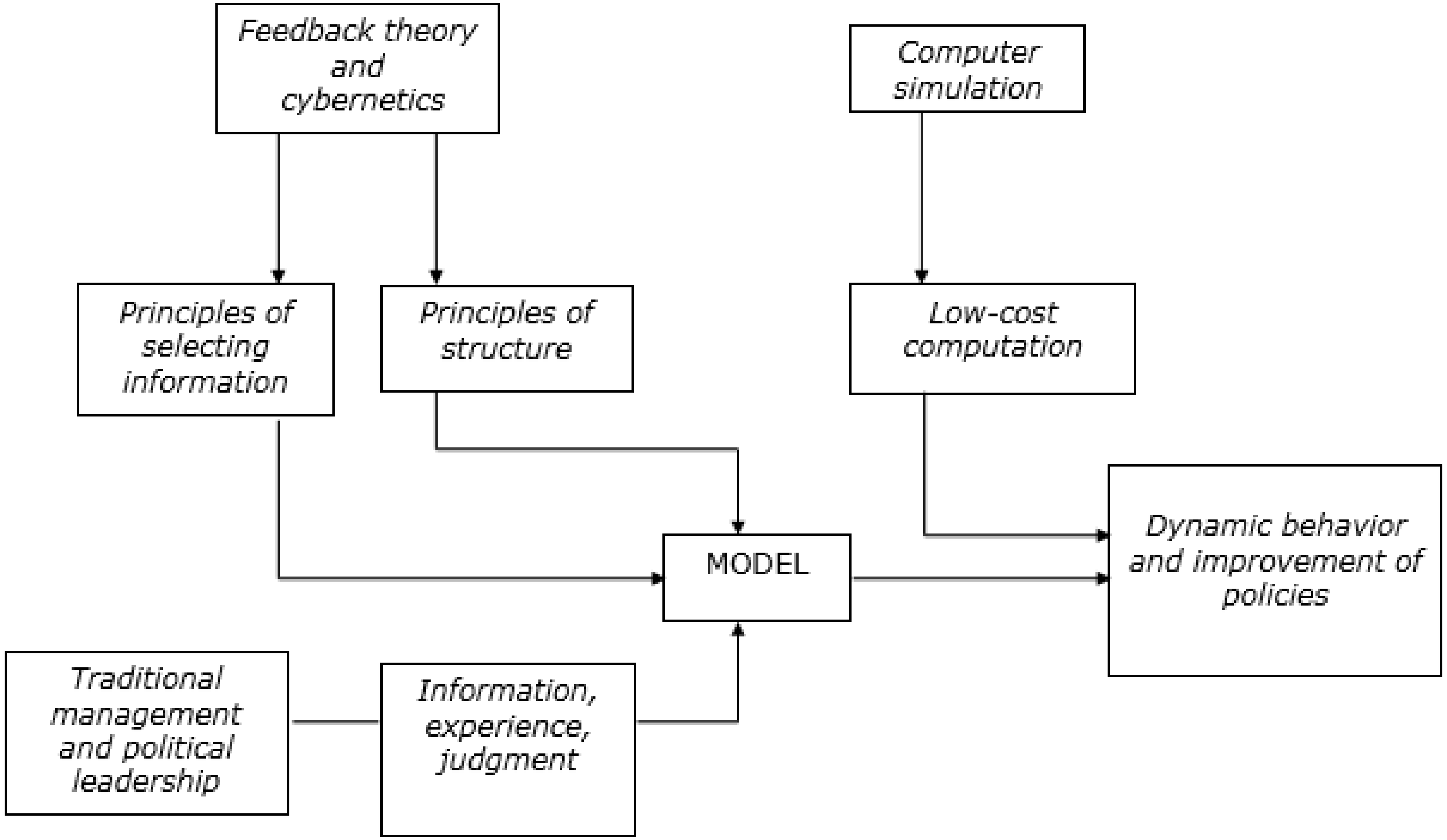
Indeks Pembangunan Manusia (IPM)





Causal loop diagram IPM

3.6 Peran beberapa bidang (*field*) dalam metodologi *system dynamics*

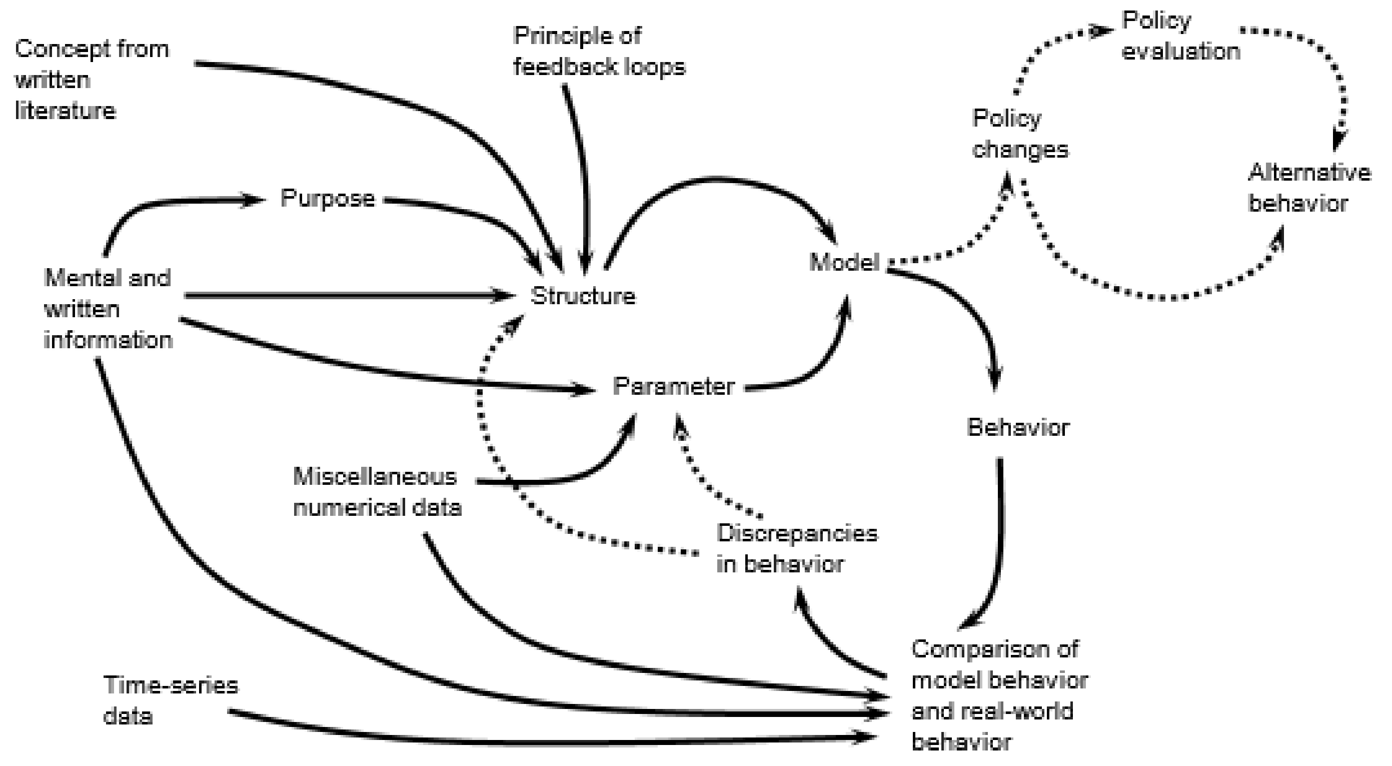


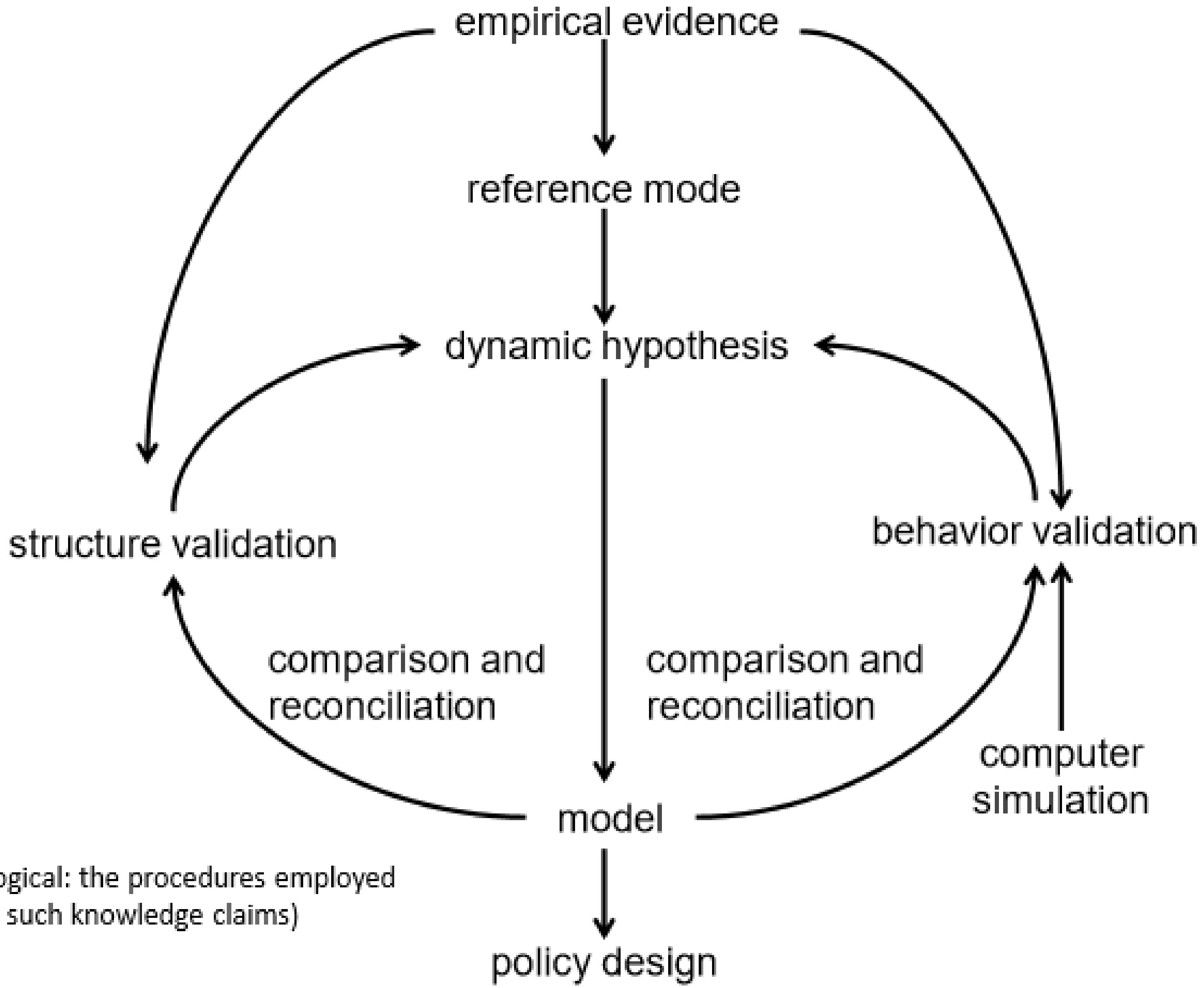
Manajemen tradisional (*traditional management*) beserta pengalamannya tentang dunia nyata merupakan sumber informasi yang mendasar untuk membuat struktur model suatu sistem. Karena semua informasi yang terkandung dalam suatu model mental tidak dapat dimasukkan ke dalam suatu model eksplisit, informasi itu perlu dipilih berdasarkan tingkat kepentingannya dalam fenomena atau gejala yang dianalisis.
Teori umpan-balik beserta sibernetika (*feedback theory* dan *cybernetics*) memberikan prinsip-prinsip untuk memilih informasi yang relevan dan menyingkirkan informasi yang tidak mempunyai hubungan dengan dinamika-dinamika persoalan.

Sekali suatu model dapat diformulasikan, perilaku dinamisnya dapat dipelajari menggunakan simulasi dengan komputer. Simulasi ini sangat membantu dalam upaya kita untuk membandingkan struktur model beserta perilakunya dengan struktur dan perilaku sistem yang sebenarnya, yang pada gilirannya akan meningkatkan keyakinan kita terhadap kemampuan model di dalam mendeskripsikan sistem yang diwakilinya. Keyakinan ini menjadi dasar bagi kesahihan model. Bila kesahihan model telah dapat dicapai, simulasi selanjutnya dapat digunakan untuk merancang kebijakan-kebijakan yang efektif.

Pada mulanya Forrester menerapkan metodologi *system dynamics* untuk memecahkan persoalan-persoalan yang terdapat dalam industri (perusahaan). Model-model *system dynamics* pertama kali ditujukan kepada permasalahan manajemen yang umum seperti fluktuasi inventori, ketidakstabilan tenaga kerja, dan penurunan pangsa pasar suatu perusahaan (lihat Forrester 1961). Perkembangannya terus meningkat semenjak pemanfaatannya dalam persoalan sistem-sistem sosial yang sangat beragam, yang antara lain dapat disimak dari tulisan Forrester dan Hamilton (Forrester 1969, Hamilton et al. 1969, dan Forrester 1971).

3.7 Perancangan suatu model *System Dynamics*





(methodological: the procedures employed to arrive to such knowledge claims)

3.8. Tests for Building Confidence in System Dynamics Model

(Forrester and Senge 1980, Richardson and Pugh 1981):

- **Test of Model Structure**
  1. ***Structure Verification***
     (Is the model structure consistent with relevant descriptive knowledge of the system?)
  2. ***Parameter Verification***
     (Are the parameters consistent with relevant descriptive [and numerical, when available] knowledge of system?)
  3. ***Extreme Conditions***
     (Does each equation make sense even when its inputs take on extreme values?)
  4. ***Structure Boundary Adequacy***
     (Are the important concepts for addressing the problem endogenous of the model?)
  5. ***Dimensional Consistency***
     (Is each equation dimensionally consistent without the use of parameters having no real-world counterpart?)

- **Test of Model Behavior**

1. ***Behavior Reproduction***

   (Does the model endogenously generate the symptoms of the problem, behavior modes, phasing, frequencies, and other characteristics of the behavior of the real system?)

2. ***Behavior Anomaly***

   (Does anomalous behavior arise if an assumption of the model is deleted?)

3. ***Family Member***

   (Can the model reproduce the behavior of other examples of the systems in the same class as the model?)

4. ***Surprise Behavior***

   (Does the model point to the existence of a previously unrecognized mode of behavior in the real system?)

5. ***Extreme Policy***

   (Does the model behave properly when subjected to extreme policies or test inputs?)

6. ***Behavior Boundary Adequacy***

   (Is the behavior of the model sensitive to the addition or alteration of structure to represent plausible alternative theories?)

7. ***Behavior Sensitivity***

   (Is the behavior of the model sensitive to plausible variations in parameters?)

8. ***Statistic Character***

   (Does the output of the model have the same statistical character as the "output" of the real system?)

❑ Test of Policy Implications

1. ***System Improvement***

   (Is the performance of the real system improved through use of the model?)

2. ***Behavior Prediction***

   (Does the model correctly describe the results of a new policy?)

3. ***Policy Boundary Adequacy***

   (Are the policy recommendations sensitive to the addition or alteration of structure to represent plausible alternative theories?)

4. ***Policy Sensitivity***

   (Are the policy recommendations sensitive to plausible variations in parameters?)

3.9 Archetypal Structures (System Archetypes) in System Dynamics

(E. F. Wolstenholme: "Towards the definition and use of a core set of archetypal structures in system dynamics" in System Dynamics Review Vol. 19, No. 1, (Spring 2003): 7-26)

System archetypes are introduced as a formal and free-standing way of classifying structures responsible for generic patterns of behavior over time, particularly counter-intuitive behavior.

Such "structures" consist of **intended actions** and **unintended reactions** and recognize **delays** in reaction time.

System archetypes have an important and multiple role to play in systemic thinking.

System archetypes are first and foremost a communications device to share dynamic insights.

3.10 System Dynamics for policy design in terms of System Archetypes

- ***System dynamics* consists of five (5) components of system "structure":**

  (1) processes, created using stock-flow chains;

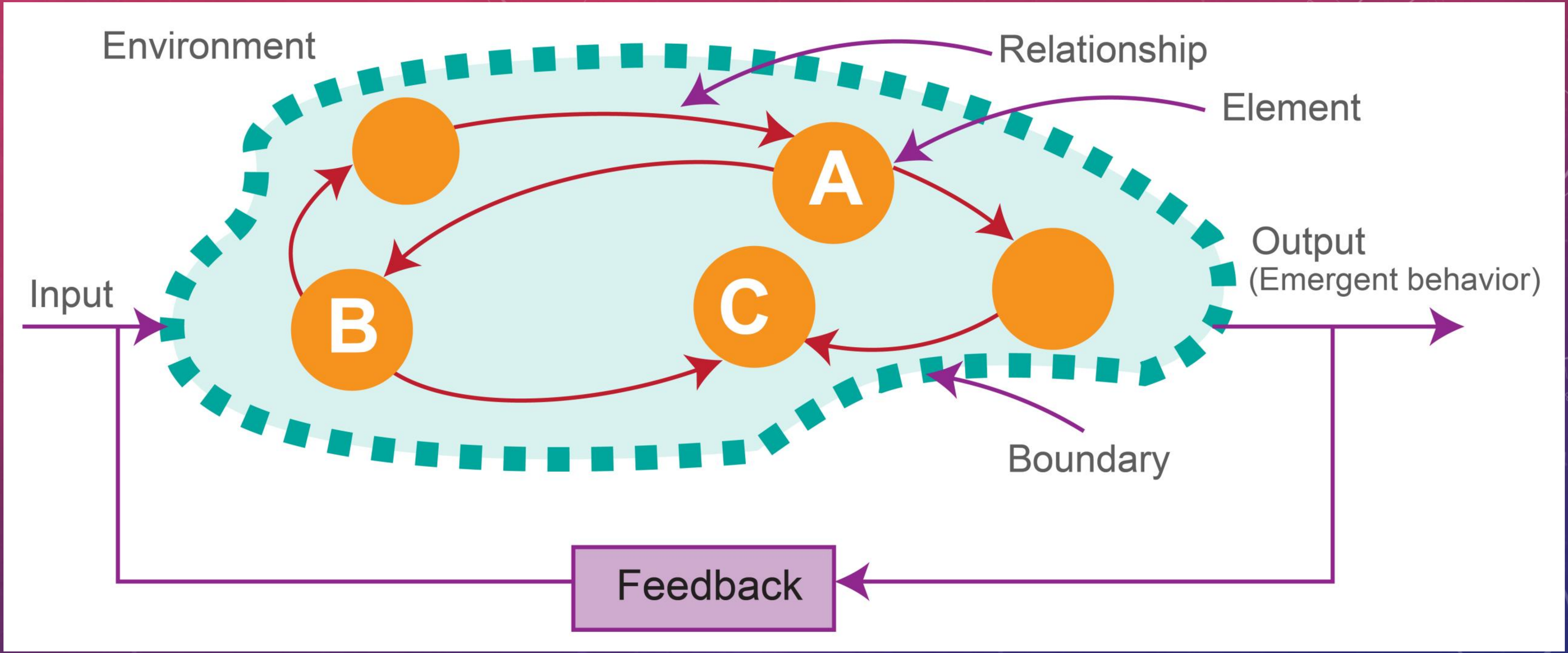
  (2) information feedback;

  (3) policy;

  (4) time delays; and

  (5) boundaries.

(E. F. Wolstenholme: "Using generic system archetypes to support thinking and modeling" in System Dynamics Review Vol. 20, No. 4, (Winter 2004): 341-356)


Environment
Relationship
Element
A
Output
(Emergent behavior)
Input
B
C
Boundary
Feedback

- **Boundaries in system archetypes**

1. Organisations are by definition very bounded entities in terms of disciplines, functions, accounting, power, and culture (the existence of boundaries as basic elements of organisational structure).
2. Boundaries are the one facet of organisations that are perhaps changed more often than any other.
3. They are often changed in isolation from strategy and process on the whim of a new top team or political party, usually to impose their own people.

4. Different types of boundaries:

a) they may be between the organisation and its environment;

b) they may be very physical accounting boundaries between different functional parts of the same organisation; and

c) they may be between management teams or indeed mental barriers within individuals.

5. The existence and importance of boundaries within organisations, as a determinant of organisational evolution over time, has to be represented in system archetypes.

6. The superimposition of organisational boundaries on system archetypes helps explain why systemic management is so difficult.

a) Organisational boundaries highlight dramatically that action and reaction are often instigated from separate sources within organisation.

b) Organisational boundaries imply that reactions are often “hidden” from the “view” of the source responsible for the actions.

c) Organisational boundaries force system actors to actively confront the need to share information and collaborate to achieve whole system objectives.

3.11 The characteristics of a totally generic two-loop system archetype

- **The basic structure of a totally generic two-loop system archetype (Figure 4.4)**

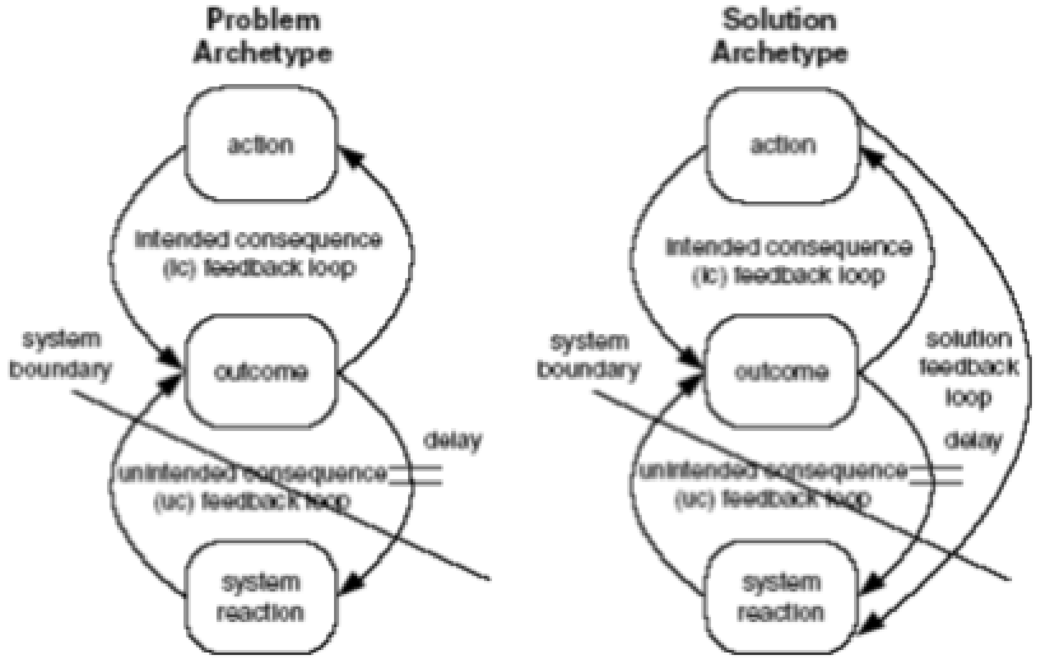


Figure 3.5 The basic structure of a totally generic two-loop system archetype

- **The characteristics of the archetype:**

1. It is composed of an *intended consequence* (*ic*) *feedback loop* which results from an *action* initiated in *one sector of an organisation* with an intended consequence over time in mind.
2. It contains an *unintended consequence* (*uc*) f*eedback loop*, which results from a *reaction within another sector of the organisation or outside*.
3. There is a *delay* before the unintended consequence manifests itself.
4. There is an *organisational boundary* that "hides" the unintended consequence from the "view" of those instigating the intended consequences.
5. That for every "*problem*" archetype, there is a "*solution*" archetype.

- **Problem archetypes:**

1. A *problem archetype* is one whose net behavior over time is far from that intended by the people creating the ic loop.
2. It should be noted that reactions can arise from the same system participants who instigate the original actions (perhaps due to impatience with the time taken for their original actions to have effect).
3. The reaction may also arise from natural causes.
4. It is more often the case that the reaction comes from other individuals, groups or sectors of the same organisation or from external sources.
5. Almost every action will be countered by a reaction in some other part of the system and hence no one strategy will ever dominate (systems are dynamic, self-organising, and adaptive).

- **Solution archetypes:**

1. The closed-loop *solution archetype* is to minimise any side effects (a generic two-loop solution archetype is also shown on Figure 4.4).
2. The key to identifying solution archetypes lies in understanding both the magnitude of the **delay** and the nature of the **organisational boundary** present.
3. Solutions require that system actors, when instigating a new action, should attempt to remove or make more transparent the organisational boundary masking the side effect.
4. Collaborative effort on both sides of the boundary can then be directed at introducing new “solution” feedback loops to counter or unblock the uc loop in parallel with activating the ic loop.
5. The result is that the intended action should be much more robust and capable of achieving its purpose.

3.12 Four generic problem/solution archetypes

- Initiating actions for change can be condensed down to one of two kinds.
- These are actions that attempt to improve the *achievement* of an organisation by initiating *reinforcing feedback* effects and those that attempt to *control* an organisation by introducing *balancing feedback* effects.
- Reactions can also be condensed to one of the same two kinds.
- There are only four totally generic two-loop archetypes possible, arising from the four ways of ordering the two basic types of feedback loops (balancing and reinforcing):

(1) *Underachievement*, intended achievement fails to be realised (Figure 4.5).

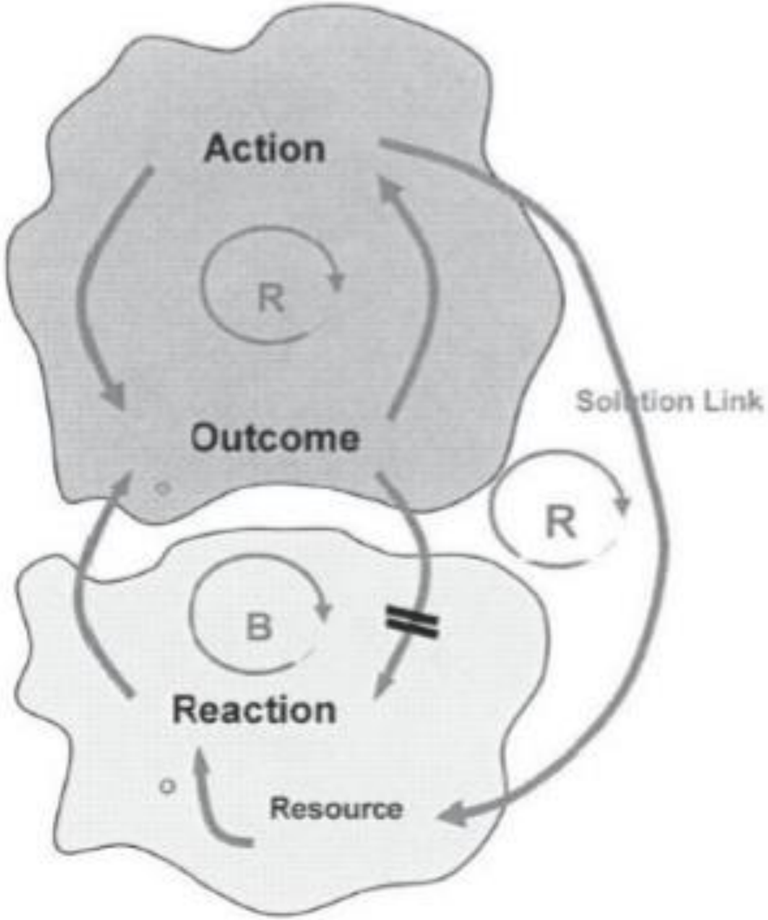


Figure 3.6 *Underachievement* archetype

(2) *Out of control*, intended control fails to be realised (Figure 4.6).

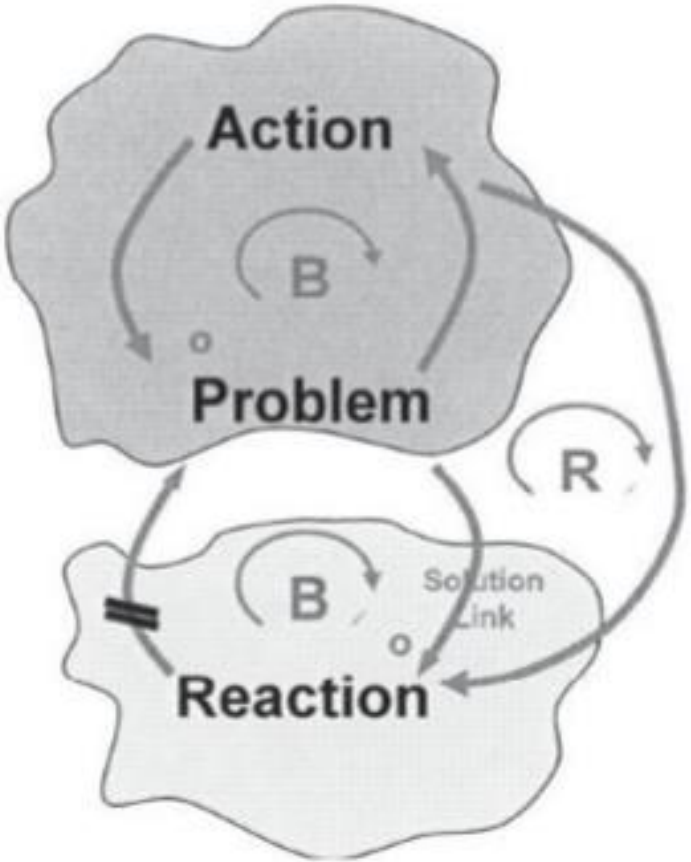


Figure 3.7 *Out of control* archetype

(3) *Relative achievement*, achievement is only gained at the expense of another (Figure 4.7).

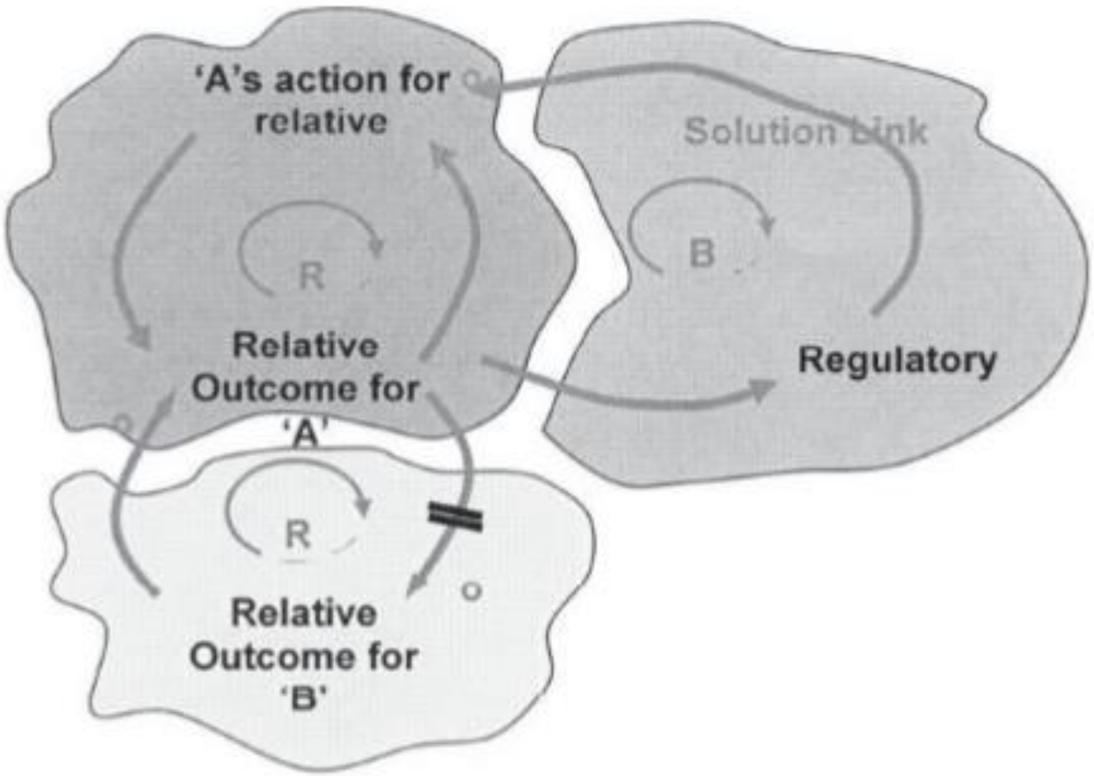


Figure 3.8 *Relative achievement* archetype

(4) *Relative control*, control is only gained at the expense of others (Figure 4.8).

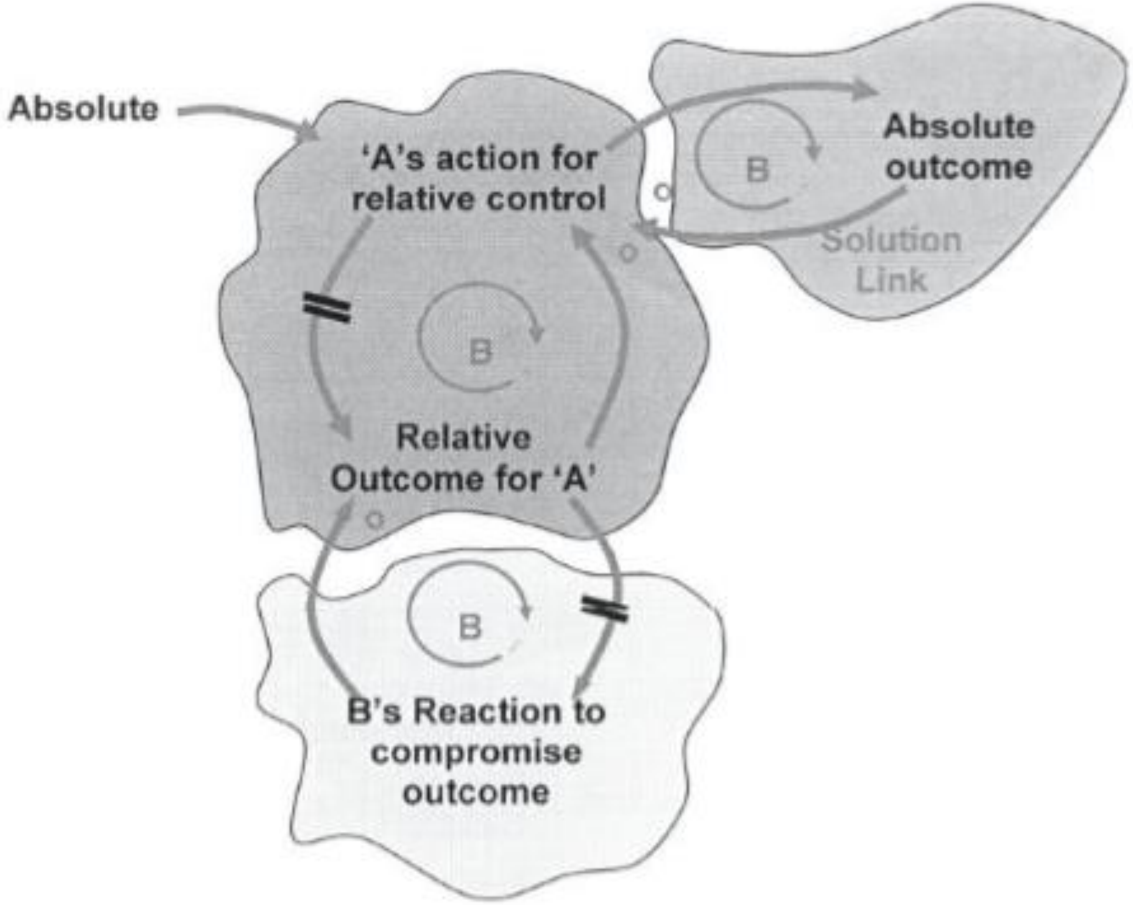
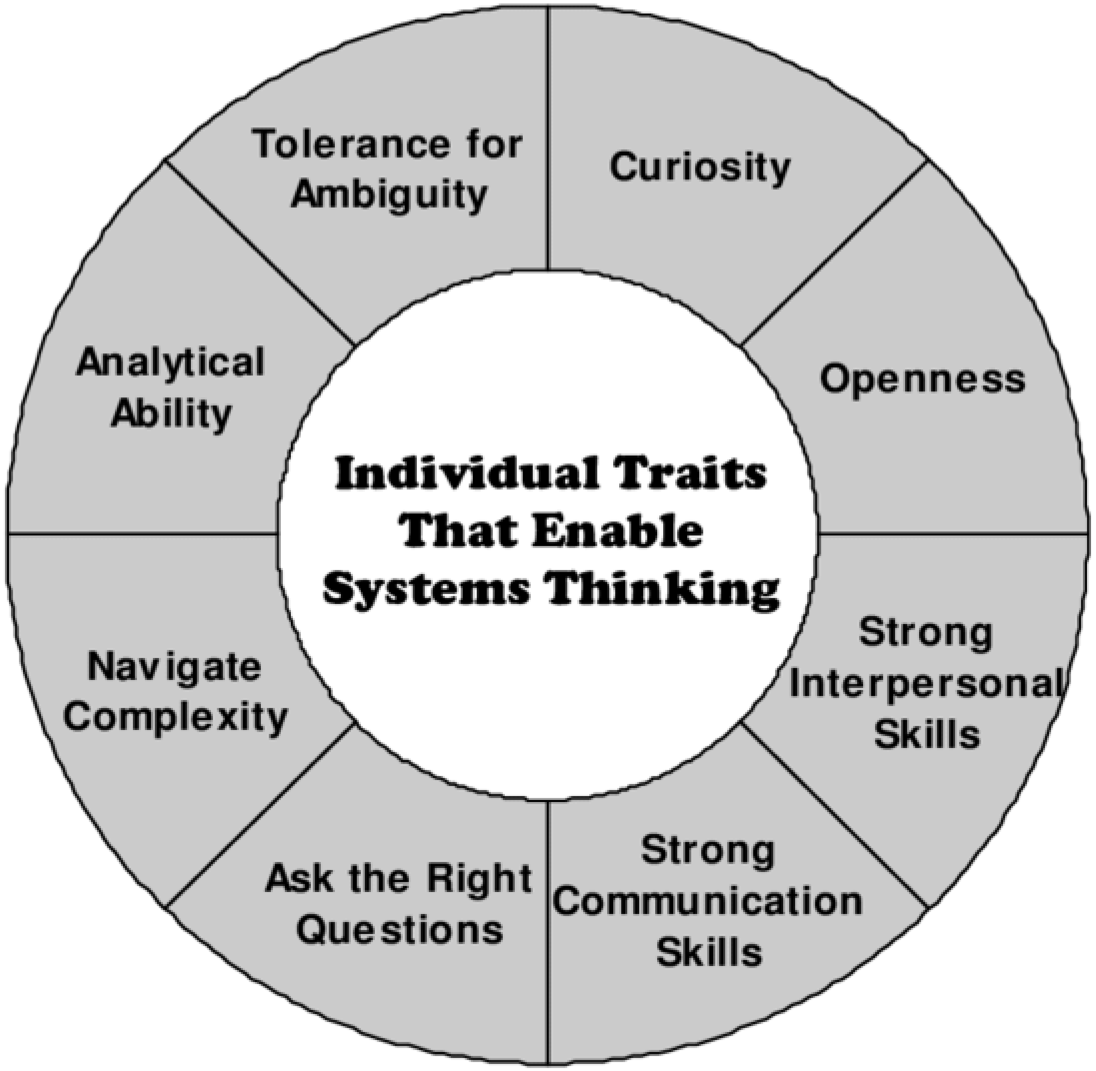


Figure 3.9 *Relative control* archetype

3.13 Mapping existing semi-generic problem archetypes onto four generic problem archetypes

- Semi-generic archetypes that can be mapped onto the generic *underachievement* archetype (Figure 4.5) are *Limits to success*, *Tragedy of the commons*, and *Growth and underinvestment*.
- Semi-generic archetypes that can be mapped onto the generic *out of control* archetype (Figure 4.6) are *Fixes that fail*, *Shifting the burden*, and *Accidental adversaries*.
- The semi-generic archetype which can be mapped onto the generic *relative achievement* archetype (Figure 4.7) is *Success to the successful*.
- The semi-generic archetypes which can be mapped onto the generic *relative control* archetype (Figure 4.8) are *Escalation* and *Drifting goals*.


Individual Traits
That Enable
Systems Thinking
Tolerance for
Ambiguity
Curiosity
Openness
Strong
Interpersonal
Skills
Strong
Communication
Skills
Ask the Right
Questions
Navigate
Complexity
Analytical
Ability