Systems Science and Innovation

Systems science for synthesis(design)

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“Necessity of Systems Science for Innovation”

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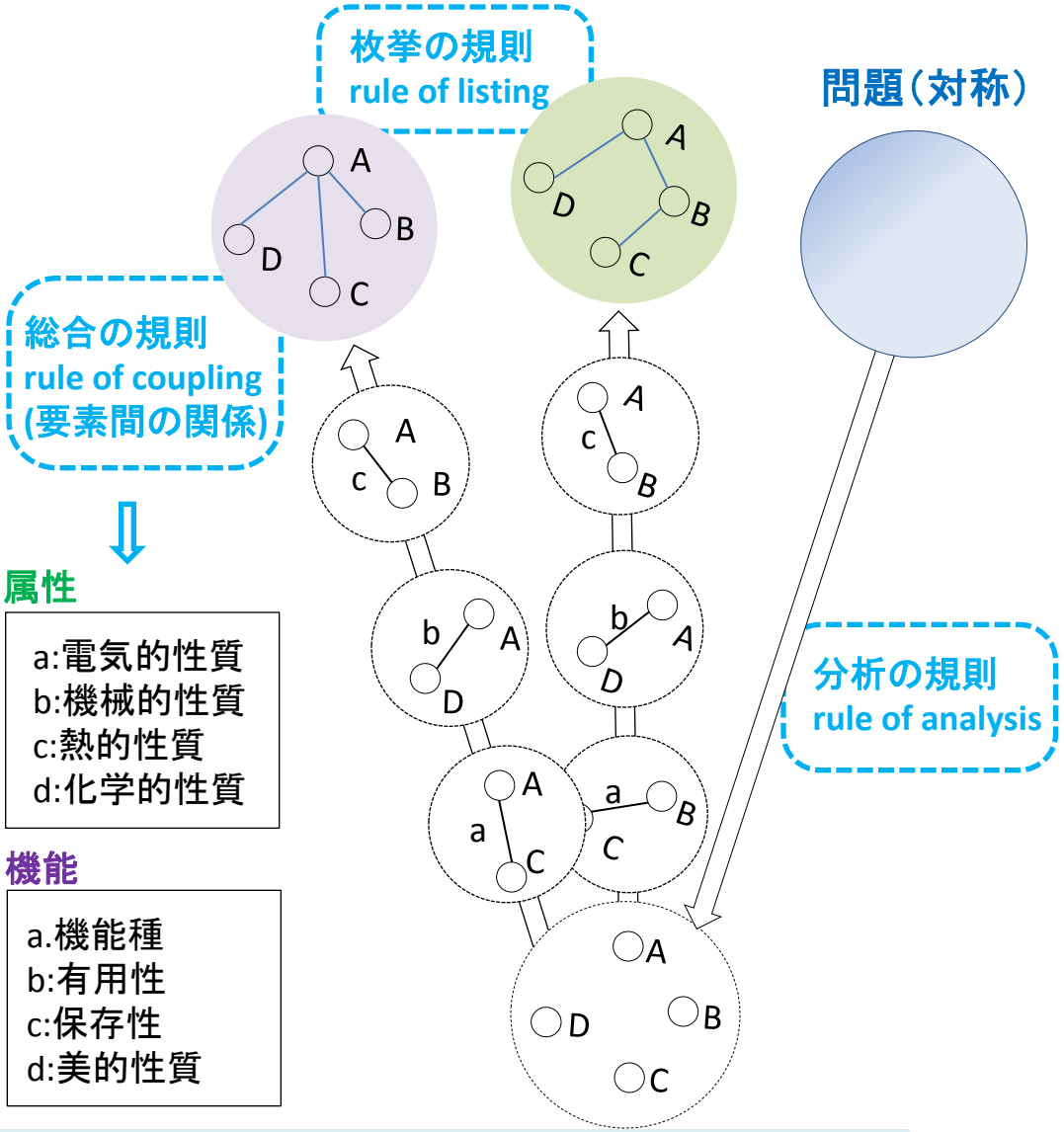
René Descartes

「精神指導の規則」:規則第5、「方法序説(1637)」:四つの規則

1. **明晰性の規則**:(明晰かつ判明に精神に現れるもののみで判断)
2. **分析の規則**:“私が検討する難問の一つ一つを、できるだけ多くの、しかも問題をよりよく解くために必要な小部分に分割すること。”
3. **総合(統合*)の規則**:“私の思考を順序に従って導くこと。そこではもっとも単純で最も認識しやすいものから始めて、少しずつ階段を上るようにして、もっとも複雑なものの認識まで登ってゆき、自然のままでは互いに前後の順序がつかないものの間にさえも順序を想定して進むこと。”
4. **枚挙の規則**:“すべての場合に、完全な枚挙と全体にわたる見直しをして、何も見落とさなかったと確信すること。”

(方法序説、岩波、谷川多佳子訳、*HY)



現代科学の偏向:現代科学では、総合規則は分析規則に比べて未開拓である。

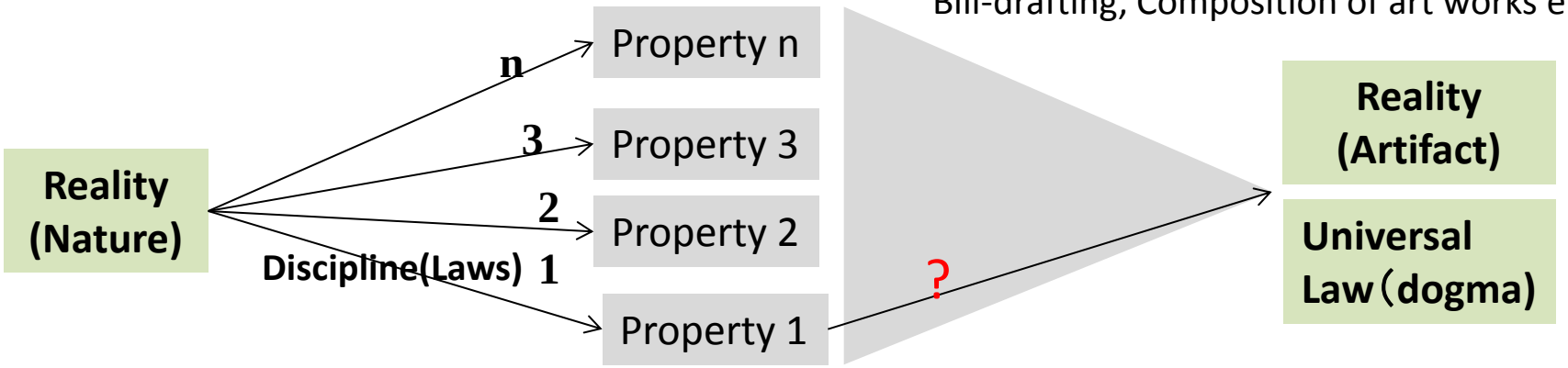
Irreversibility of Scientific Method
Knowledge for Understanding and Knowledge for Action

Analysis:

Experiment, Measurement, Theory
(Hypothesis, Discovery, New discipline,)*

Synthesis:

Design, Planning, Innovation,
Management, Policy-formulation,
Bill-drafting, Composition of art works etc



Science for Analysis

Deduction **=Always right**

Systematic scientific method

Science for Synthesis

Abduction **=Fallible**

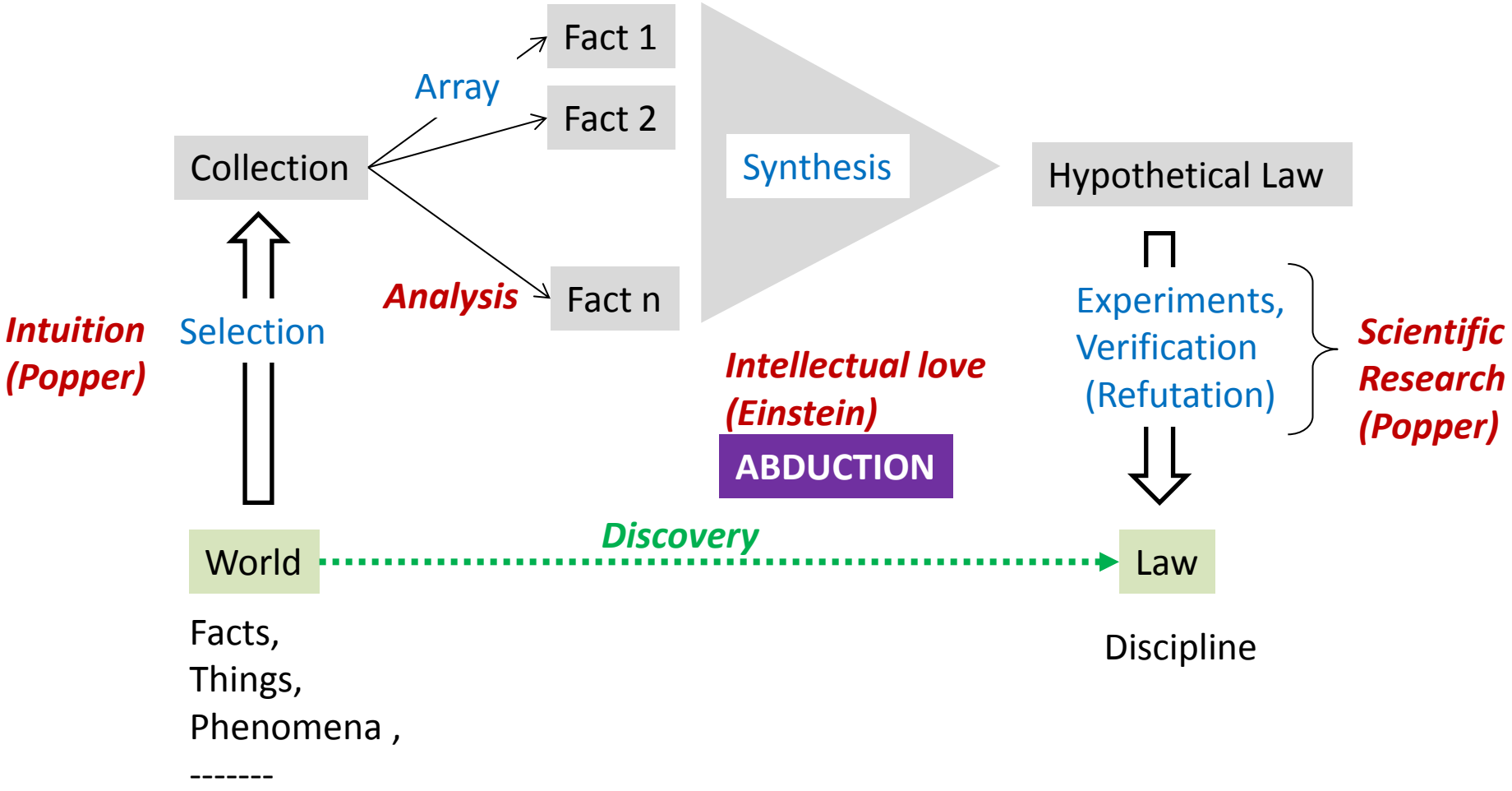
Less systematized singular methods
(know-how, technology or engineering)

* These belong to synthesis. See next page.

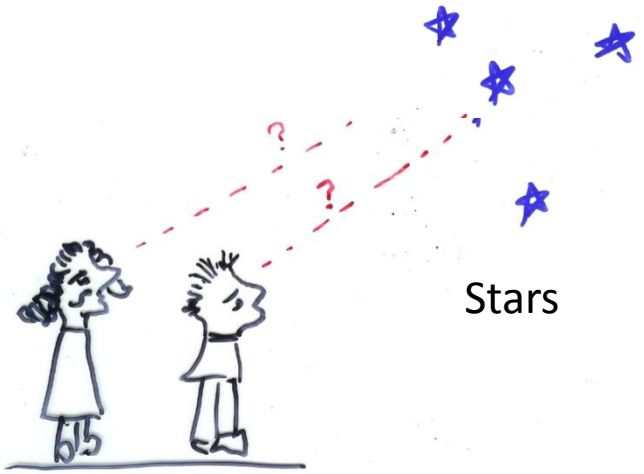
Examine(use) the real to create knowledge ⟷ **Asymmetry of Human Thought** ⟷ **Use(examine) the knowledge to create real**

Discovery of Highly Universal Scientific Law

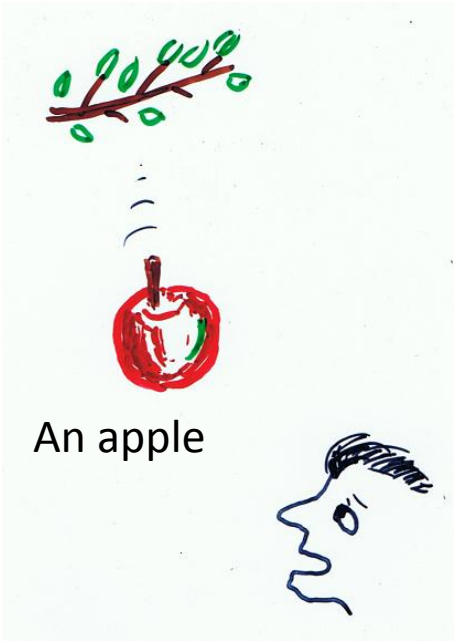
Discovery of new theory (construction of new discipline) in basic science



Science is to find Universal Principles behind diversified phenomena in nature. (Discovery)



Stars



An apple

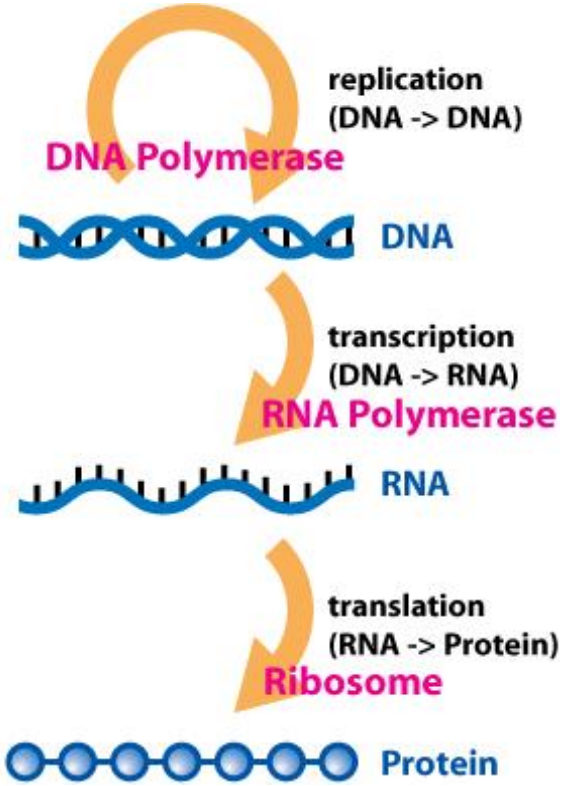
$$\sum \mathbf{F} = 0 \Rightarrow \frac{d\mathbf{v}}{dt} = 0.$$

$$F = M\alpha$$

$$\sum \mathbf{F}_{a,b} = -\sum \mathbf{F}_{b,a}$$

Newton's three laws were discovered through abduction.

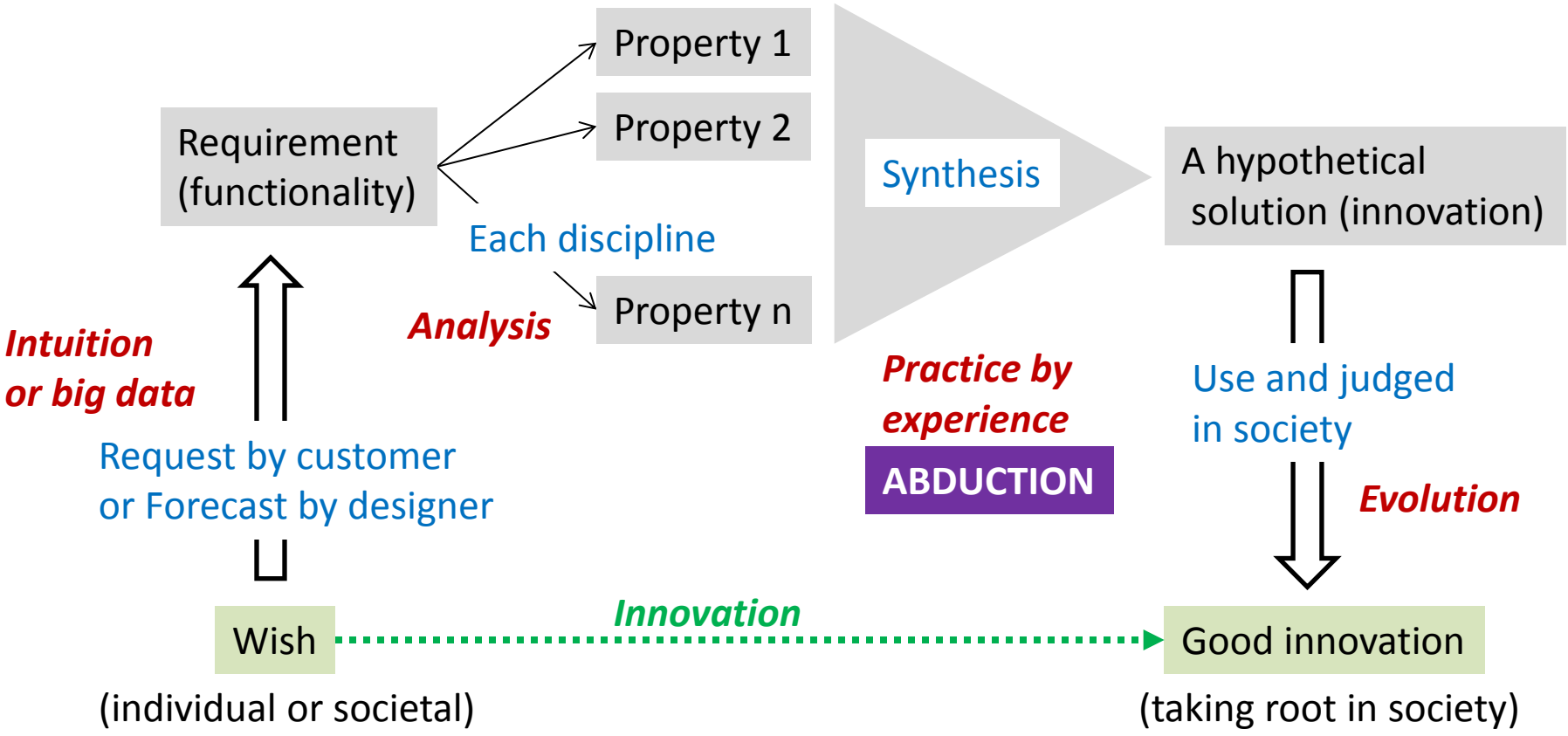
Central Dogma of Molecular Biochemistry with Enzymes



Dogma by Francis Click

The central dogma of molecular biology deals with the detailed residue-by-residue transfer of sequential information. It states that such information cannot be transferred back from protein to either protein or nucleic acid.

Engineer's Design: Systematic Innovation



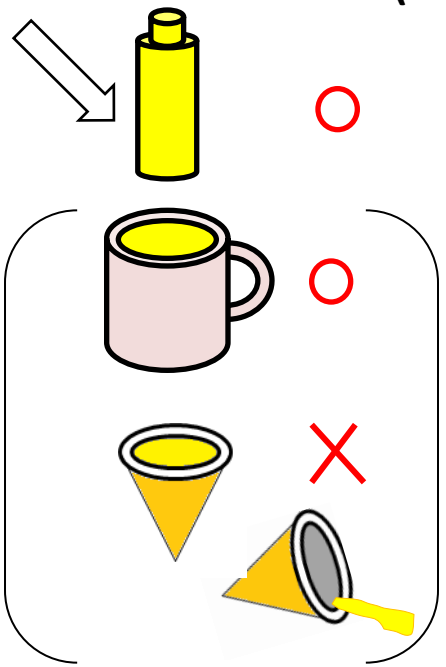
Properties（attributes）and Effects（functionality）

“Pour liquid into it, store it, and people can drink liquid from it.”

Property to be poured (fluid dynamics, material)

Property to store the liq. (geometry, material)

Property by which she drinks the liq. (weight, shape, surface)

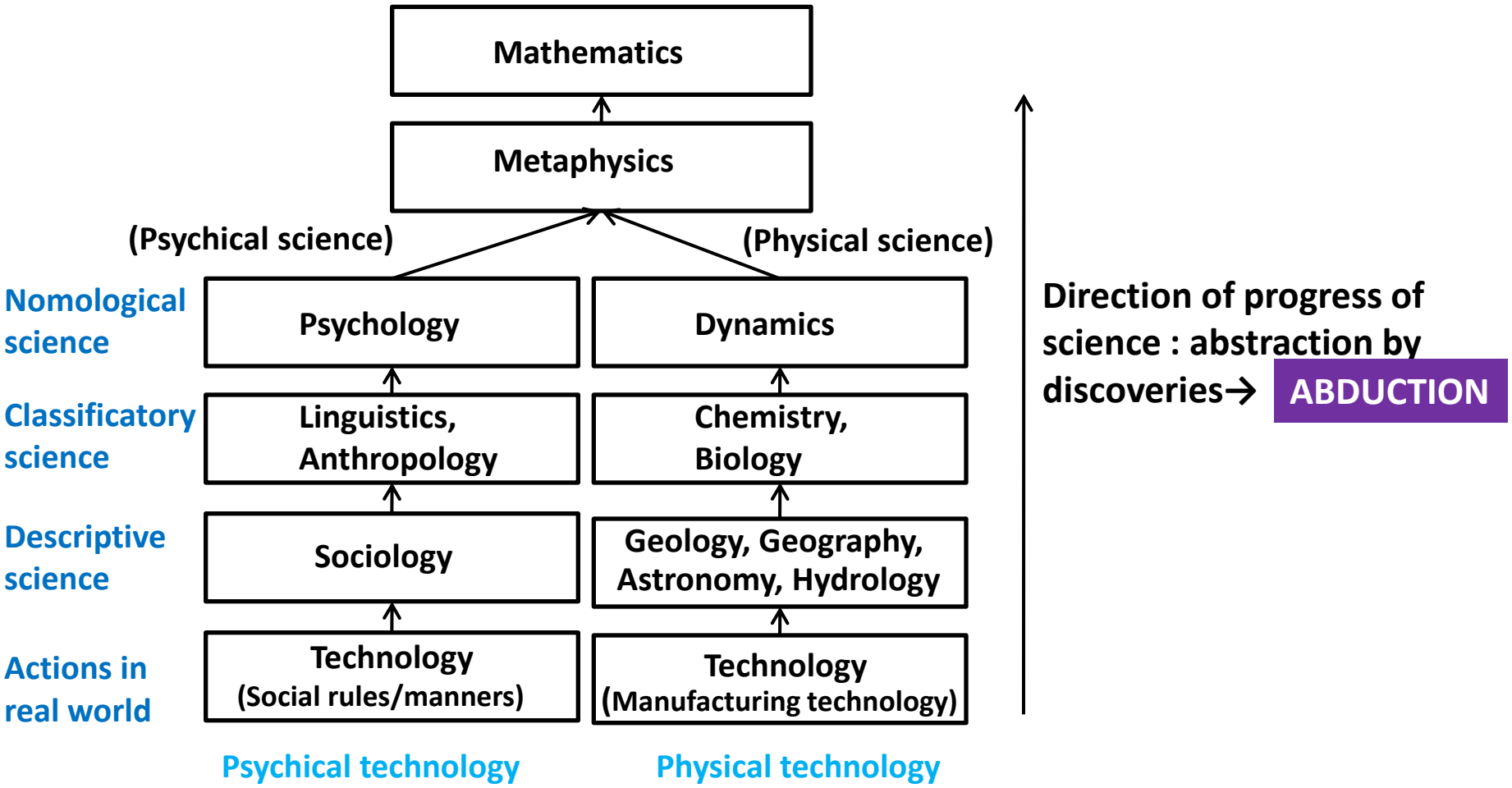


Even when we know the properties (geometry, material, weight, surface, esthetics) necessary for the function, it is not easy to realize an artefact which satisfies the function.

Progress of Abstraction

Developing model of Science by C.S.Peirce

Charles Sanders Peirce (1839-1914)



Deduction, Induction and Abduction

Charles Sanders Peirce (1839 -1914)

Deduction

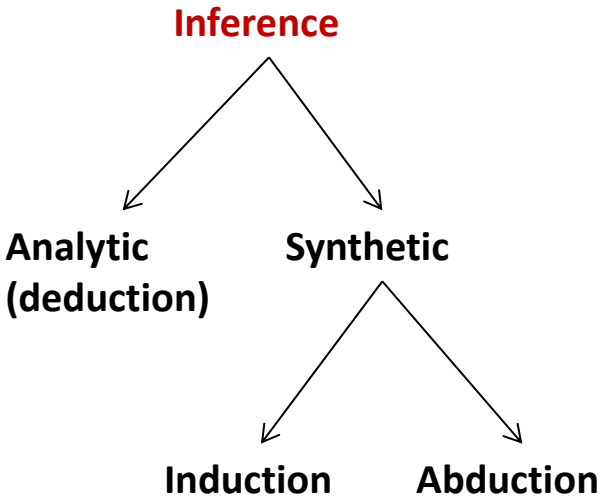
Rule --- All the beans from this bag are white.
Case --- These beans are from this bag.
Result --- These beans are white

Induction

Case --- These beans are from this bag.
Result --- These beans are white.
Rule --- All the beans from this bag are white.

Hypothesis(abduction)

Rule --- All the beans from this bag are white.
Result --- These beans are white.
Case --- These beans are from this bag.



Similarity between Abduction and Design
(Similarity between Scientific Discovery and Innovation)

Deduction

Rule --- Any body keeps some law.

Case ---This is a body.

Result ---This body keeps some law.

Hypothesis(abduction)

Rule --- All bodies keep some law.

Result --- This body keeps some law.

Case ---This is a body.

What is some law which covers any body?

⇩ Abduction by CSP

Newton's Law and Dynamics

Design is also an abduction. (Design formally has the same logic with abduction)

Deduction

Rule---In a good house any family lives comfortably.

Case---This house is a good house.

Result---A family lives comfortably in this house.

Design

Rule---In a good house any family lives comfortably.

Result---A family lives comfortably in this house.

Case---This house is a good house.

What is good house for any family?

⇩ Design Theory, Systems Science,

Design Law and Theory

(Design Methodology)

“Science” of Discovery (synthesis)

Karl Popper (Logik der Forschung 1935, The Logic of Scientific Discovery 1959)
----. However, my view of the matter, for what it is worth, is that there is no such thing as a logical method of having new ideas, or a logical reconstruction of this process. My view may be expressed by saying that every discovery contains ‘an irrational element’, or ‘a creative intuition’ in Bergson’s sense.

Albert Einstein (ref. Popper ditto)
‘search for those highly universal laws …. from which a picture of the world can be obtained by pure deduction. There is no logical path, leading to these….. laws. They can only be reached by intuition, based upon something like and intellectual love of the objects of experienced.

Ernst Cassirer (Substanzbegriff und Funktionsbegriff 1910)
The theory of abstraction is premised on existence of “a form of ordered diversity ” which is not identified previously , and maybe conducted by intuitive or psychological processes. …… Generalisation of concept of a thing (or finding of general model from a phenomenon) is the liberation of the thing from its singularity, through which its intrinsic structure emerges. The structure should be described in mathematics (HY).

Discovery is synthesis. It is a tough subject in science.

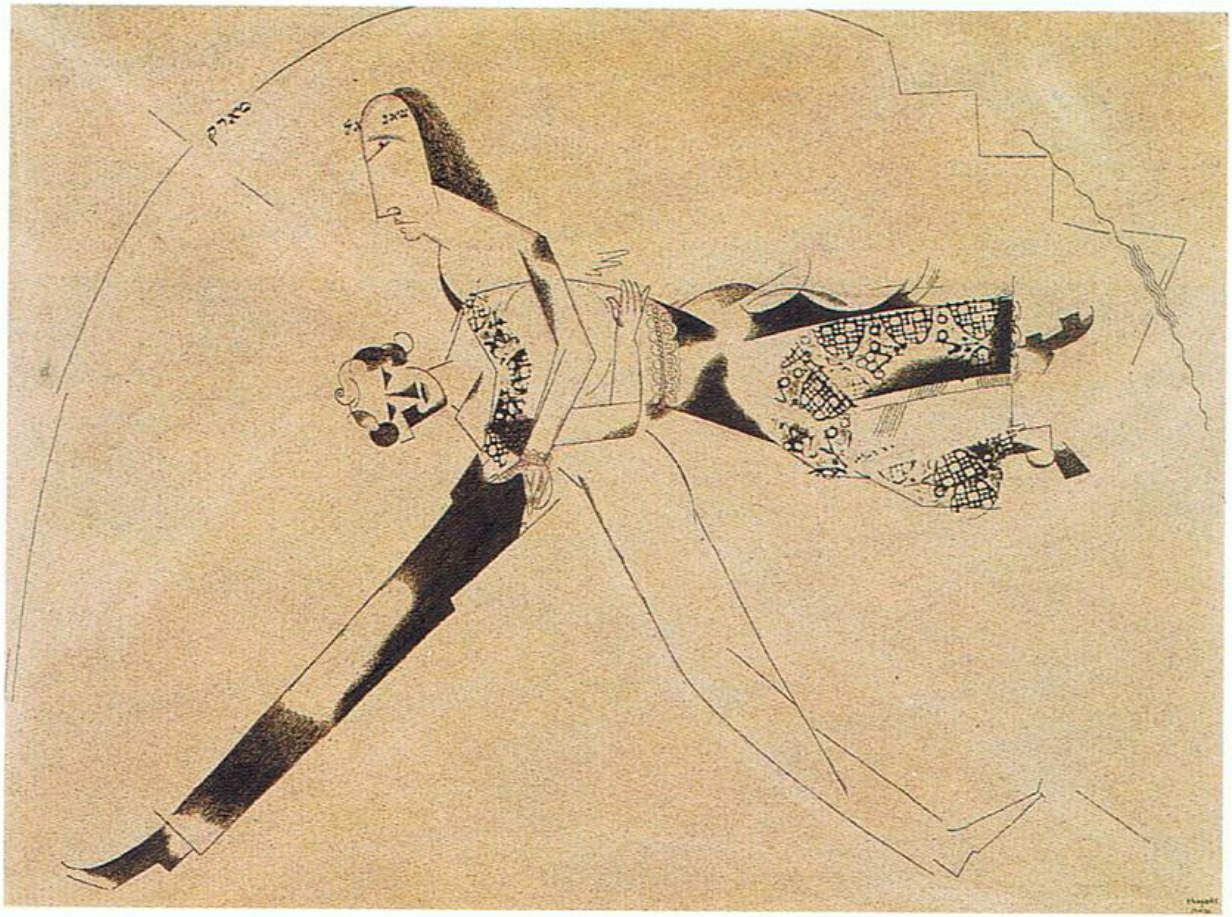
⇨ **ABDUCTION** by ***Charles Sanders Peirce***

Chagall

Love and the Stage 1914–1922

Edited by Susan Compton

MERRELL HOLBERTON
PUBLISHERS LONDON

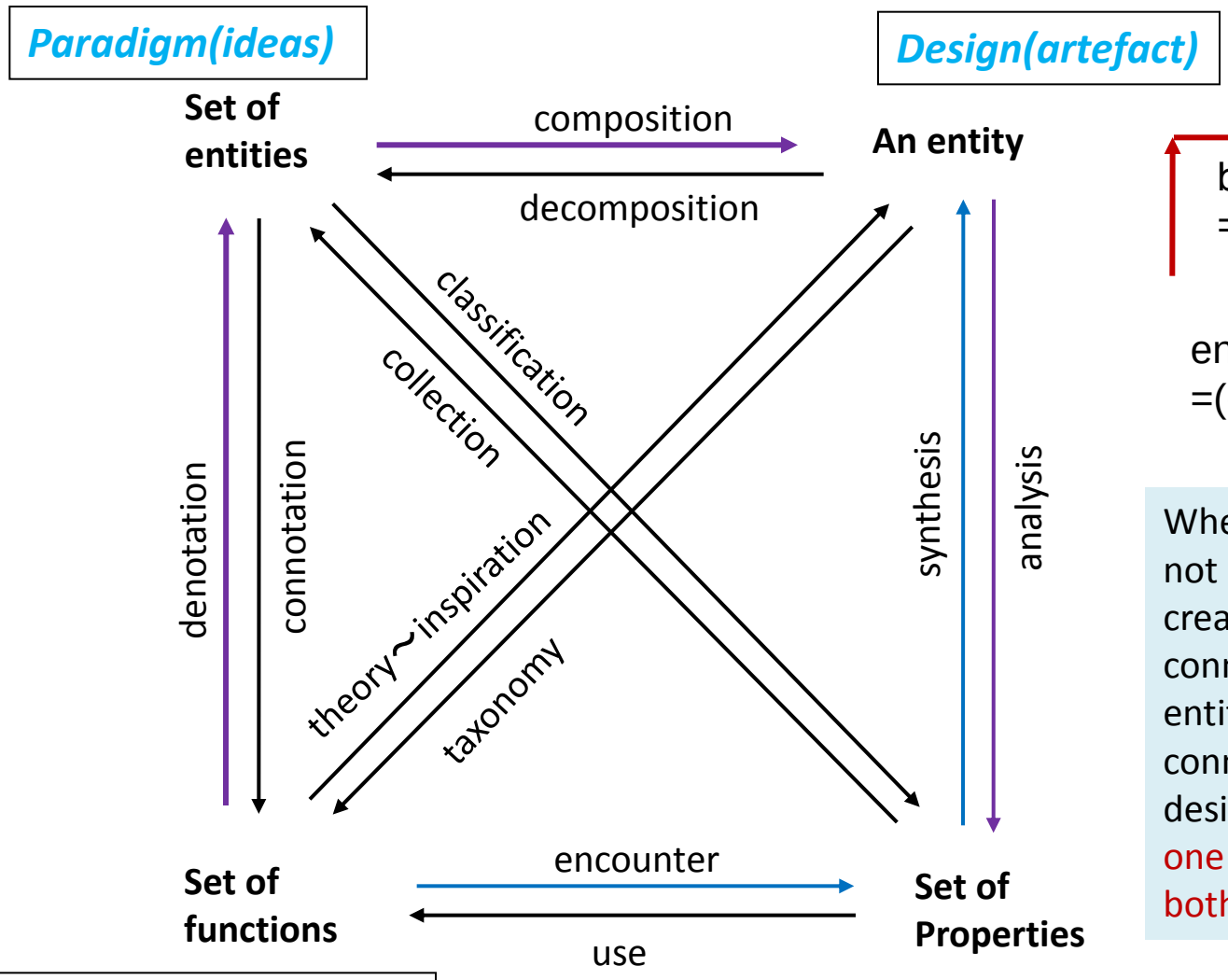


56 Abduction, 1920 （ひとさらい）

black ink on grey paper, 34 × 47.1 cm,
Musée national d'art moderne, Paris

Transition of Thinks in Design（HY）

“Square of Concepts”



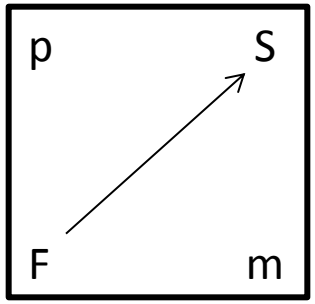
(Claude Levi Strauss literarily named:)

bricoleur’s design
=selection→composition

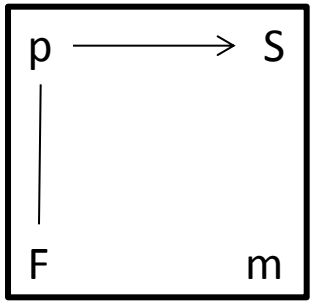
engineering design
=(encounter→synthesis)

When a theory for design is not available, the design must create a “path” of concepts connecting function and entity. There seems to be two connecting paths by which design is possible. At least, one abduction appears in both cases.

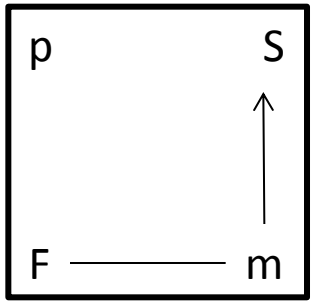
Basic Types of Design（transforming system of concepts）



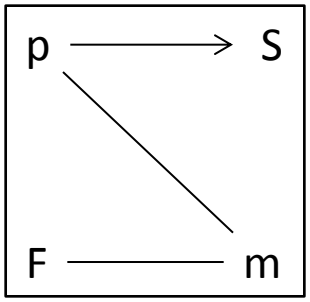
serendipity



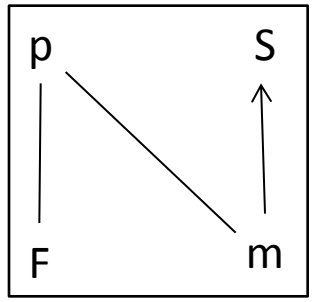
bricoleur



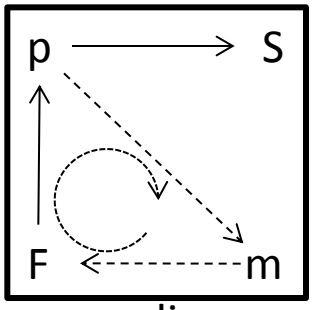
engineer



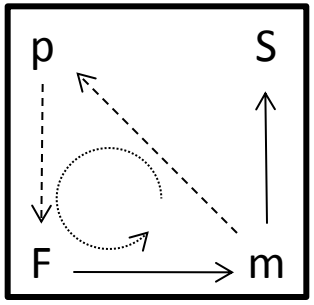
engineer-bricoleur



bricoleur-engineer



paradigm



metamodel

F=requirement
（要求：複数の機能（要素機能）

p=paradigm(elements of requirement
（要素機能の実体表現選出→その構造化したものが範型paradigm ）

m=metamodel
（要素機能の属性表現（臨時領域*内）
→その構造化したものがmetamodel）

S=solution（解）

F=requirement
(described by elements of requirement)

p=paradigm
(entities that respectively satisfy elements of requirement, structured entities are called a paradigm)

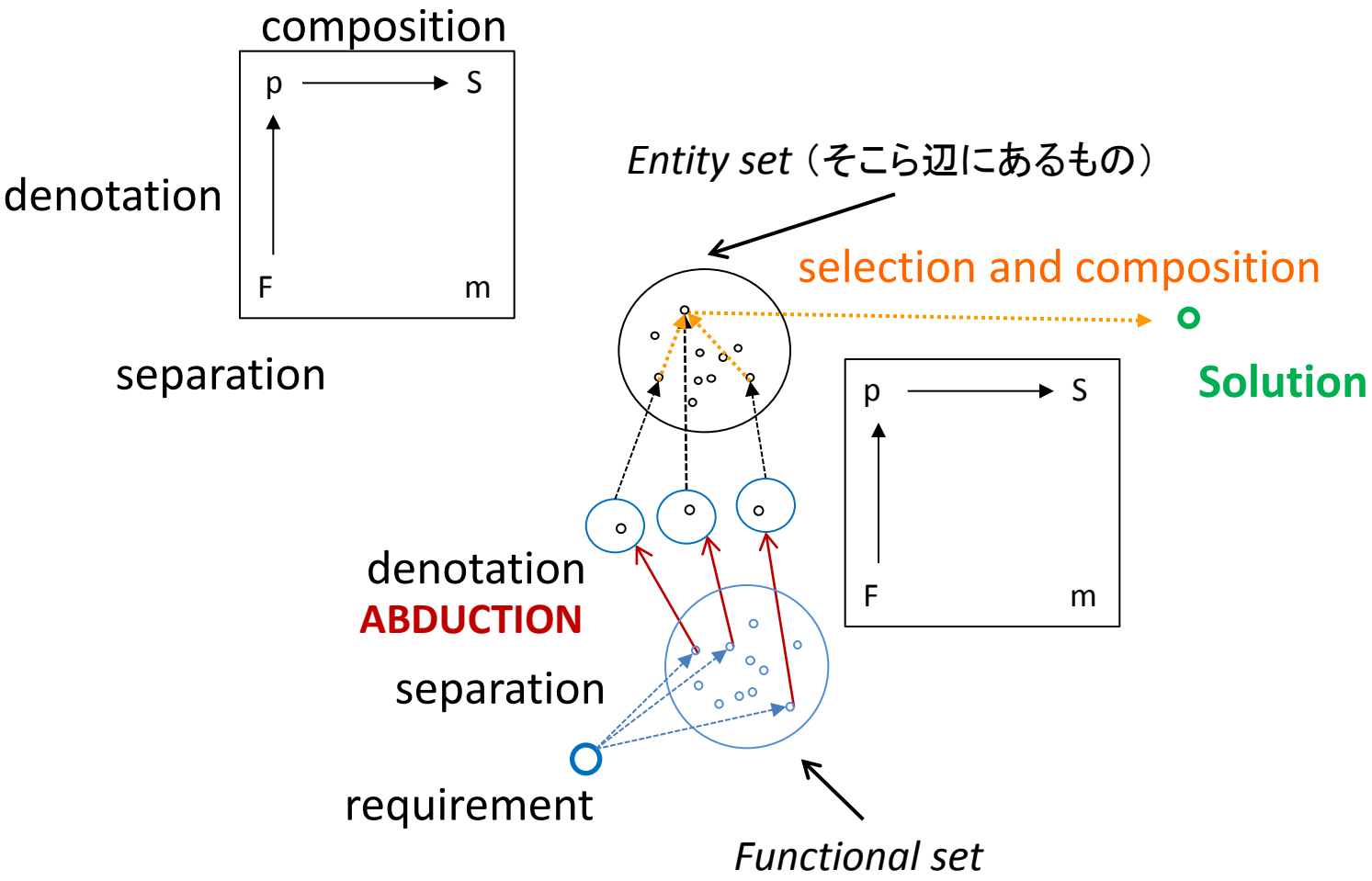
m=metamodel
(attributive description of elementary functions (preliminary discipline), structured description of attributes in preliminary discipline is called metamodel.

S=solution

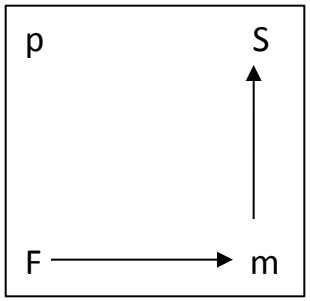
*ある機能範囲（たとえば自動車）に含まれる実体（すべての自動車）を属性で空間化した集合
（同時に要素機能の臨時領域も作る。臨時領域の階層）

Bricoleur defined by Levi Strauss

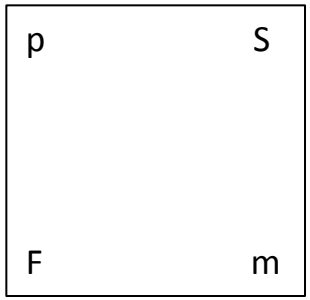
（separation-denotation-composition）



Engineer defined by Levi Strauss
（provisional discipline）



intersection-calculation



Solution

logical process
(calculation)

Provisional discipline
(Topological set)

ABDUCTION

Functional set

each discipline

requirement

Union of property sets

Design Square:

Two paths of design: Bricoleur and Engineer

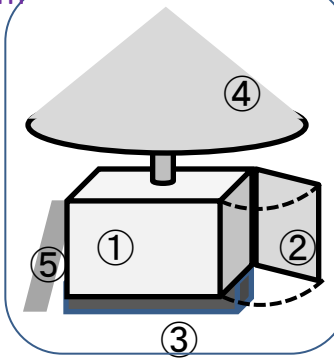
Bricoleur

Solution

selection

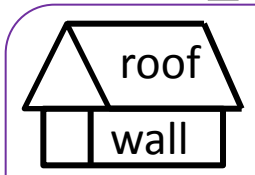
①box
②door
③foundation
④umbrella
⑤structure

Collection of elements into paradigm



A paradigm

A Solution:
Satisfactory house



preliminary discipline "house"

A maquette

Elaboration of required function

①isolate, ②in-out,
③fix-on-ground,
④good -for-rain,
⑤strength-against-outer-force

Living space to isolate people from outer world

Separation

Fix

metamodel

Top Separation (stop-rain)

Side Separation (stop-wind)

Support(strength)

Bottom separation (pace to walk)

adhesion
strength

Fix to the ground

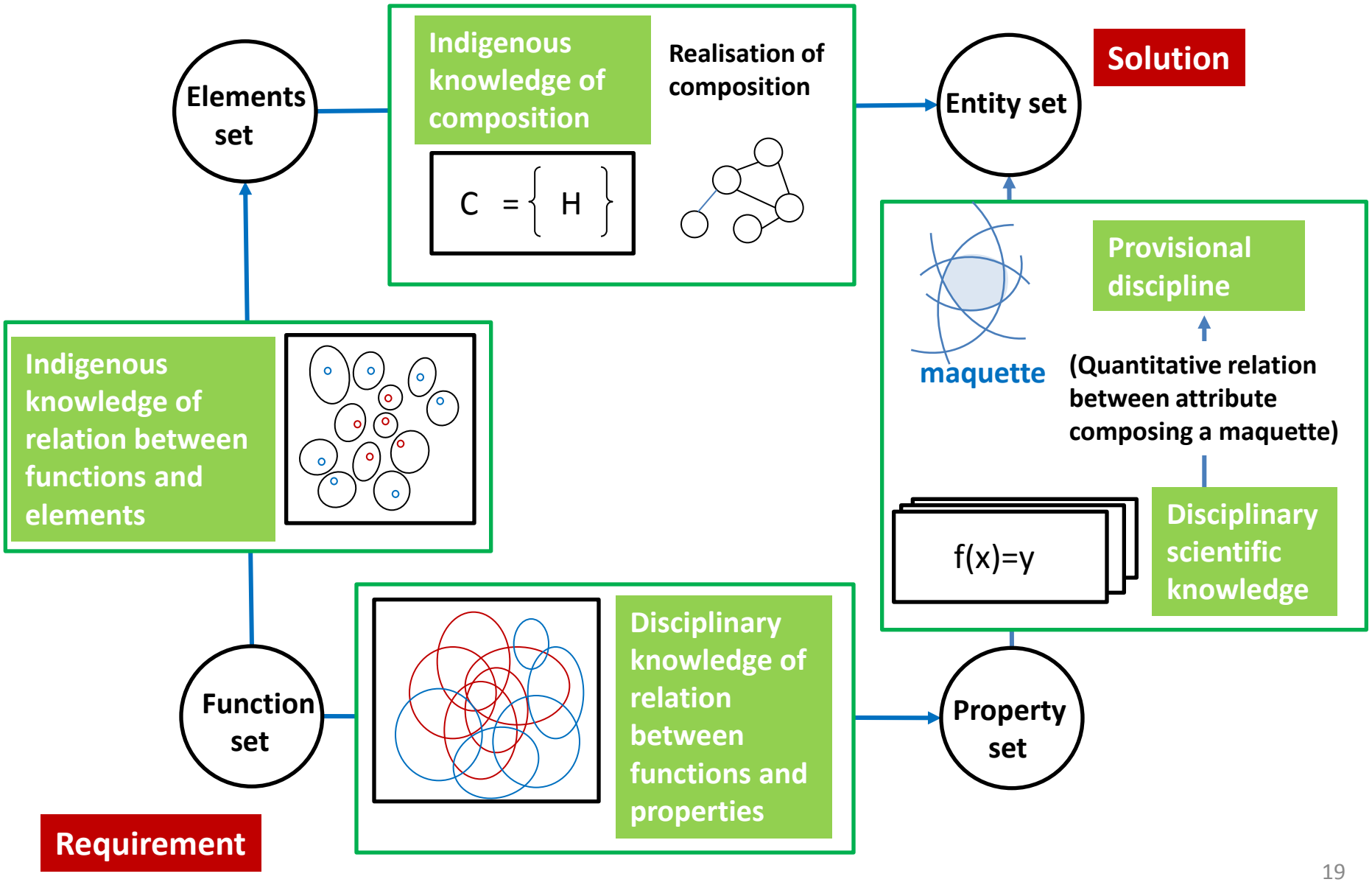
Ground

evolution of metamodel

Engineer

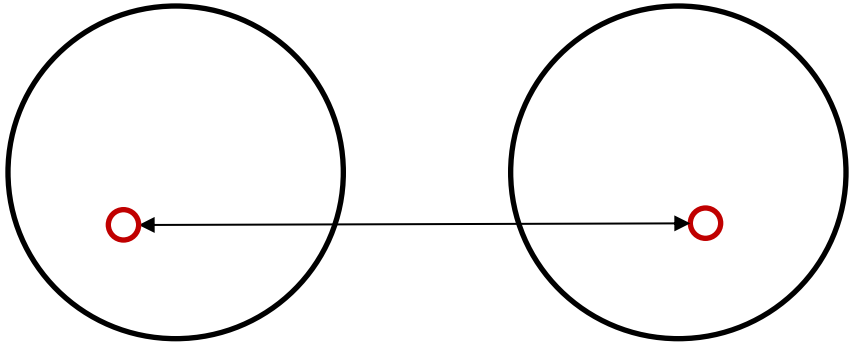
Requirement

Knowledge used in Design

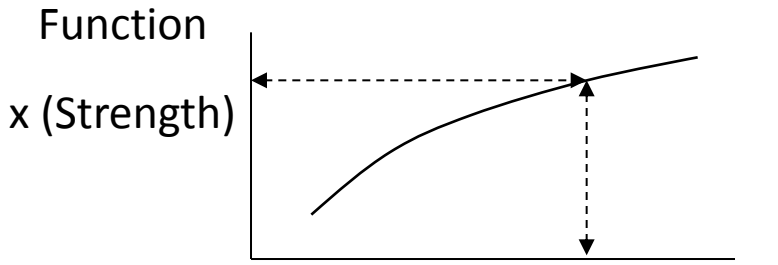


Discipline

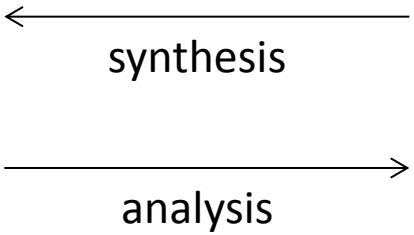
Reversible translation between concepts



Functional Set{x} Property (attributive) set {y}

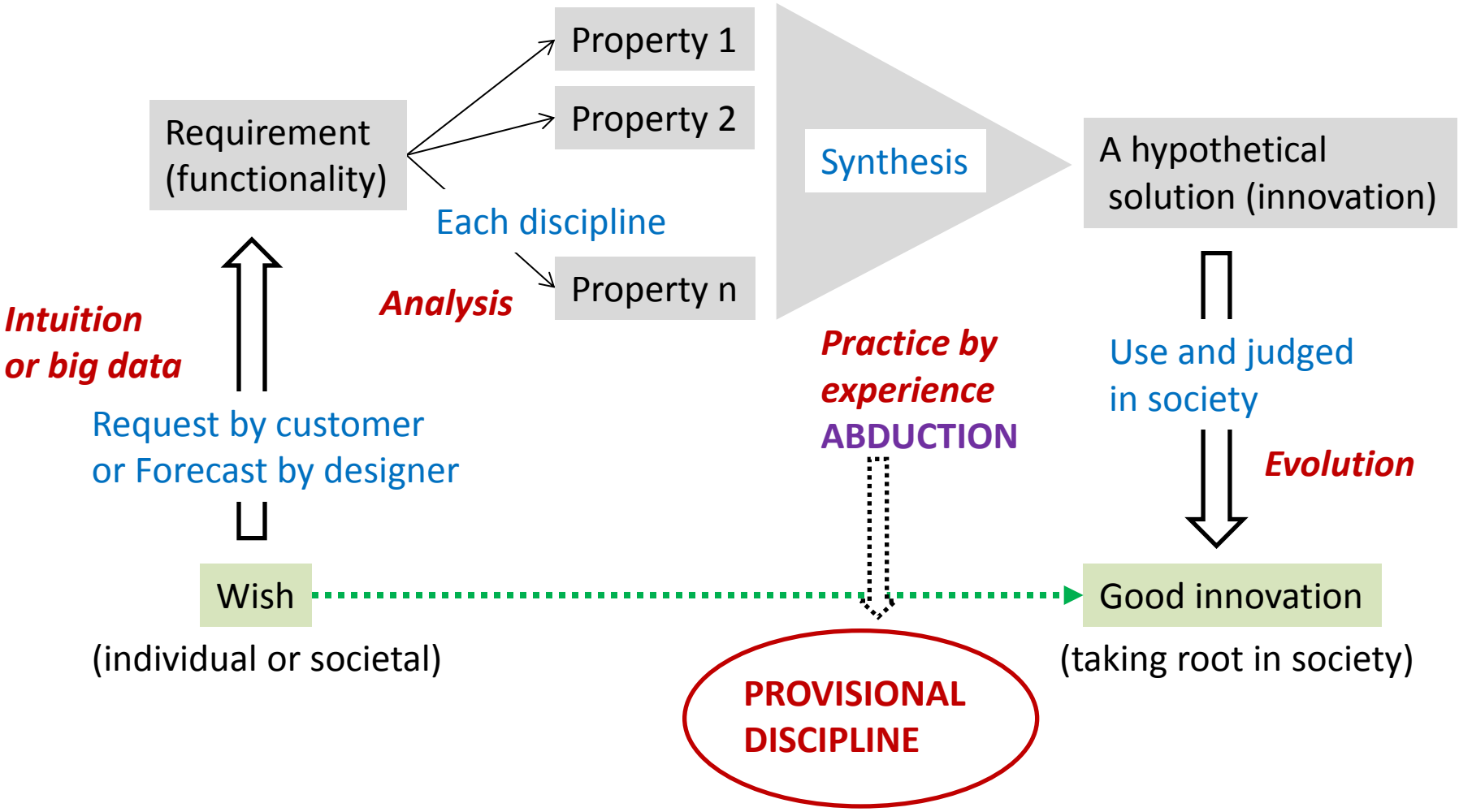


【In case quantified】

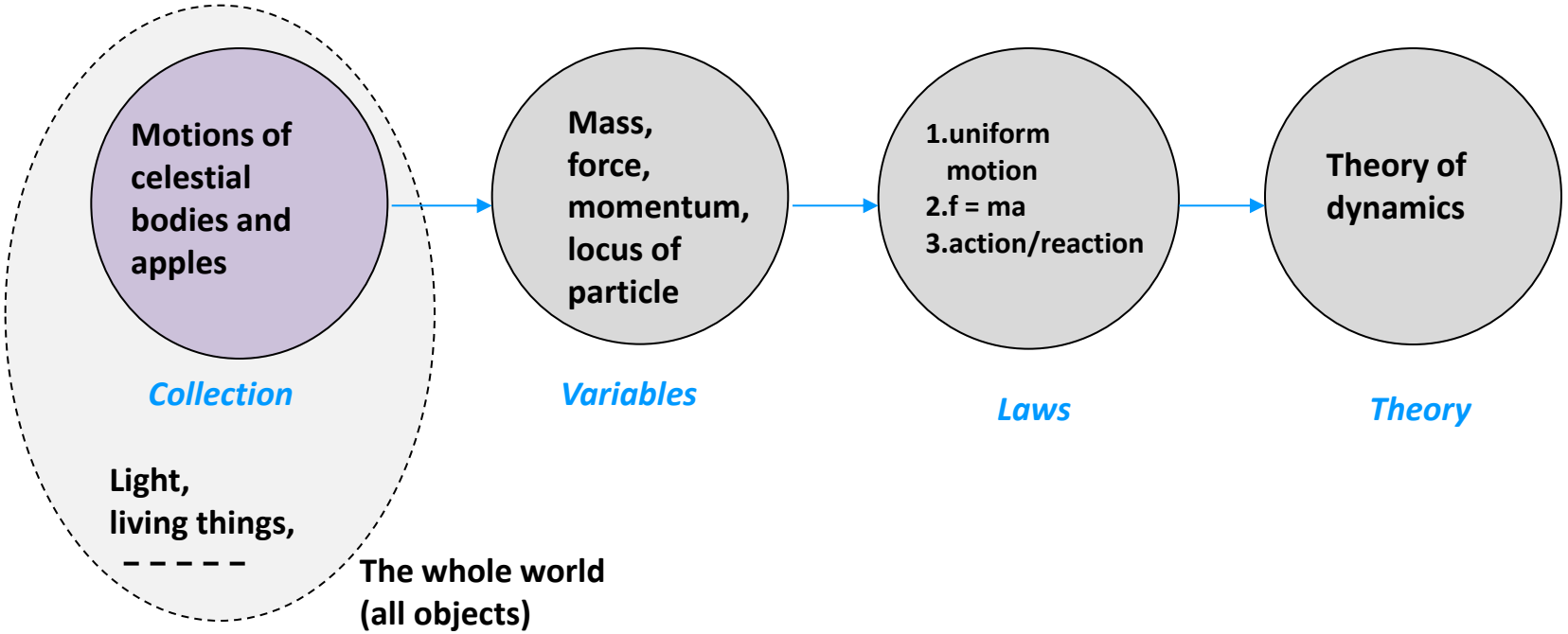


Within a discipline, function and property has mutual correspondences. It means that the translation between concepts of property and function are **reversible**. The reversibility is available in cases of indigenous knowledge and quantified discipline.

Engineer's Design: Systematic Innovation



Formation of Dynamics by Sir Isaac Newton

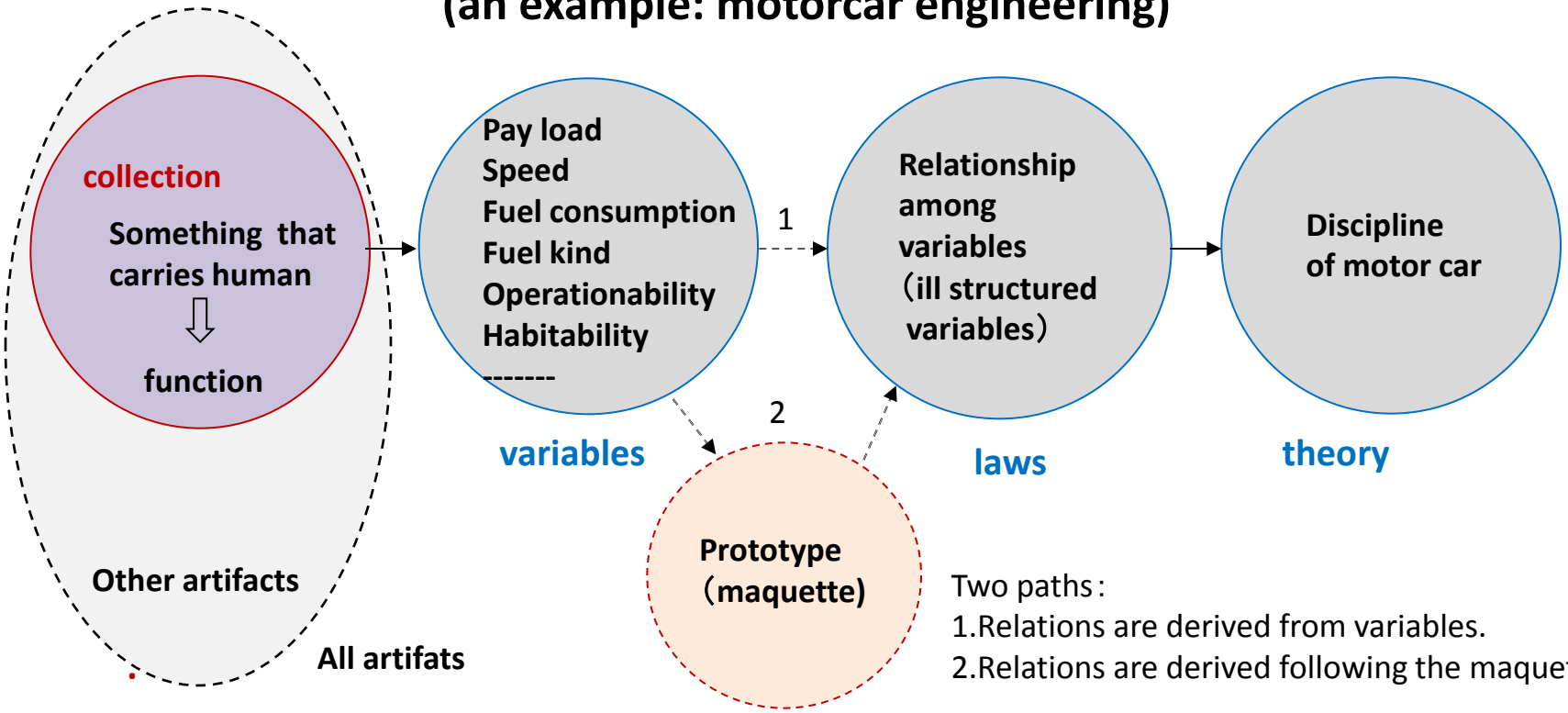


Newton's dynamics explicitly explains the motion of objects, such as celestial bodies in the universe or a thrown body on the earth.

It should be noted that the disciplines in science are established in order to explain the collection of phenomena systematically, in other words one-to-one correspondence between a phenomenon(function) and property by selecting objects so as to get good explanation, such as physics, chemistry, biology, sociology, linguistics, etc. We call them "basic disciplines".

Disciplines of Artifacts (synthesis)

(an example: motorcar engineering)

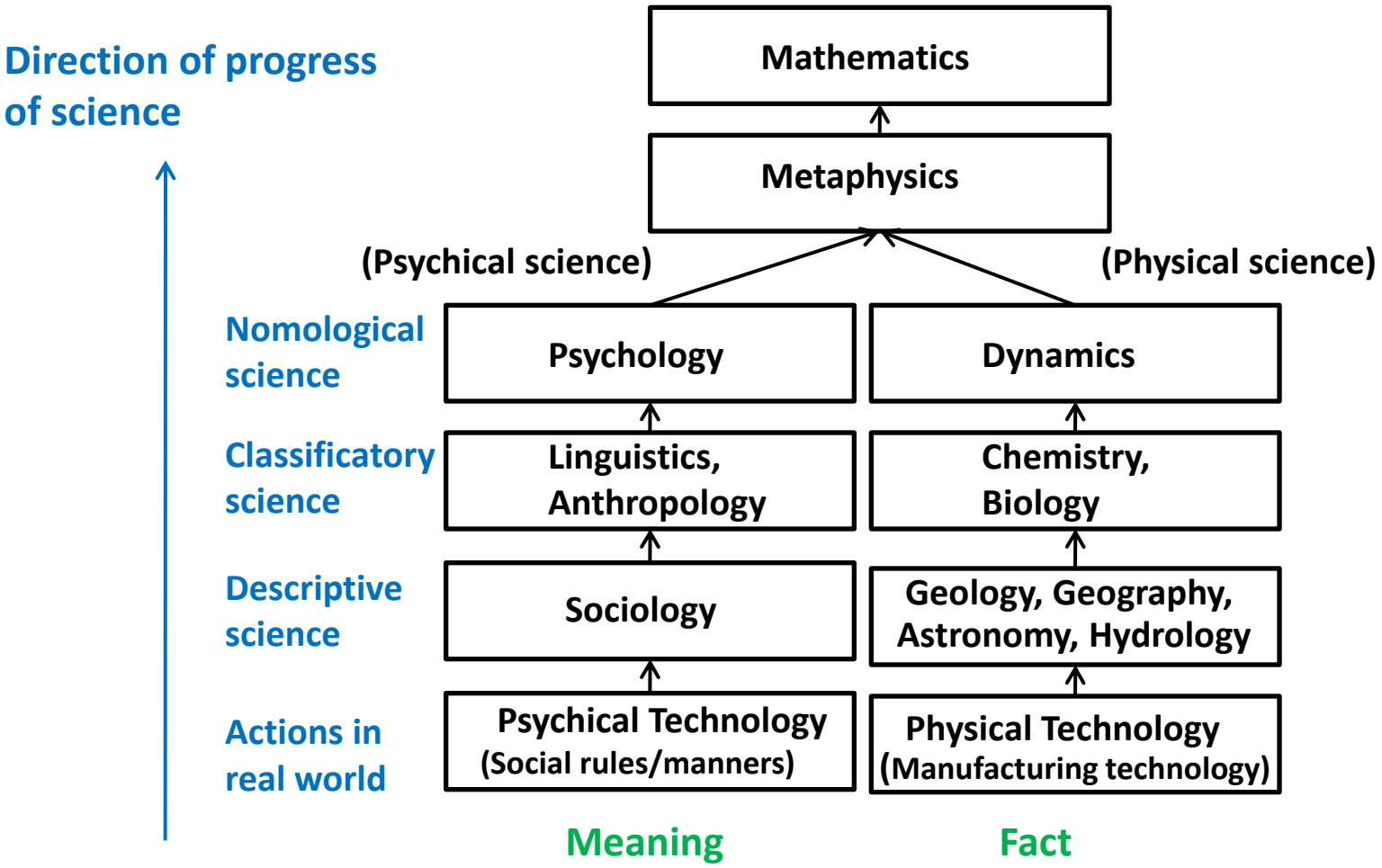


Two paths:
1.Relations are derived from variables.
2.Relations are derived following the maquette

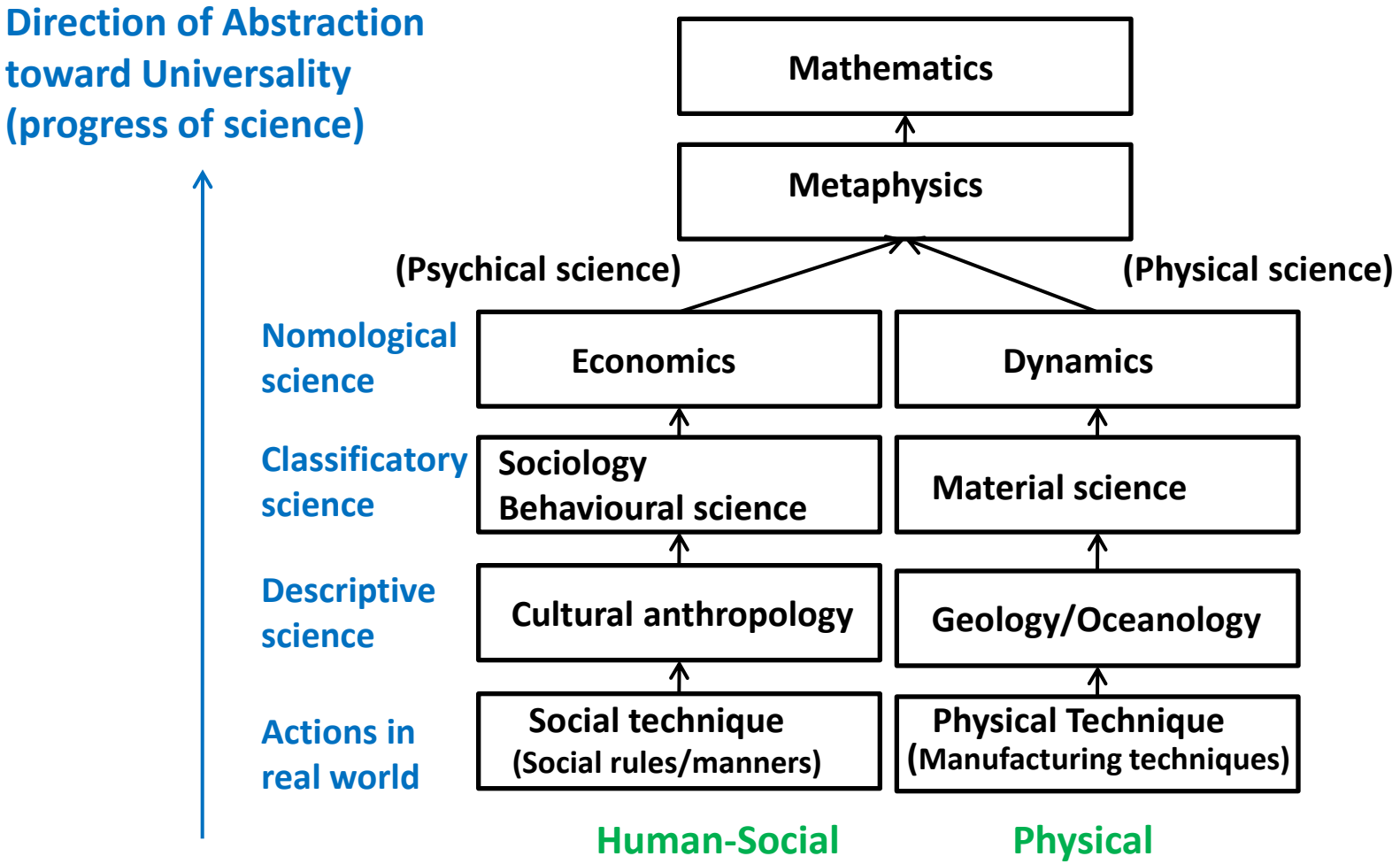
In case of disciplines of nature, collections of the phenomena(of existing things) which can be explained by a few and systematic variables are good collections. In other words, disciplines are established by collecting those which promise good theories. On the contrary, the disciplines of artifacts must be established from collections which have common functions, and thus including various phenomena which cannot be explained systematically by a principal law. This kills the reversibility of thoughts. Discipline of artifacts is called provisional discipline or engineering discipline. Scientific discipline covers a set of phenomena but engineering discipline covers artifacts which have similar functions.

Progress of Disciplines and Reversibility

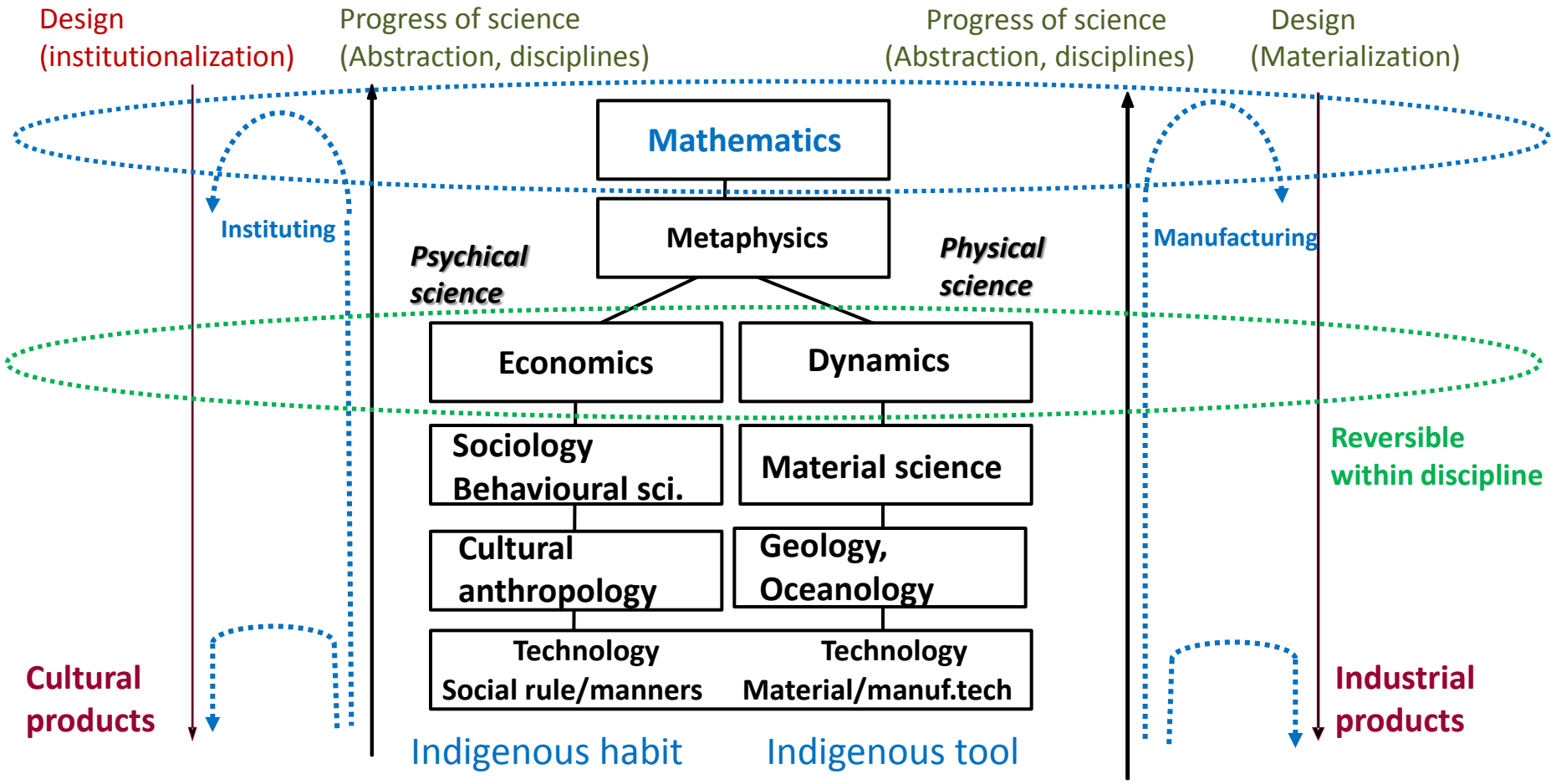
In each discipline, we may find corresponding properties to a function(an entity which exerts the function), but may not find a function (an entity) which corresponds to given properties.



Application of Peirce Category to the Present Disciplines

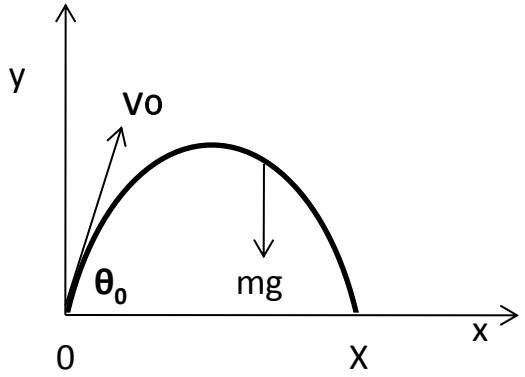


Reversibility of Indigenous Knowledge and Mathematics



1) **Dynamics: If we understand that a ball flies x meters when it is thrown at speed of v and at angle of θ, then we can throw any ball just x meters by v and θ. It means that when we understand phenomena through a law, we can realize what we want. This is the reversible knowledge. Mathematical nomological science is reversible, although at an abstract level.**
2) **Material science: If we understand that diamond is composed of carbon atoms in tetrahedral structure, we can not produce diamond only by this knowledge. This is irreversible knowledge.**

Reversibility in Dynamics



1) When I threw a ball by v_0 and θ_0, then it flew x meters; understanding a law as follows:

$$X=v_0^2 \sin 2\theta_0 / g$$

2) When I understand 1), then I can make a ball to fly any x by throwing it at v_0 and θ_0, calculated by using the law.

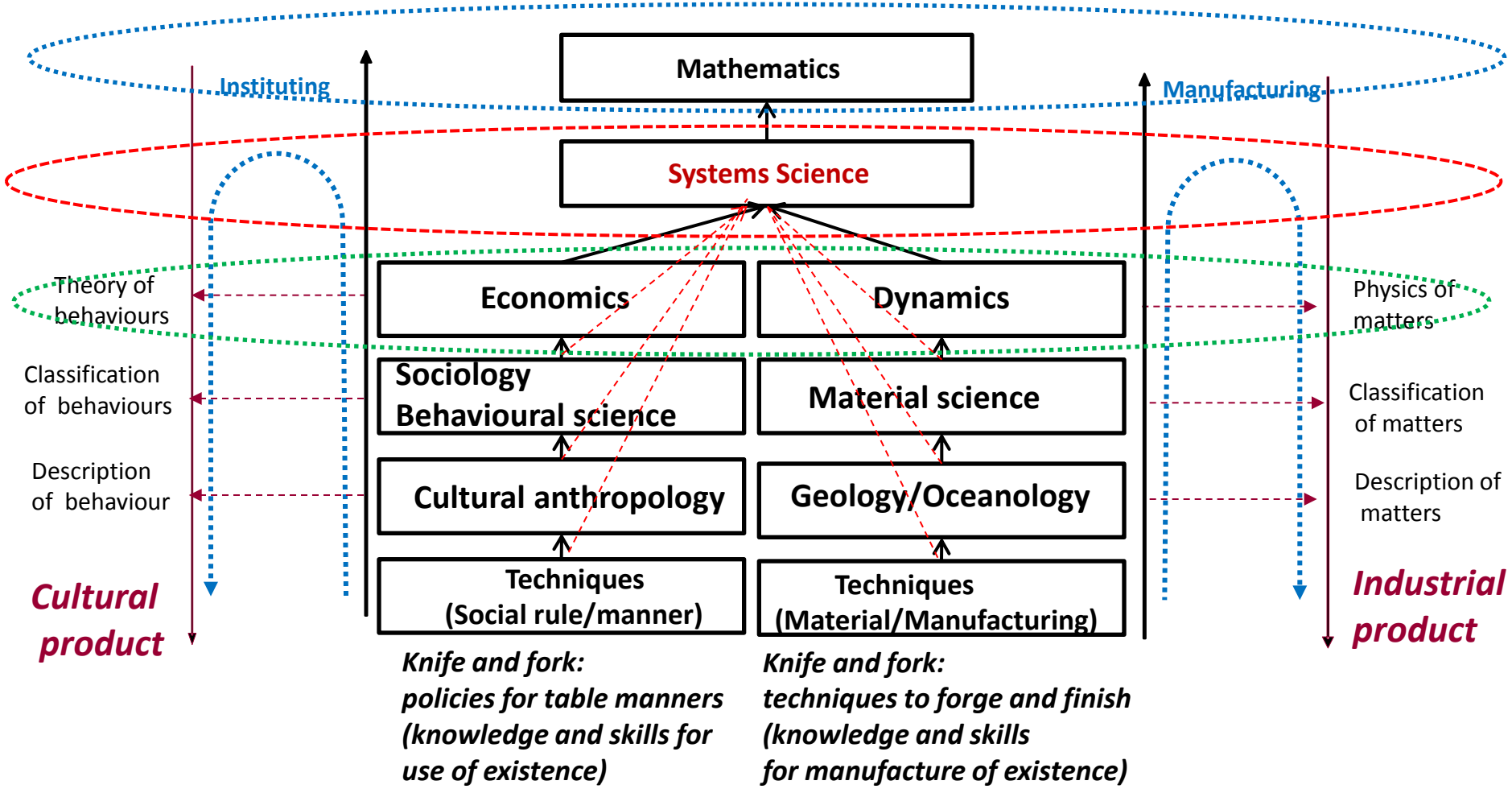
$$v_0^2 = X\, g / \sin 2\theta_0$$

$$\sin 2\theta_0 = X\, g / v_0^2$$

The property that a ball flies x at v and θ is only a part of the properties of the ball which is known by dynamics law. The ball has many other properties which were neglected by establishing a discipline "dynamics".

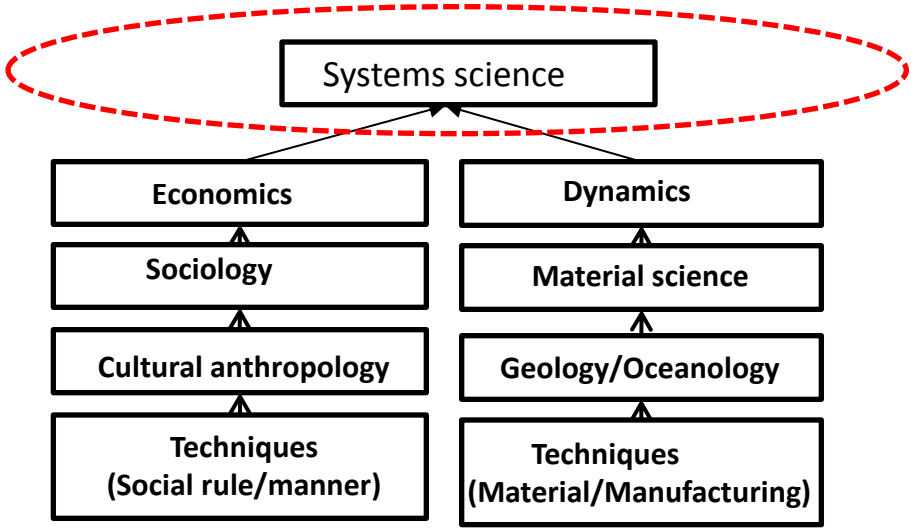
This is the reason why reversibility has been lost except throw-fly property in dynamics.

Systems Science to Recover Reversibility

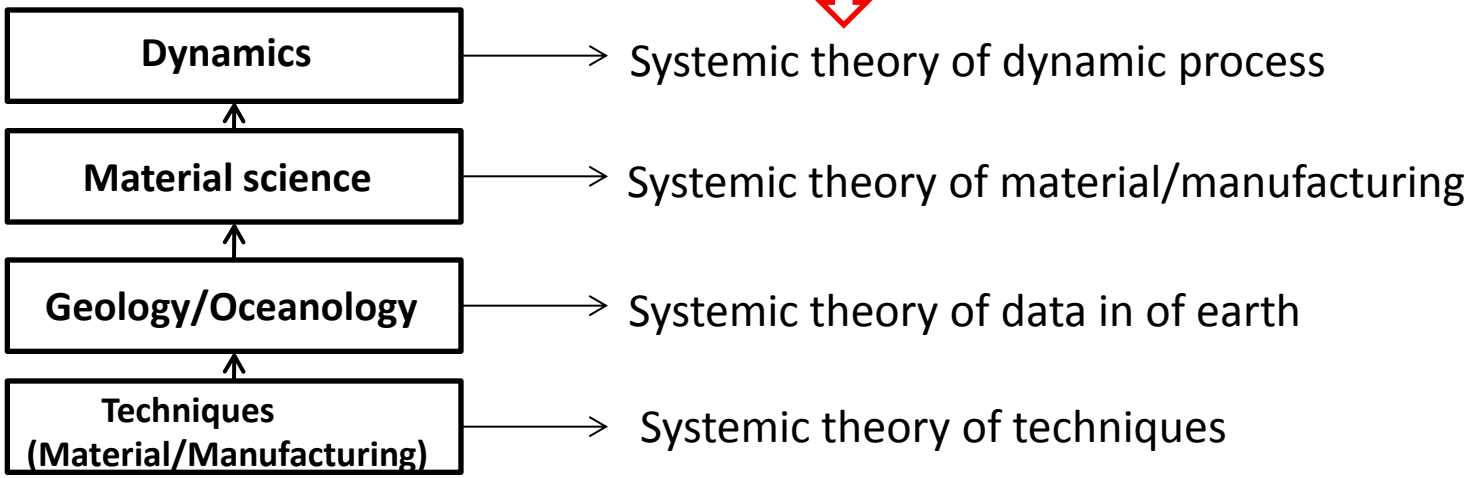


Peirce placed the metaphysics above the nomological science. If metaphysics deals with the fundamentals of all entities, it may be requested to be transdisciplinary and reversible at any level of abstraction. If so, it must be useful to solve the difficulties: the incommensurability among disciplines and irreversibility between abstraction level. Unfortunately, however, as terms in it are described in too much qualitative manner, it cannot be a useful tool to solve the present problems. Therefore, we substitute systems scientific method for metaphysics.

Systemic Theories

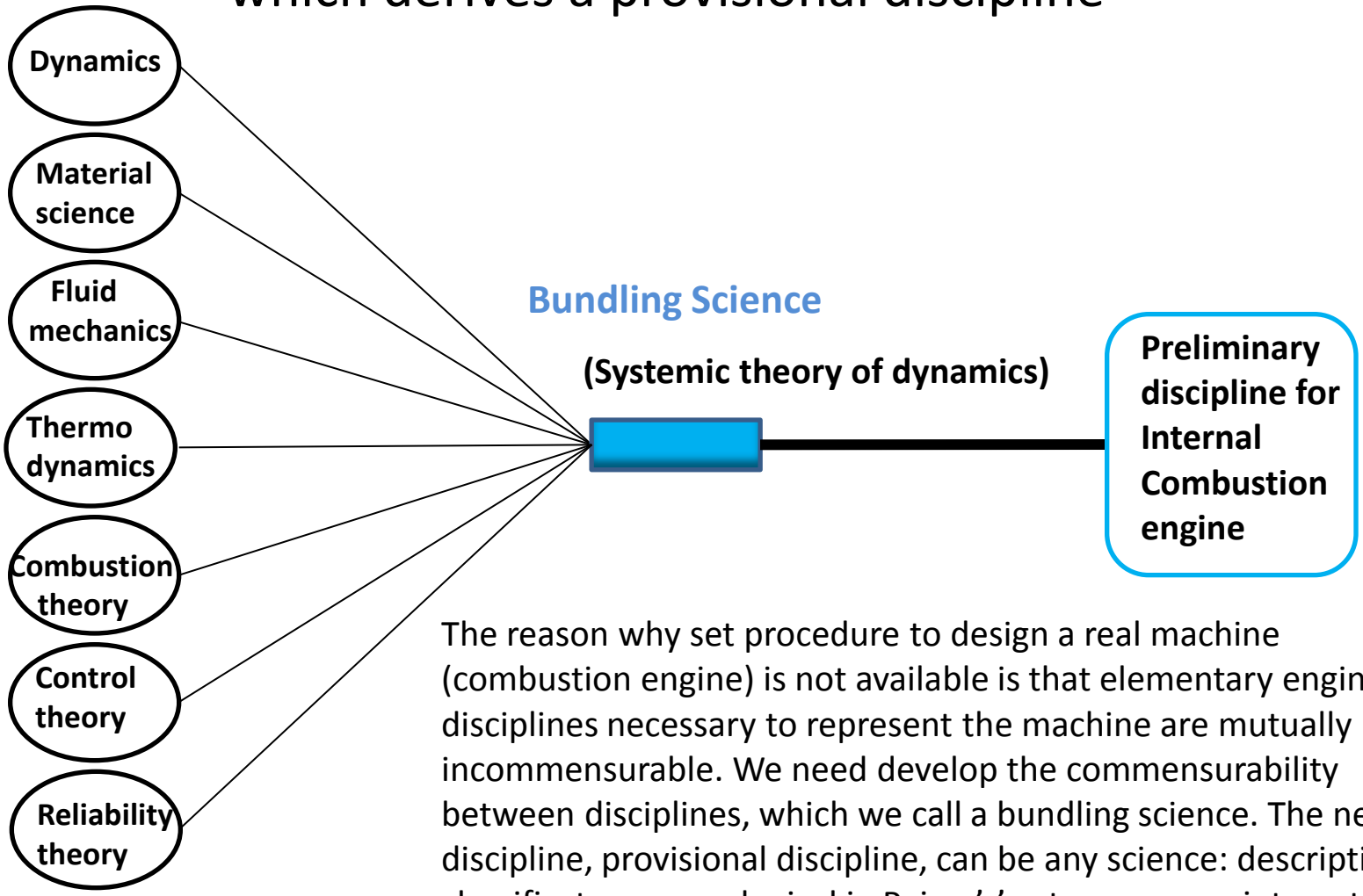


System Science is the systematisation of disciplines to recover reversibility through disciplines.



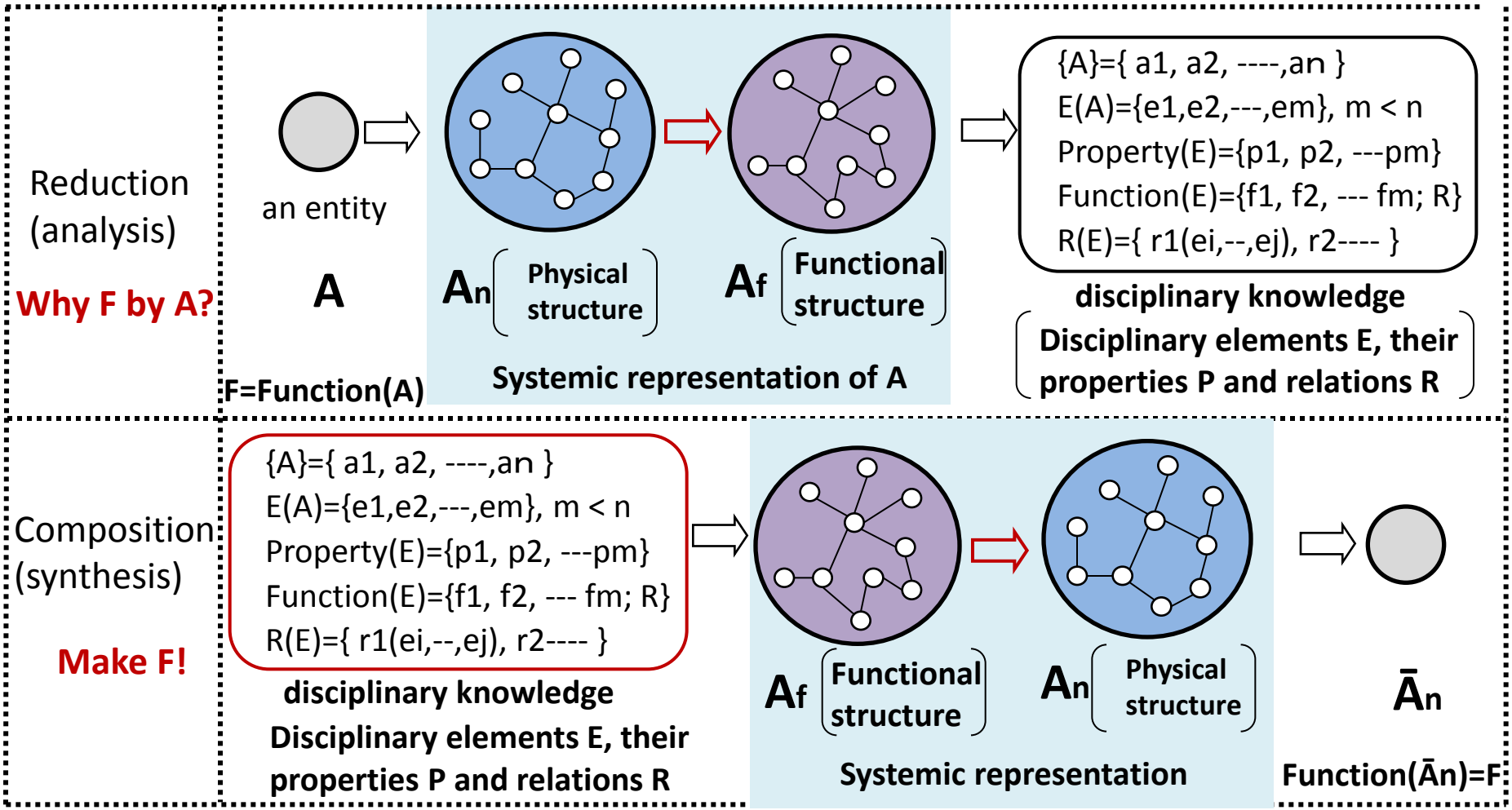
Bundling Science

which derives a provisional discipline



The reason why set procedure to design a real machine (combustion engine) is not available is that elementary engineering disciplines necessary to represent the machine are mutually incommensurable. We need develop the commensurability between disciplines, which we call a bundling science. The new discipline, provisional discipline, can be any science: descriptive, classificatory, nomological in Peirce's' category or an integrated textbook, but hopefully we develop a quantified preliminary discipline.

Approximate Realisation of Reversibility by System Science

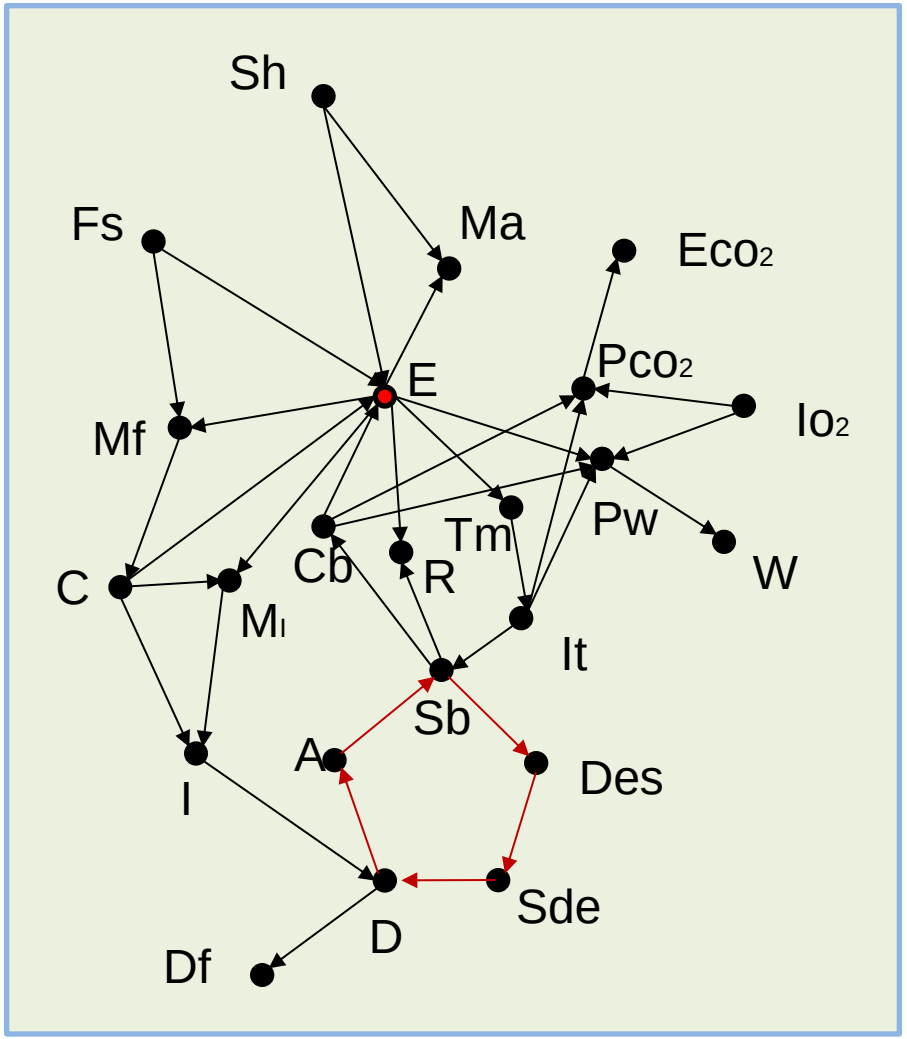


The reversibility of system science is based on its character that analysis and synthesis can be conducted by the same descripting method of objects. Designation of elements and relationship among them is a typical example of system science which can be used for establishing reversibility, in case when a universal designation and relationship is achieved.

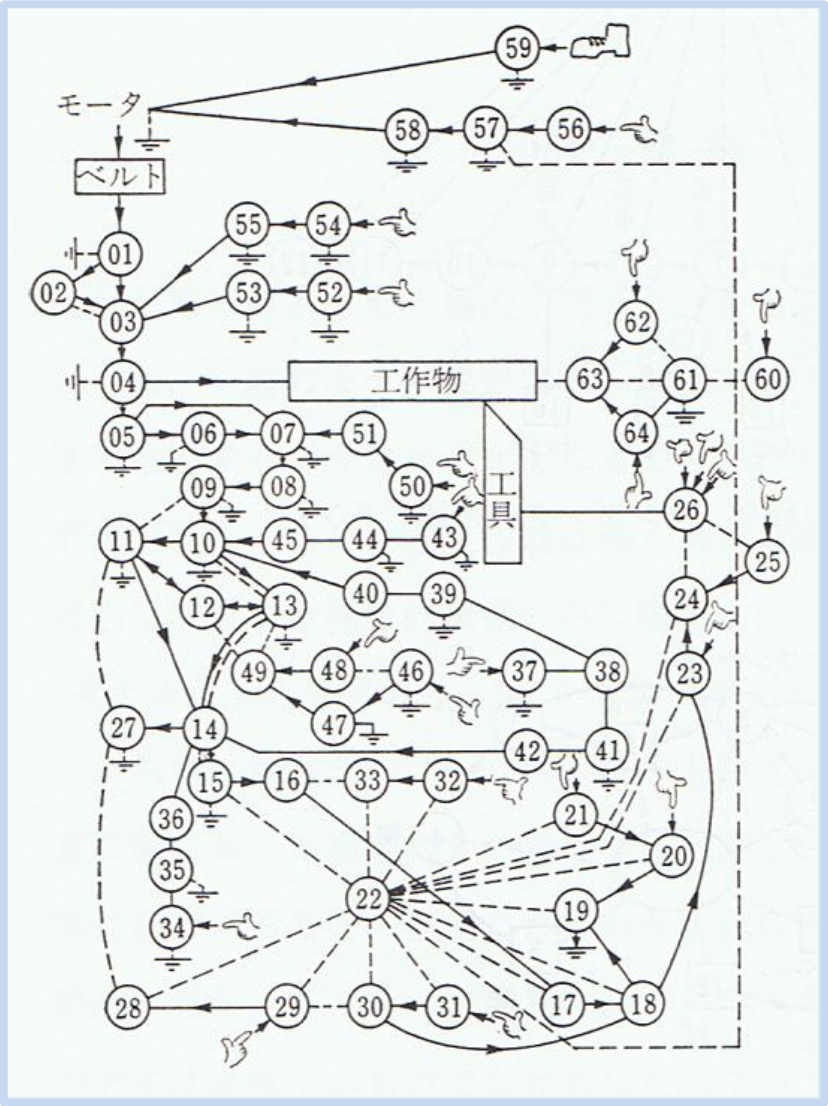
Nicolau Rashevsky

Structure of functionality of living things

C contact to food
I ingestion of food
D digest
A absorption
Df defecation
Sb synthesis of body
Des digestive enzymes
Sde secretion(分泌)
It inner transport
Cb catabolic process（異化作用）
E release of energy
Pco_2 production of CO_2
Eco_2 elimination of CO_2
W elimination of catabolic waste product
Pw production of catabolic waste
Tm protoplasmic movement
Io_2 oxygen consumption
Fs stimulation
Mf movement
Ma avoiding movement
Mi movement for digestion
R reproduction
Sh harmful stimulus



工作機械（旋盤）の固定複合体接続グラフ



全体：8本のパス（動力、信号）

切削機能：3本のパス

設定機能：5本のパス

（吉川弘之、信頼性工学、コロナ社、1979）

2014/2/4 フェロー戦略会議

強靭で持続可能な社会の実現に向けた統合社会インフラ管理システムの研究

～ 社会インフラチーム G4 ～

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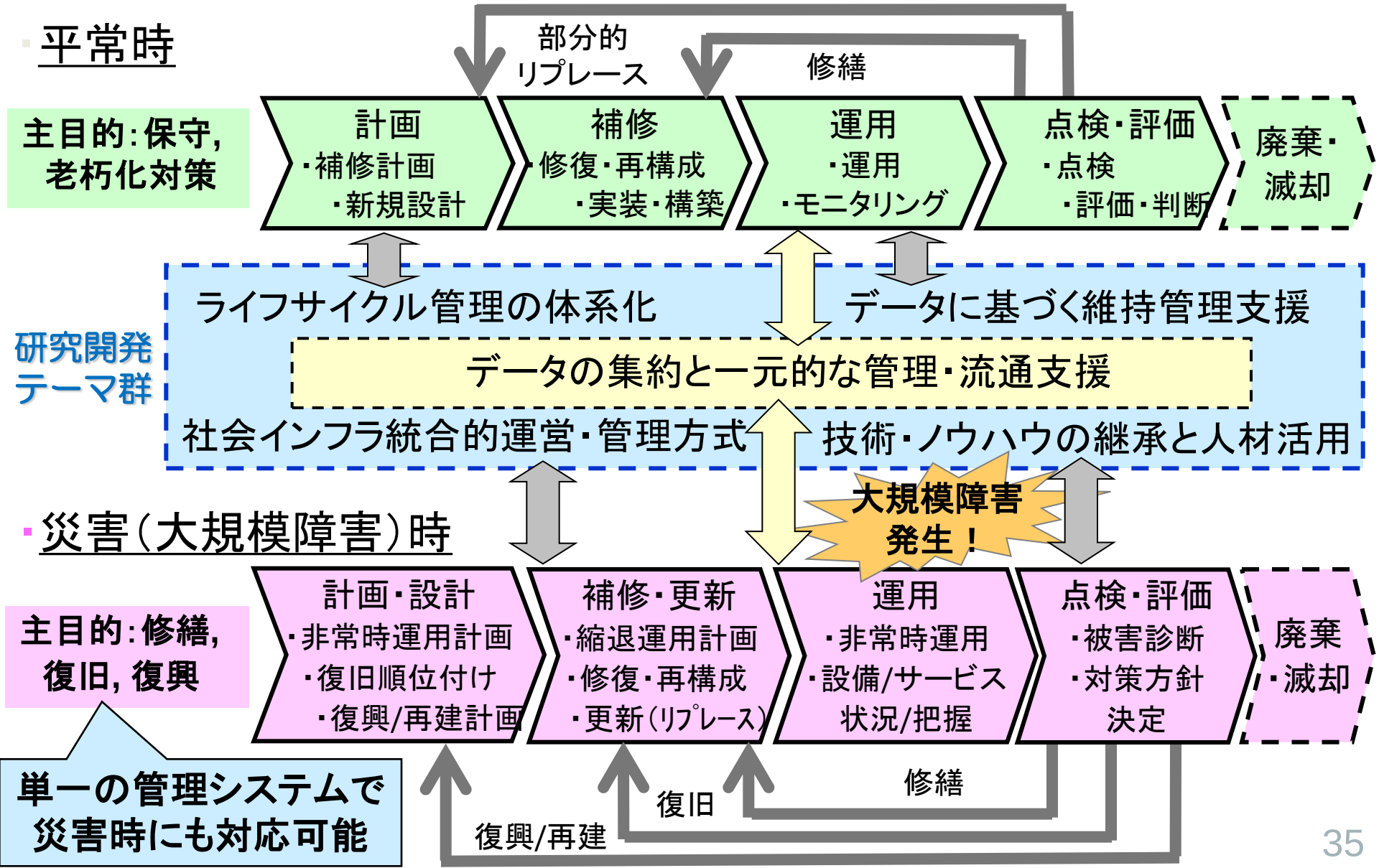
緒方F（環境エネルギーユニット）

CRDS JST
独立行政法人科学技術振興機構 研究開発戦略センター
Center for Research and Development Strategy Japan Science and Technology Agency

【研究開発テーマ3】 災害時の修繕や復旧にも適用可能なライフサイクル管理方式とシステム



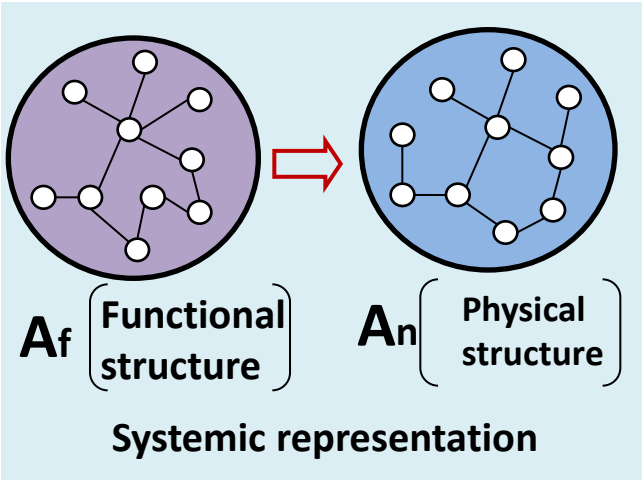
社会的期待プロジェクトにおけるシステム科学

現代における科学技術の課題としての「インフラのメンテナンス」研究戦略の例

保全に必要な視点

インフラ分類（メンテナンスの視点）
インフラ以外の固定施設
各種メンテナンスの関連制度
受益者
製造技術
事業主体
コスト
コスト負担者
メンテナンス技術
インフラ群が作るシステム
ミクロ（技術）理論
　（計画、運用、補修、点検--）
マクロメンテナンス（システム）理論

{A}={ a1, a2, ----,an }
E(A)={e1,e2,---,em}, m < n
Property(E)={p1, p2, ---pm}
Function(E)={f1, f2, --- fm; R}
R(E)={ r1(ei,--,ej), r2---- }



開発するべき理論・技術

行政政策と科学技術政策

end