

Philosophy of science

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Abstract

This is a concise presentation of important aspects of modern philosophy of science and humanities. It is based primarily on the Oxford Philosophy of science [1], and gives for every chapter in concise formulation the prevailing contemporary concepts and the concept of the author [JH], in some chapters only the latter.

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1 Basics

1.1 Theory and experiment

The traditional approach to the notion of natural science is:

The empirical content of theories, models, and data is a characteristic feature that distinguishes natural science from mathematics and other intellectual endeavors [1] ch.1.4 .

Proposed concept [JH]

[8]

0 An abstract science (e.g. various branches of mathematics) is a **set of axioms** with corresponding concepts (e.g. axioms of group theory with concepts {multiplication, unit element, ...}), a **collection of models** of this respective set of axioms (e.g. group S_3 ={permutations of 3 elements}), and **theorems** formulated with these concepts of this respective set of axioms (e.g. theorems in group theory).

1 A natural science, e.g. physics is a **collection of mathematical theories**, which describe a set of real-world phenomena, where this **set of real-world phenomena is a realization of the theory** (in the mathematical sense. see below).

2 Experiments are verifications of a theory in a particular numerical setting, e.g. measuring the phase diagram $p(T)$ of water and comparing it to the theoretical model in thermodynamics. An experiment yields a mapping of theory variables to measurable quantities, e.g. temperature $T=E/k_B$ into experimental temperature measured by a mercury thermometer. On the other hand, an experiment provides a real-world action-sequence for the measurement, e.g. build a mercury thermometer, fix the length scale (e.g. by water freezing point and water boiling point) and read the length of the mercury column.

3 A real-world phenomenon (phase diagram of water) is a **realization of the theory**, here the function $p(T, \text{material-parameters } \zeta)$, for water= H_2O , **a realization in the same sense** as the group S_3 ={permutations of 3 elements} is a realization of a non-commutative finite group.

So in a theory there is a **mathematical model** with variables in (continuous, non-discrete) **real numbers** -state function

classical Ψ = {location= $x(t)$, energy= $E(t)$, momentum= $p(t)$, angular momentum= $L(t)$, ...}

quantum Ψ = {location= $\bar{x}(t)$, energy= $\bar{E}(t)$, momentum= $\bar{p}(t)$, angular momentum= $\bar{L}(t)$, ...}, where

$\bar{x}(t) = \text{mean}\left(x(t), |\psi(x, t)|^2\right)$ is the location averaged with the probability density $|\psi(x, t)|^2$ based on the fundamental wavefunction $\psi(x, t)$, correspondingly for the other parameters

-fundamental rotation group, which defines physical equivalence, e.g. in our world the Lorentz group $SO(1,3)$ of space-time rotations: physical systems are independent of Lorentz-rotations

-Lagrangian (function of state, and underlying algebra $A(\tau_i)$) $L(t, x(t), \tau_i)$ based on a symmetry algebra $A(\tau_i)$, e.g. Lagrangian of the SU(3) quark color interaction

-partial differential equations-of-movement (e.g. Maxwell equations), derived from the Lagrangian via variational calculus from the principle of minimal action

-statistical dynamical system with states, state transition probabilities, state probability distribution (e.g. ideal gas with Maxwell probability distribution of velocity, elastic collision as state transition)

3a The mathematical model consists of a **structural part** (e.g. basic particles and fields in the Standard Model of particle physics) and a **functional part** (e.g. fundamental particle equations, symmetry groups, and field equations of the Standard Model), and has **parameters** (e.g. the 29 parameters of the Standard Model). The **number of parameters should be minimal**, i.e. among competing models compatible with experiment, the one with minimal numbers of parameters is chosen (this is known as **Occam's razor**).

Example 1: cosmological Lambda-CDM model [8]

with 13 parameters, FLRW metric, fundamental equations = Einstein equations, fundamental symmetry=general covariance of General Relativity

Example 2: Standard Model of particle physics [8],

with 29 parameters , basic particles: 3x2 quarks, 3x2 leptons, basic fields: photon , weak bosons (W, Z), 8 gluons, higgs ;

fundamental gauge interactions: electrodynamic trivial SU1-symmetry, weak Pauli SU2-symmetry, strong color SU3-symmetry

fundamental equations: Dirac eq. for particles, field equations: Maxwell (electrodynamics), color Maxwell (strong interaction)

Example 3: experimental model of water [45],

with structure H₂O of 2 hydrogen atoms and 1 oxygen atom,

with model parameters OH-bond length in angström, OH-bond energy in kJ/mol, molecule enthalpy in kJ/mol .

Example 4: Energy

-Energy in theoretical physics (mathematical model) is:

in relativistic classical mechanics: $E = c p^0 = \frac{mc^2}{\sqrt{1-v^2/c^2}}$

in non-relativistic classical mechanics via force: $\vec{K}(\vec{x}) = -\nabla E(\vec{x})$

in thermodynamics: heat=thermal energy=kinetic molecular energy $E(T) = k_B T$

in non-relativistic quantum mechanics: expectation value of Hamiltonian $E = \langle \psi | H | \psi \rangle$,

$$H(\vec{x}) = -\frac{\hbar^2}{2m} \nabla^2 + V(\vec{x})$$

in relativistic quantum mechanics: expectation value of momentum operator p^0 : $E = \langle \Psi | i\hbar D_\mu | \Psi \rangle$,

$D_\mu = \partial_\mu - ieA_\mu$ with electromagnetic interaction

-Energy is measured in experimental physics (measurement):

in non-relativistic classical mechanics potential energy measured via force e.g. with a spring: $\vec{K}(\vec{x}) = -\nabla E(\vec{x})$

in thermodynamics: heat measured in a calorimeter $Q = E(T) = k_B T$

in non-relativistic quantum mechanics: $\Delta E = E_1 - E_2 = h\nu$ electron falling from an excited energy level E_1 to a ground level E_2 emits a measured photon with frequency ν

The mathematical variable (classical function, quantum operator) E is uniquely and precisely defined and has arbitrarily precise values.

The measured quantities $E_m = E_m(\text{setup}, a_i, \vec{x})$ depend on the experimental setup (verbally defined, e.g. a spring fixed on one end with a weight of $m=1\text{kg}$ attached, measures the local gravitational acceleration g , and with it the gravitational potential energy $E_m = m g h$), and parameters a_i (e.g. elasticity modulus of the spring) . Furthermore, E_m has limited resolution: it carries a measurement error δE_m .

Nevertheless, all E_m are mapped into the single mathematical variable E , and, given a correct mapping, E is a **valid representation of reality**.

Example 5 Information [93]

The mathematical model of information is the Boltzmann-Shannon information $H_{BS} = -\sum_{i=1}^n p_i \log_2 p_i$,where

$p_i = p(s_i)$ are the probabilities of a random variable (s_i) (e.g. a physical state, or a text string position i , or a bit string position i). In the limit of large length $|s| = L(s)$, an equivalent model is the Kolmogorov information of a string s ,

$K(s) = \min \text{length}(\text{Turing machine } T_n \mid \text{output}(T_n)=s)$, $s = \text{bit-string}(0,1)$,

which is the minimum length of a machine program of a Turing machine L , which produces the string s , i.e. $K_L(s) = \min(|p|, L(p)=s | p)$ minimal in program $p \in L$ of fixed language L . Kolmogorov information $K_L(s)$ is a precise measure of complexity and is universal (L can be any language, $K_L(s)$ is independent of it).

The realizations (measurable quantities) :

for H_B it is the heat energy $Q = \int T dS_B$

for H_S it is $C = \frac{1}{t_0} \log_2 \left(1 + \frac{S}{N} \right) = \frac{\max(H_S)}{t_0}$, $B = \frac{1}{t_0}$ the channel capacity C of a signal transmission channel

with the signal-to-noise ratio $\frac{S}{N}$

for $H_K(s)$ it is $H_K(s, L, p) = |p| 2^{-|p|}$ for the length $|p|$ of a real program p in a programming language L (e.g. text processing language LISP), which outputs the string $s : L_{out}(p) = s$

3b There is a mapping theory-> quantitative experimental measurement

e.g. pressure p -> physical pressure in Pa ,

temperature T -> physical temperature in K, material parameter ξ -> physical quantity like density in g/cm^3 .

The mapping maps real number variables of the model into measurement results in real numbers.

The mapping is **correct** if the theoretical value agrees with measured value within the measurement error for all experiments. In this case, the theory is considered as a **valid** model of reality.

In this sense, Standard Model of particle physics and the cosmological Lambda-CDM model are valid theories.

4 An experimental measurement is a **statistical confidence test** of N samples, in which the mean μ and the variance σ^2 of a random real variable x with the (approximately Gaussian) probability distribution $P(x, \mu, \sigma)$ are measured with a confidence of $P_c(3\sigma) = 0.9973$. The object of a measurement can be a **continuous function** (like $p(T)$ for water) or a **discrete simulation** mapping (like a weather simulation pressure $p(r_i, t_i, bcond)$ on a lattice (r_i, t_i) of location and time depending on boundary conditions $bcond$) .

5 Summary

science= triplets (mathematical theory, mapping functions, experimental measurement)

As a summary, one can consider a **natural science**, e.g. physics, as a **collection of triplets (mathematical theory, mapping functions, experimental measurement)** in the sense of Nagel's interpretation [44] 2.2.1 .

The mapping maps **real variables of the model** into **measurement results in real numbers**.

Mathematical models in physics are based on the **following six areas**:

- partial differential equations (e.g. equation-of-motion Dirac equation, wave equation)
- variational calculus (e.g. principle of minimal action, Lagrangian and Hamiltonian)
- group theory (e.g. rotational Lorentz group, interaction Lie groups of the four fundamental interactions)
- matrix calculus (Lorentz-rotations, color and weak interaction, tensors in GR)
- probability theory in thermodynamics and quantum statistics
- functional analysis (operators with eigen functions and Hilbert spaces in quantum theory)

Specifically, mathematical theory in physics is characterized by an energy density **Lagrangian** obeying the **minimum principle** (minimal action + corresponding Lagrangian) and on **space-time rotation invariance** (Lorentz-group symmetry), and fundamental **interactions based on symmetry algebras**, e.g. $SU(3)$ Lie algebra in the color interaction.

However, there are currently several areas in physics, where only an **empirical model**, but no (fundament-based) **theoretical model** exists: high-temperature superconductors, Dark Matter, glasses, material constants like specific heat.

Phenomena , which are outside the scope of physics, are often described by other mathematical theories than the six areas of physical mathematics.

E.g. the functionality of the brain is described by neural networks (feed-forward NN , transformer NN), biological organisms are described by state automata and cellular automata, natural languages are described by formal language theory, economic and social systems are described by behavioristic-statistical models.

Example 1 **Classical mechanics CM**

In classical mechanics, the physics consists of

CM1 the **minimal-action-principle** with the Lagrangian $L_N = \frac{m \left(\frac{dx}{dt} \right)^2}{2} - V(x)$ and the action

$$S[L] = \int L \left(x, \frac{dx}{dt}, t \right) d^3x dt = \min$$

from which result the Euler-Lagrange equations-of-movement (eom), i.e. the Newtonian law

$$m\ddot{\vec{x}}(t) = \vec{F} = -\nabla V(\vec{x})$$

CM2 rotational **symmetry**: space rotations O(3) and Galilei transformation $\vec{x}' = \vec{x} - \vec{v}t$

According to the Noether-theorem, space-rotation-invariance yields the conservation of angular momentum, the Galilei transformation yields the conservation of energy.

CM3 The basic **experimental model** consists of the measurable quantities (potential) energy V , force $\vec{F}$, movement velocity $\vec{v}$, position $\vec{x}$, time t , mass m .

The **mapping function** maps measurable quantities into the corresponding mathematical variables, e.g. the

measurable movement velocity $\vec{v}$ into the time derivative of the position: $\vec{v} \rightarrow \frac{d\vec{x}}{dt}$

In a **measurement event**, a relation derived in the mathematical model is mapped into a measurable relation,

and verified by measuring the involved quantities, e.g. the Newtonian law $m \frac{d^2\vec{x}}{dt^2} = \vec{F}$ is verified by

measuring the involved quantities force $\vec{F}$ and (finite) difference quotient of velocity $\frac{d^2x}{dt^2} \approx \frac{\Delta v}{\Delta t}$ by measuring Δv and Δt and m .

Example 2 **relativistic color quantum field theory (chromodynamics) CQFT**

In color QFT, the physics consists of

CQFT1 the **minimal-action-principle** with the Dirac Lagrangian is

$$L_D(x^\mu(\tau)) = \bar{\Psi}(x^\mu(\tau)) (i\hbar c \gamma^\mu D_\mu - mc^2) \Psi(x^\mu(\tau)) \text{ and the action } S(L_D) = \int_{\tau_1}^{\tau_2} L_D(x^\mu(\tau)) d\tau$$

from which results the Dirac equation as the Euler-Lagrange equations-of-movement

$$(i\hbar \gamma^\mu D_\mu - mc) \Psi = 0$$

The derivative in the Lagrangian is the color covariant derivative $D_\mu \equiv \partial_\mu - i g A_\mu^a \lambda_a / 2$ with the 8 generators of the SU(3) $\lambda_a = 3 \times 3$ Gell-Mann matrices, and the corresponding 8 gluon field vectors A_μ^a .

basic entities: 3×3 quarks (u, d) (c, s) (t, b) , 8 gluons g_a

state function quark Dirac bi-spinor $\Psi(x^\mu(\tau))$, gluon vector A_μ^a

CQFT2 rotational **symmetry**: space-time rotations SO(1,3) of the Lorentz group

CQFT3 the underlying **color symmetry** algebra SU(3), the generators λ_a satisfy the commutator relations

$$[\lambda_a, \lambda_b] = 2i f^{abc} \lambda_c$$

field tensor $G_{\mu\nu}^a = \partial_\mu A_\nu^a - \partial_\nu A_\mu^a + g f^{abc} A_\mu^b A_\nu^c$, field Lagrangian $L_{col} = -\frac{1}{4} G_{\mu\nu}^a G^{a\mu\nu}$

CQFT4 The basic **experimental model** consists of the measurable probability density $|\Psi(x^\mu(\tau))|^2$, and

expectation values of energy $\bar{E} = \langle \Psi | E(x) | \Psi \rangle = \int \bar{\Psi}(x^\mu(\tau)) E(x^\mu(\tau)) \Psi(x^\mu(\tau)) d^4x$ resp. discrete

eigenvalues $E_i = \langle \Psi_i | E(x) | \Psi_i \rangle = \int \bar{\Psi}_i(x^\mu(\tau)) E(x^\mu(\tau)) \Psi_i(x^\mu(\tau)) d^4x$ in eigenstates Ψ_i , and

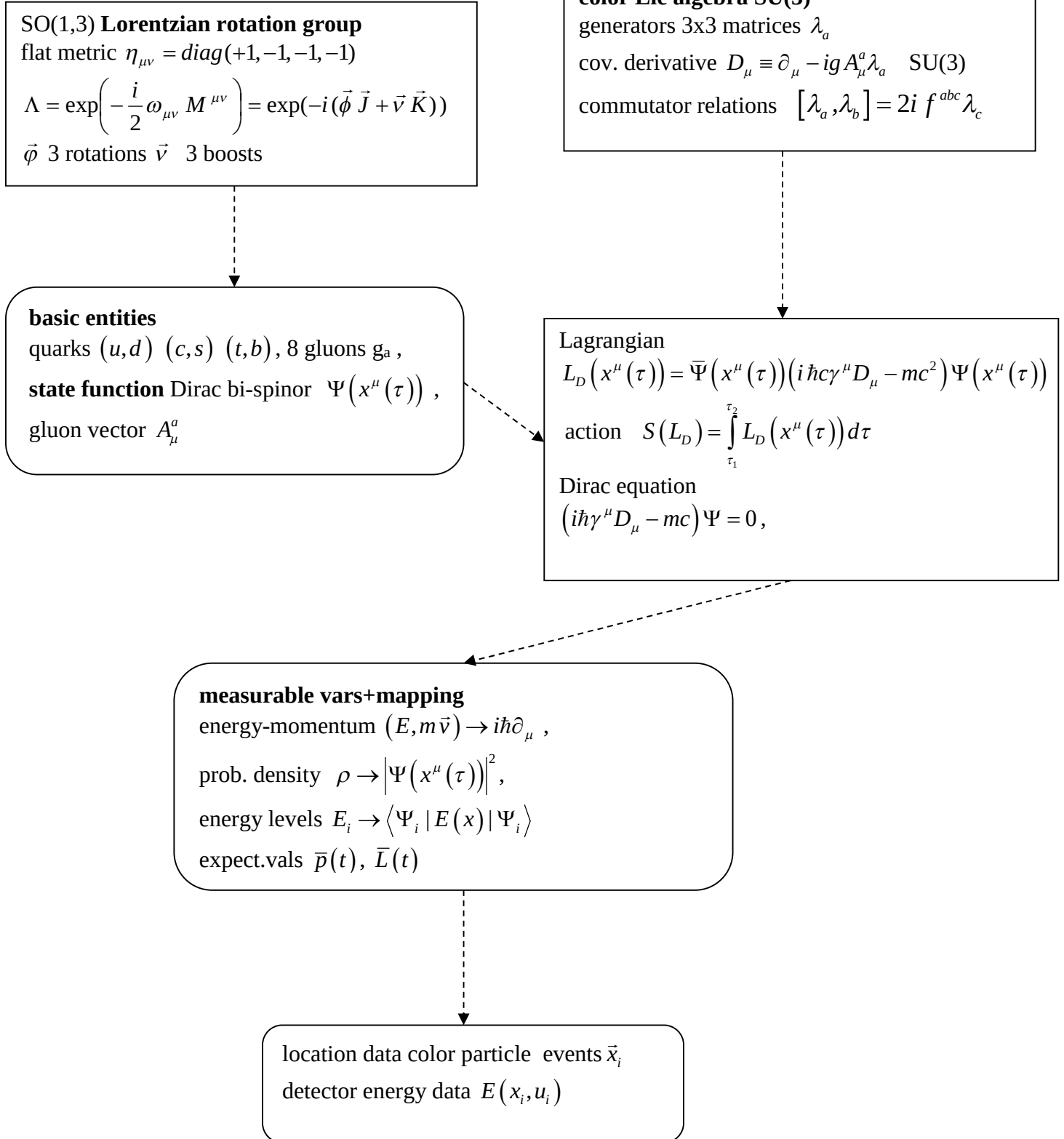
corresponding values for momentum = $\bar{p}$, angular momentum = $\bar{L}$, etc.

The **mapping function** maps measurable quantities into the corresponding mathematical variables as follows: energy-momentum into 4-derivative $(E, m \vec{v}) \rightarrow i\hbar \partial_\mu$, probability density into square wavefunction

$$\rho \rightarrow \left| \Psi(x^\mu(\tau)) \right|^2, \text{ energy levels into eigenstate-averages } E_i \rightarrow \langle \Psi_i | E(x) | \Psi_i \rangle, \text{ etc.}$$

In a **measurement event**, a relation derived in the mathematical model is mapped into a measurable relation, and verified by measuring the involved quantities in particle events, event location data in the Wilson chamber, and energy data from detectors.

quantum physics scheme for color interaction



1.2 Theories of different sciences

Fundamental physics

A theory in fundamental physics consists of **equations** for physical objects (e.g. Dirac field equation of SU(3)-color-interaction for the wave-function $\Psi[q](x^\mu)$ in space-time 4-vector x^μ of a physical object q , e.g. u-quark $q=u$) and a **structural model** of these physical objects (e.g. quark model of color-interaction).

The equations are derived from a minimum principle of the corresponding Lagrangian $\int L(q, x^\mu) d^4x$

In physics, there are **two fundamental theories**: the Standard Model of Particle Physics describing the small-scale quantum gauge field universe (microcosm) and the Lambda-CDM model describing the large-scale GR universe (macrocosm).

The **Standard Model of Particle Physics** consists of the $SU(1)_{\text{elm}} \times SU(2)_{\text{weak}} \times SU(3)_{\text{color}}$ Lagrangian (with the derived Dirac gauge field equations) and the structural quark-lepton-model with 28 parameters (masses, gauge field constants) [88].

The **Lambda-CDM model** is a pure equation with 2 Friedmann equations based on GR with 13 parameters [88] :

$$\Lambda(\Omega_b, \Omega_c, t_0, n_s, A_s, \tau, \Omega_\Lambda, w, \sum m_\nu, N_{\text{eff}}(\nu), r, dn_s/dk, H_0),$$

with denominations:

physical baryon density parameter Ω_b ; dark matter density parameter Ω_c , world age t_0 , scalar spectral index n_s ; curvature fluctuation amplitude A_s ; and reionization optical depth τ , dark energy density Ω_Λ , dark energy state factor w , neutrino masses sum $\sum m_\nu$, number of neutrino generations $N_{\text{eff}}(\nu)$, spectral index gradient dn_s/dk , Hubble constant H_0 .

Physics of species

Species are typical large collection of objects with common properties.

Classical species consist of non-identical components with parameters in a certain range: e.g. stellar systems, galaxies, or mesophysical structures like tectonic plates, mountain formations. They are described by a structural-evolutionary model, e.g. stellar models, and governed by statistical evolution laws (e.g. Hertzsprung-Russell diagram for stars) and static structure laws (e.g. equation-of-state for a star).

Quantum species consist of identical components: materials like water consist of molecules with fixed parameters (material parameters like density, boiling temperature etc.). They are governed by thermodynamic and chemical laws: the phase diagram $p(\rho, T)$, the density $\rho(p, T)$, chemical reaction rate

$$(r = k[A]^{n_A}[B]^{n_B} \quad k = \frac{1}{T_0} e^{-\frac{E_A}{RT}}) \text{ of a molecular substance like water H}_2\text{O, are precise, and their parameters can}$$

be calculated from the molecular structure.

Biology

Biological species are described a structural model consisting of **phenotype** (typical structure), **genotype** (typical genetic code) and typical **behavior**. All these structural models have parameters, which have a Gaussian distribution among individuals with a relatively small variance. The description in time is the **evolution history** of the species.

The governing laws in biology can be formulated as behavioral statistical Markov systems, resulting in statistical differential equations like the Lotka-Volterra equations for predator-prey-systems.

Economy/sociology

In human societies, the structural model has as its components the important agents in a society: labor unions, religious organizations, parties, powerful companies etc. The structural parameters (financial power, influence factor, cohesion of members etc.) are derived from statistical data.

The governing laws in economy/sociology can be formulated, like in biology, as behavioral statistical Markov systems, resulting in statistical differential equations.

1.3 General philosophy of science

The four dimensions of general philosophy of science (GPoS) [1] ch.1.7

The *epistemic dimension* deals with science as a *mode of knowledge*: science relies on theories, hypotheses, and principles that typically go beyond the observable aspects of the world.

The *metaphysical dimension* deals with the way to explain and ground the regularity there is in the world.

The *conceptual dimension* deals with ways to understand relation of physical theories to experience and experiment.

The *practical dimension* deals with ethical and social implications of science.

Proposed concept of four GPoS dimensions [JH]

Epistemic: the generalization of observable experimental parameter range is accepted on the basis of Occam's razor.

Metaphysical: there is no need for explanation of the mathematical model: it is simply a way to know the past and to predict the future where it is possible.

Conceptual: this is answered by the duality of theory and experiment as presented in ch.1.1.

Practical: ethical and social implications do not belong to the area of natural science, they are dealt with by social science.

Truth of mathematical and physical expressions [JH]

Mathematical-logical expression

(e.g. number(primes)=infinite)

-true: if it can be derived from axioms (=proved)

-syntactically false: if its negation can be derived from axioms

-semantically false: if there is a model of the axioms, where the expression is false

-undecidable: if it cannot be derived from axioms

-correct: if formulated in the relevant language of the axioms; e.g. in group theory there is only one operation (multiplication), a second operation (addition), like in natural numbers, is undefined.

Physical function or constant

(e.g. function: phase diagram of water $p(T, \text{water})$, constant: boiling temperature of water at normal pressure: $T_{\text{boil}}(\text{water}, p=1\text{bar})$)

-valid: if confirmed by measurement with relative error of 3σ (0.3%) in meso-physics, of 5σ ($0.4 \cdot 10^{-4}$) in particle physics

-measurable: if it is in principle possible to measure it directly or indirectly

1.4 Analogue and analytic human thinking [JH]

There are two fundamentally different human approaches to understanding our world:

-the analogue thinking, which started presumably with the introduction of the fictive language in the Cognitive Revolution around 70000 years ago [2], and until today continues in the humane sciences (psychology, sociology, law, literature, art)

-the analytical thinking, which started with the Greek geometry around 300 BC, continued with the foundation of physics by Galilei and Newton, and is today the valid paradigm in mathematical-natural sciences (physics, chemistry, biology, mathematics, informatics).

-analytical thinking

precise notions

biological: organism with certain common features (e.g. fish)

physical-mathematical: mathematical objects like e.g. groups, physical entities fundamental (e.g. satisfying preservation theorem or minimum principle) in a region of reality (e.g. energy)

quantitative notions symbolic (e.g. day: $24 \cdot 3600$ seconds) or sensory (e.g. color red 625-740nm wavelength) entities

representation of reality

physical/technical laws = structure e.g. aggregate structure and transition laws (solid, fluid, gas, plasma)

quantitative data = actual instantiation on Earth, e.g. aggregate(temperature, pressure) data of a substance (e.g. water)

prognosis, planning

quantitative value fixed, quantitative value statistical (with standard deviation)

decision, causation

logical deduction mathematical derivation

physical action biological: running, geological: mountain folding

-analogue thinking

fuzzy notions

topological entities: e.g. mountain

man-made entities: e.g. house

psychic entities: e.g. anger

biological entities: e.g. fish

representations of reality

time: chains of events

space: maps

social/biological: networks (graphs)

psychic: emotions

patterns: image , sound, text patterns

hierarchies: symbolic top-down graphs

prognosis, planning

analogical sequence of events: e.g. tempest

analogical sequence of actions: e.g. hunting

decision, causation

pattern recognition: e.g. face recognition

analogy reasoning: e.g. flow of water-expansion of fire

hierarchy insertion: e.g. to which group inside the natural grouping belongs a certain plant

-four Aristotelian properties of notion [14]

material=composition, efficient=originating action, formal=form, final=purpose

notion	composition	original action	form	purpose
table	wood	cutting, fixing wood	rectangle, oval	mechanical support
mountain	silicate rock	geological pressure leads to folding	roughly conical	none
recognized face	schematic features	automatic pattern learning	neural network activity	internal representation of reality
hunting	follow, catch, kill, process for food	hunger, need for food	movement description	feeding
cloud	water droplets	water condensation	fuzzy boundary, volatile random form	none
anger	none	environmental stress, attack	emotional state	defense
fish	biological tissue of cells	sexual reproduction, growing from egg	oblong	survival of species, individual survival

1.5 General cognition [JH]

Natural science, with physics at its center, is essentially a *description of the reality*. This description is formulated in the language of quantitative mathematics for the quantitative sciences like physics, it is formulated in natural language and in images for qualitative sciences like biology.

An example for the *quantitative-mathematical* (conceptionally sharp) description are the Maxwell equations, which are the basis for classical and quantum electrodynamics.

An example for the *qualitative-verbal* (conceptionally fuzzy) description are genotypes and behavioral schemes of a species, or evolution-taxonomy trees in biology.

Humans, like all biological beings have a *representation of reality*, in order to act appropriately within this reality, i.e. live and survive. This representation works in simple organisms through biochemical feed-back loops [3], in complex organisms through a nervous system with sensors, motoric actuators, memory, learning, executive control. In humans, it works through a complex dual-hemispherical brain with consciousness and linguistic communication.

This representation of reality is at the center of human cognition, i.e. acquirement of knowledge. The original form of it is the qualitative-verbal knowledge like in biology or history. The advanced form is the quantitative-mathematical knowledge, which began with the Greek geometry in antiquity and continued with the birth of classical physics founded by Galilei and Newton in the 17th century.

Acquirement of knowledge is an algorithmic process, and we humans have two ways to achieve it: the *analytic abstract quantitative-symbolical* process controlled basically by the left brain hemisphere and the *analog intuitive non-verbal* process controlled by the right brain hemisphere (which is also responsible for “discoveries, i.e. the so-called eureka-experiences”).

Philosophical approaches to cognition

In respect to cognition and reality, there are **three fundamental philosophical approaches**: the analytic, the pragmatic-adaptive, and the hermeneutical approach [76].

In the **analytic** approach, the reality is *precisely describable* by a mathematical model of a definite type (in classical and quantum physics: partial differential equations of second degree as equation-of-motion derived from minimization of action= integral of Lagrangian, plus symmetry described by gauge Lee groups and Minkowski metric with Lorentz group, plus statistics with some basic distributions (Gauss, exponential), plus structural parametric models (standard model for particle physics, general-relativistic lambda-CDM model for the universe)).

The validity of the model is verified by experiment with a finite precision. This approach holds that reality is a specific parametric representation of a parametrized mathematical structure. Famous proponents of this approach were, among others, Einstein and Heisenberg.

In this approach, reality is a fixed mathematic structure, which in principle can be deduced from fundamental principles, like Einstein deduced General Relativity from the principle of general covariance.

The model of reality is improved by *extending the model in steps until it reaches the “real” interpretation*

Example

$$\text{ideal gas eos } p V = n_{\text{mol}} R T \rightarrow \text{v.d.-Waals } \left(p + a \frac{n_{\text{mol}}^2}{V^2} \right) (V - n_{\text{mol}} b) = n_{\text{mol}} R T$$

Our human approach to this way of knowledge acquisition is : the *analytic abstract quantitative-symbolical* process controlled basically by the left brain hemisphere. The underlying mathematical model machine is the *von-Neumann computer* or in a more abstract generalized form the *universal Turing machine*.

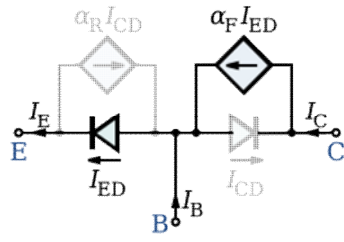
In the **pragmatic-adaptive** approach, the reality is *approximated* by a mathematical model, which is verified by experiment within the current measurement error. The model must be continuously refined and corrected according to the current experimental results. The experimentally verified (within the current measurement error) mathematical model is the valid knowledge of reality (Popper 1934), but it is valid only until falsified, there is no precisely accurate description. The most famous proponents of this approach are Popper from the philosophical point of view, and Bohr from the physical point of view.

In this approach, reality has a structure, not necessarily quantitative, which can be “learned” from experience, like mapping an unknown area.

The model of reality is improved by *introducing and adapting new parameters* and is always an approximation

Example

Ebers-Moll model of the bipolar transistor



$$I_E = I_{ES} \left(e^{\frac{V_{BE}}{V_T}} - 1 \right)$$

$$I_C = \alpha_F I_E$$

$$I_B = (1 - \alpha_F) I_E$$

The underlying mathematical model is a *neural network* [73], which describes well learning and cognition, in biology (brain), and in artificial intelligence (transformer neural networks like GPT).

Our human approach to this way of knowledge acquisition is and the *analog intuitive non-verbal* process controlled by the right brain hemisphere. The fitting mathematical model machine is the *spiking binary neural network*, as we know from the modern measurement techniques of brain functionality.

In the **hermeneutic** approach, the mathematical description is only one possibility of cognition, and it cannot describe reality completely. Famous proponents are Bergson (with his concept of time as permanent movement, and his concept of life energy (“elan vital”)) and Heidegger with his concept of life as an evolving and non-reducible entity in time (“Sein und Zeit”).

Roughly speaking, in the hermeneutic “naturalistic” Bergson-Heidegger approach, building blocks of reality in our perception are seen as a collection of patterns (images) connected to notions, and events are seen as series of such patterns in time.

In terms of human brain functionality, this corresponds to the processing of impressions and responding to them in the senso-motoric cortex areas and the midbrain.

A possible fitting representation of this approach are *cellular automata*. Stephen Wolfram [77] has proved that many physical phenomena, especially in regard to complex collective dynamical systems, can be represented by corresponding cellular automata, the same applies to parts of mathematics, e.g. Turing machines and differential equations.

Cellular automata with n states are interacting systems of state automata [94]. As such, they are well adapted to describe collective phenomena in physics (e.g. solids, gases, galaxies), in biology (bacterial communities, animal communities), in biological informatics (nervous system, brain). Cellular automata describe such systems much better than statistical physics (thermodynamics).

Cellular automata can handle series of patterns, i.e. behavior: an input of a time-series of sensorial conditions (patterns) is transformed into a time-series of mechanical conditions (movement) and chemical conditions (chemical reaction, e.g. enzyme or neurotransmitter production).

The series of patterns which represents reality is improved in approximation by refining the rules of the input series and output series.

Example in biology: a rabbit sees a series of images and sounds caused by a fox, recognizes it as such, and responds with an action pattern of immediate and fast running away.

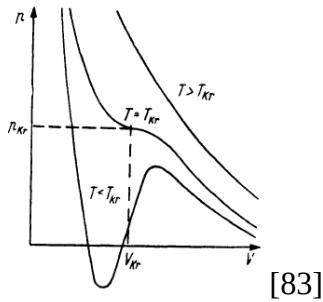
In physics and technology, the model is digitalized functional data instead of a closed mathematical expression, e.g. the current-voltage characteristics of a Mosfet transistor, as it is in common use in electronics.

The model is improved *by extending and improving in precision the digitalized data* of a process or a function.

Example

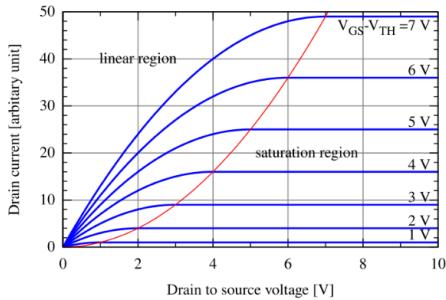
-real gas v.d.Waals

represented by the corresponding digitalized graph produced by a cellular automaton increases in resolution



-MOSfet transistor

represented by its current-voltage characteristics, digitalized and reproduced by a cellular automaton



1.6 Mathematical models of cognition [JH]

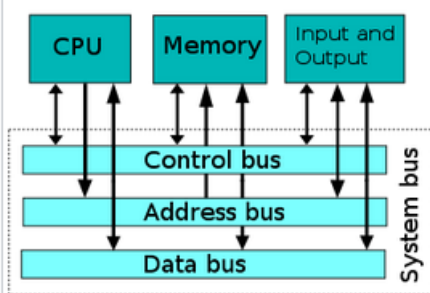
There are three mathematical models capable of describing the process of cognition of reality:

- von-Neumann computers
- neural networks
- cellular automata

Von-Neumann computer (analytic approach)

The abstract quantitative-symbolical verbal thinking with its logical deduction and numerical calculation, emerged probably from the complex sequential movement control located in the cerebellum and the sensorimotoric cortex. The underlying mathematical model is the *von-Neumann computer* (specifically the ALU and program-data-memory). This model works well for rule-based deduction and numeric calculation, but is not well-adapted to “fuzzy” description, representation of psychic reality, pattern recognition and structure recognition, as required in AI.

Structure of a von-Neumann computer



A von-Neumann-computer consists of CPU (processing unit), memory (containing opcode and data), input-and output-unit, they connected by control-bus (opcode), data-bus(data) and address-bus (memory address of current opcode).

Application

- Applicable objects

The analytic approach is fully applicable for systems, which can be completely described by *analytic continuous mathematical models* with complexity of ~ 100 parameters, i.e. by partial differential equations, analytic functions, and continuous statistics (continuous probability distributions).

Examples are: classical macroscopic systems: solids, fluids, gasses; quantum systems in the molecular, atomic, and sub-atomic range

- Functionality

The cognition process is *carried out by a von-Neumann program*, which analyzes measurement data, extracts the essential information, calculates the model data, compares them, and modifies the model parameters accordingly.

This cognition process is the established scientific method, where the von-Neumann program is represented by the human brain, specifically the left-hemisphere cortex, where the analytic-logical processing takes place.

During the last 30 years, most part of the data analysis and model calculation is done by a true von-Neumann program, more and more including the adaptation of the model structure itself.

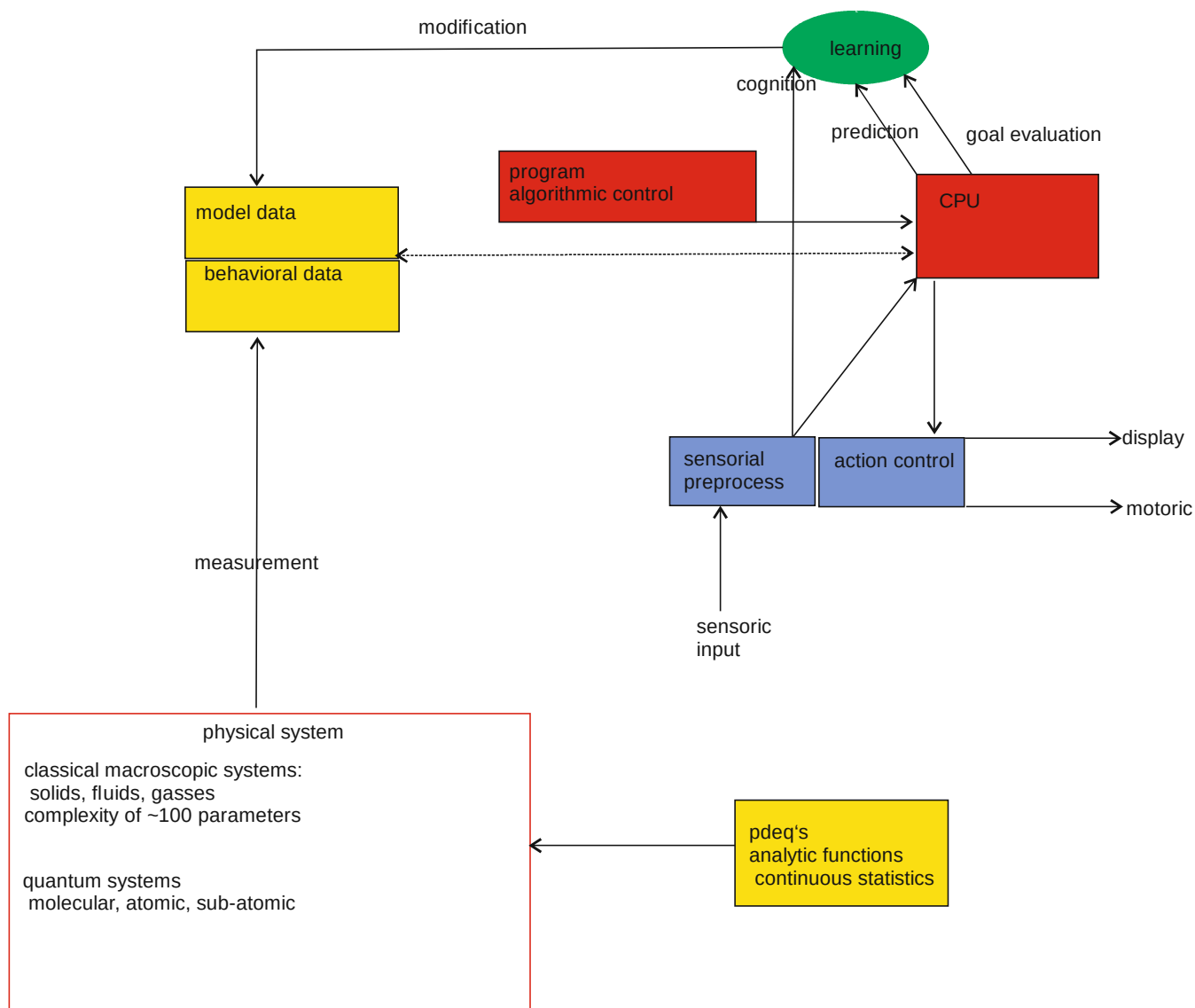
- Self-modifying von-Neumann robot

In future, the computer program will be able to learn actively by self-modification of its code, and take over the complete cognition process.

The program itself is written by humans, but in principle, the robot can modify its own program. However, experience shows that von-Neumann machines are not well-suited for this. A viable alternative is a transformerNN-based deep-learning AI machine, which can be trained to produce reliable program code, and also modify a von-Neumann machine code.

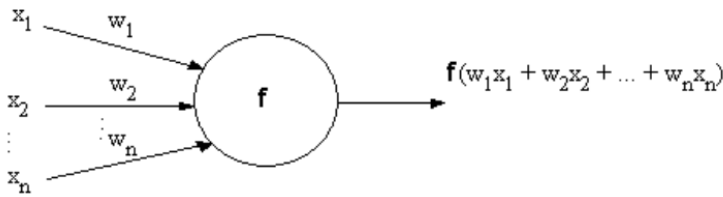
Therefore, the best machine for the analytic approach is a *self-modifying learning hybrid* von-Neumann and transformerNN-based AI machine .

learning Neumann computer-robot

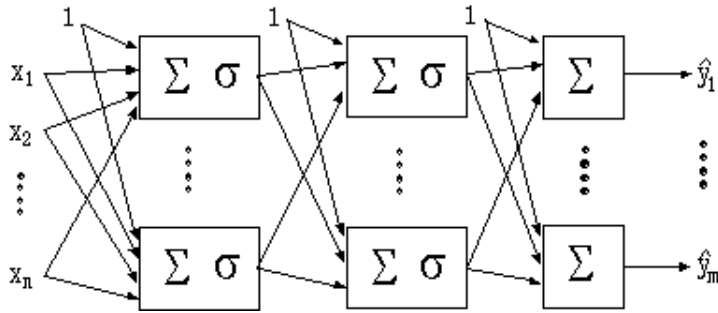


Neural network (adaptive approach)

We know [73] that neural activity in brain happens on the basis of *spiking binary neural network*, where cognition works via pattern recognition, relational structuring, hierarchy forming, prediction by analogy, memory based on relational and spatial-temporal structure. This is the mathematical model, used and verified in artificial intelligence (AI), for our intuitive non-verbal thinking. Neural networks are capable of pattern memorizing recognition by enforced learning with weight adaptation, structure recognition by free learning, and of evolution by learning-induced structure adaptation. As practiced in AI, neural network work in two modes: learning mode with memorization by weight adaptation and recognition mode with similarity and analogy processing, exactly as high-level living organisms. A neural network is also of course well fitted for description of our psychic reality and the “fuzzy” functionality of natural language and its symbolic representation in the brain.



Structure of a neuron in a neural network



A multi-layer feedforward network with several hidden layers and one output

A neural network is a network of neurons with function f and input vector $x=(x_1, x_2, \dots, x_n)$ with weights $(w_1, w_2, \dots, w_n)$ and the output $y=f(w_1 x_1 + w_2 x_2 + \dots + w_n x_n)$. The weights are adapted in such a way that the network of m neurons yields the output vector $Y=(y_1, y_2, \dots, y_m)$ with desired result.

Application

- Applicable objects

The adaptive approach is fully applicable for systems, which are described by *patterns and transformation rules*, but which cannot be described by analytical mathematical models.

Examples are *information-carriers*: natural languages with their grammar and semantics, with complexity of $\sim 10^4$ parameters (symbols and rules); biological communities: bacterial colonies, animal communities.

There is a clear connection between these systems and neural networks. Pattern recognition and language analysis are areas, in which humans and neural-network-based AI-machines perform especially well.

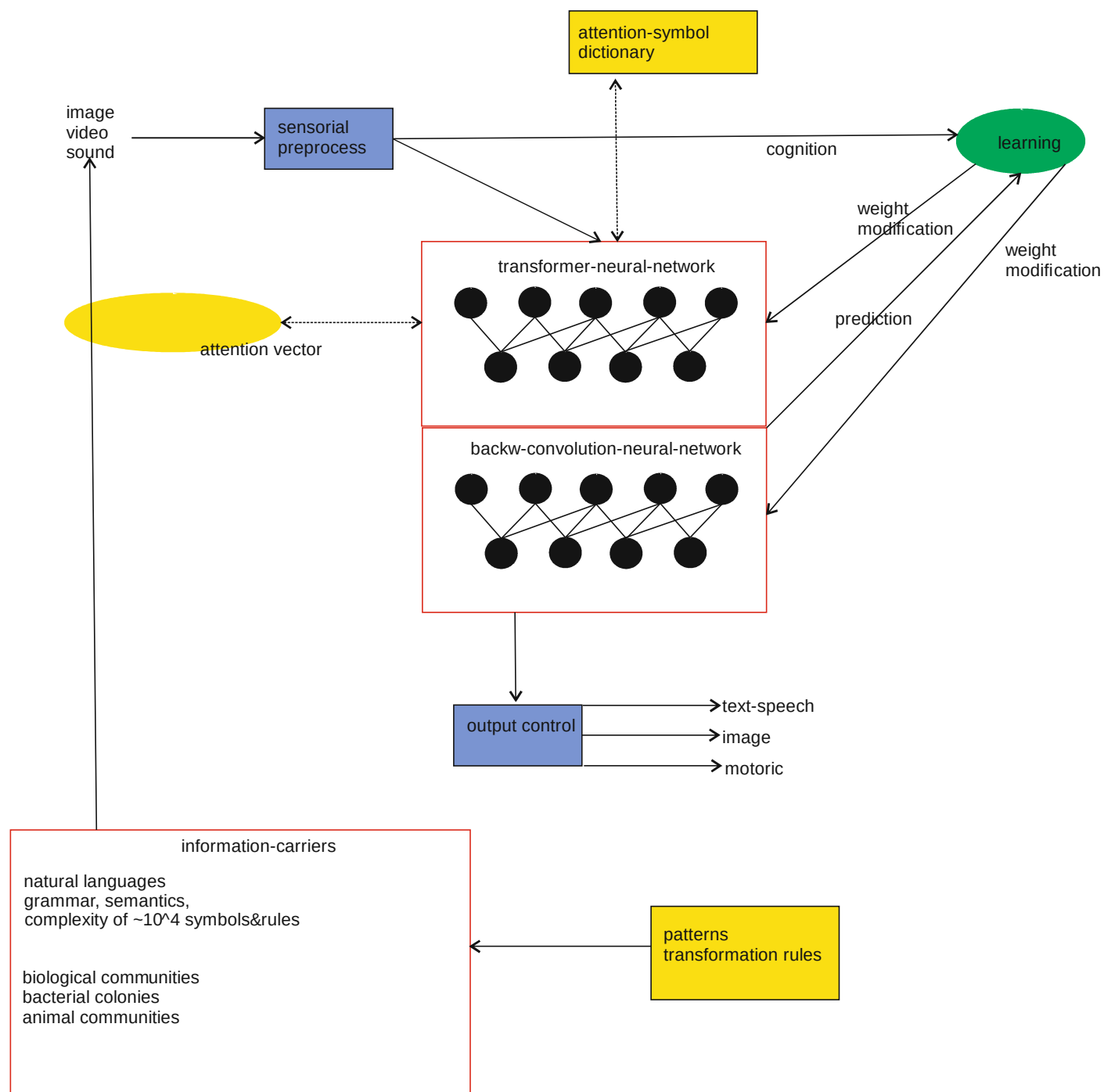
- Functionality

A typical application of the adaptive approach is the *analysis and production of spoken language*.

The modern *transformerNN-based deep-learning AI machines* like Lamda and ChatGPT can analyze spoken language and participate in human talk in real time, and are indistinguishable from a human, i.e. they pass the Turing test.

These AI machines can also be trained to produce reliable program code for a given purpose.

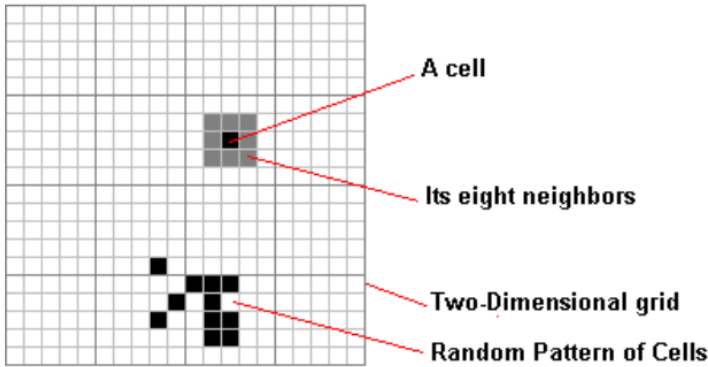
In future, they will be equipped with a symbol memory, and will be able to build a genuine representation of reality, and become a true intelligent learning goal-oriented robot.



Cellular automaton (hermeneutic approach)

There is a third mathematical model for the description of reality, especially of deterministic and stochastic processes, collective phenomena and fractal structures. This is the *cellular automaton* governed by transition rules, known from Conway's "game-of-life" and from Stephen Wolfram's work [77]. This model is also capable of performing algorithmic calculation, rule-based deduction, and evolution by adaptation of rules [94]. A cellular automaton is essentially a state machine based on a set of transition rules. But it generates also a process in time, which can be viewed as a series of images, and therefore resembles a film or a story from our human intuitive concept of reality.

A two-dimensional cellular automaton



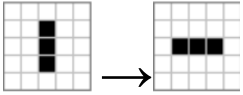
It is comprised of a two-dimensional grid of cells. Each cell can be in one of two states, on or off (dead or alive). Cells may transition from one state to the other, and become on or off, based on a set of rules.

Example: Conway's Game of Life

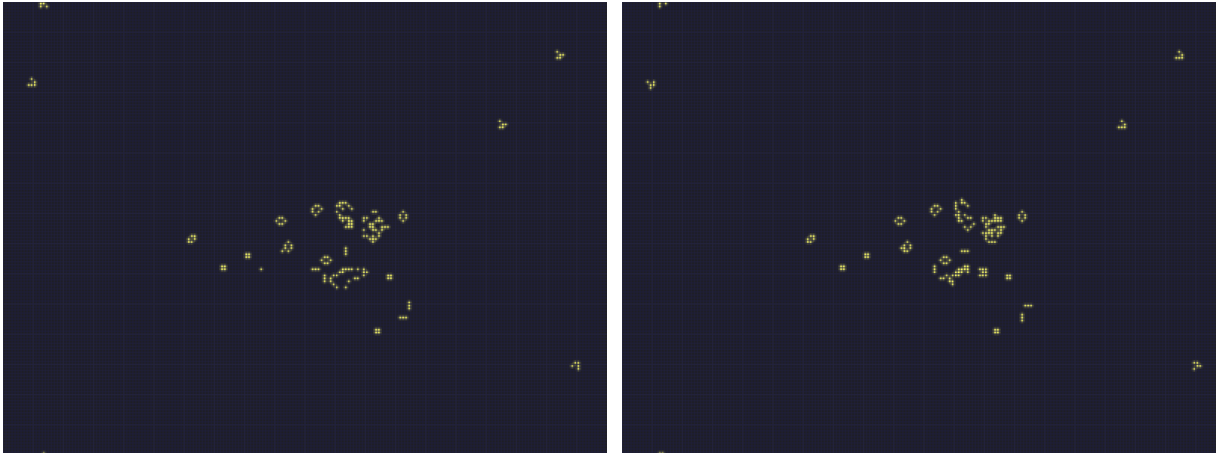
Rules of the Game of Life

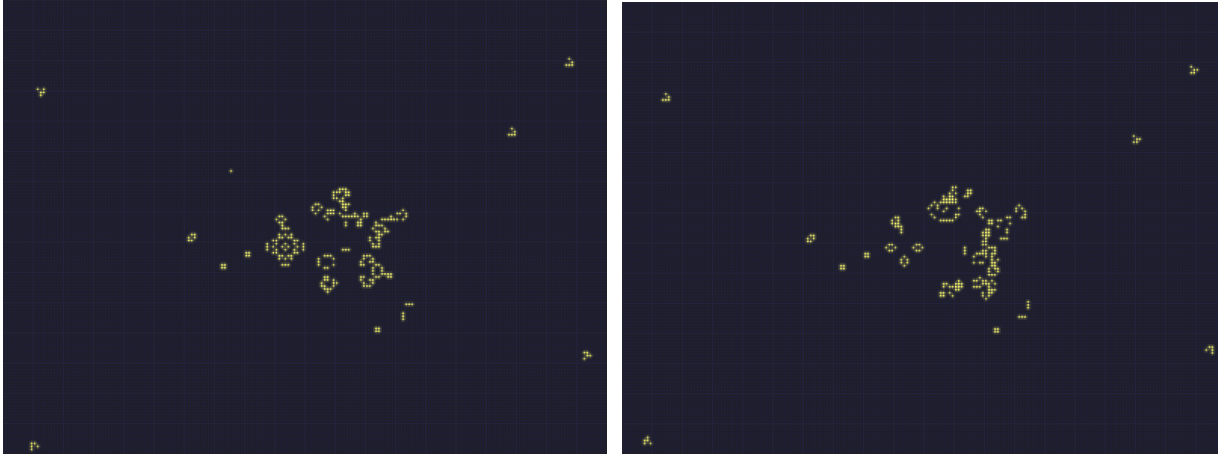
Let N be the number of neighbors of a given cell. If $N = 0$ or 1 , cell dies. If $N = 2$, the cell maintains its current state (status quo). If $N = 3$, the cell becomes alive. If $N = 4, 5, 6, 7$ or 8 , the cell dies.

e.g. transition



Game of life, Pentomino





Application

- Applicable objects

The hermeneutic approach is fully applicable for large *systems of elements interacting and transforming (multiplying) according to certain rules*, like cellular automata. These are biological multicellular systems like animals and plants. They cannot be described by analytical models, but neither by patterns and transformation rules.

Examples for *applicable objects* are: higher animals and plants with complexity of $\sim 10^5$ parameters (genes), which consist of trillions of cells organized in substructures (organs) and interacting and multiplying using $\sim 10^5$ chemical reactions.

- Functionality

A typical application is *simulation of the functionality of the human body* for medical purposes.

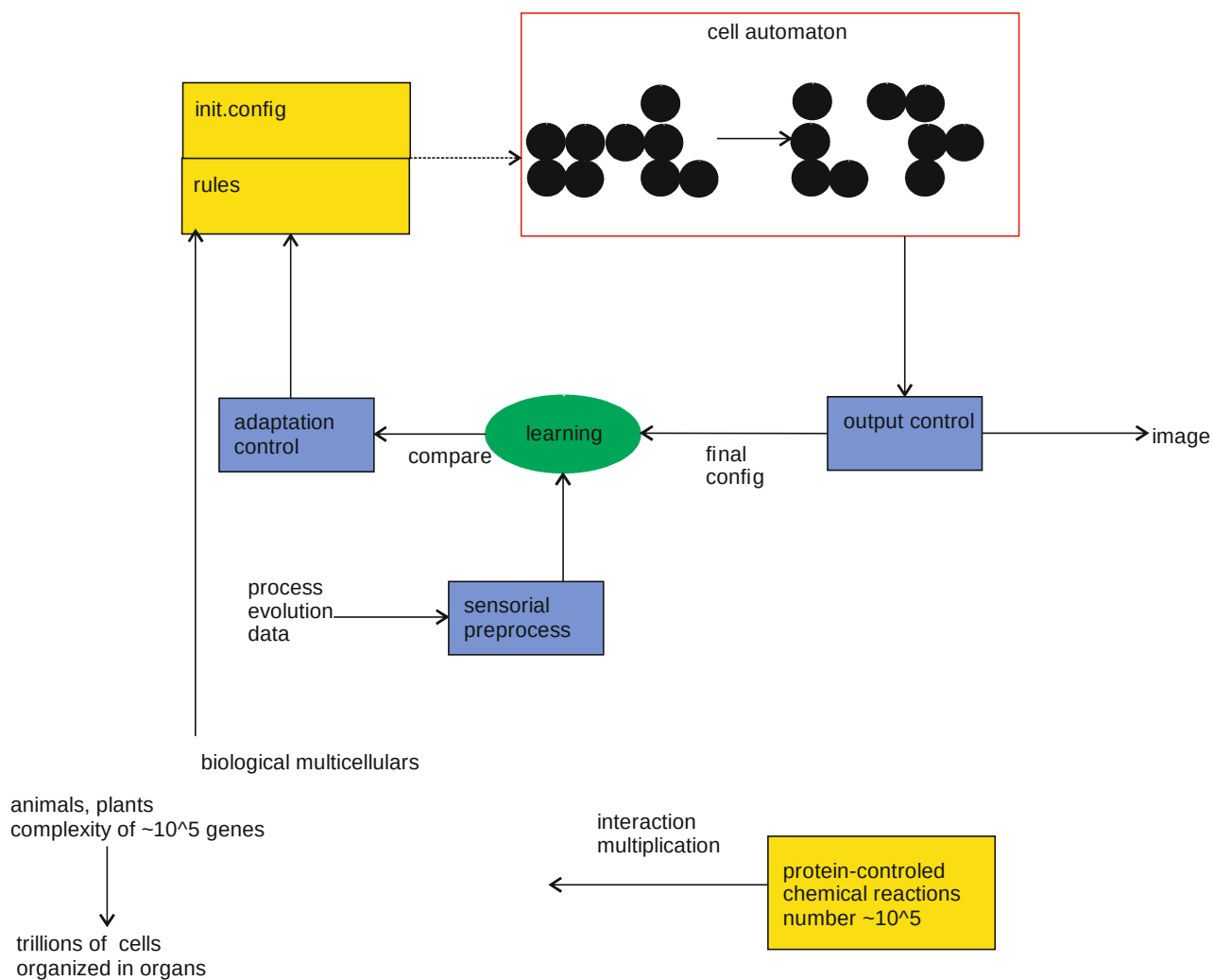
Such a simulation on a von-Neumann computer with pdeq's and statistics is completely out of reach and will remain so, given the enormous numerical complexity of the task.

The simulation on a (hardware-parallel) self-adapting (i.e. rule-adapting) cellular automaton appears possible, but remains currently purely speculative.

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Schematic of hermeneutic cognition

adaptive cell-automaton process simulator



1.7 Limits of knowledge [JH]

There are fundamental limits to knowledge.

This has been known in mathematics for 100 years: Gödel's undecidability theorems, the halting problem of Turing machines (whether a Turing machine ever stops or runs endlessly is generally undecidable) and Kantor's undecidable continuum hypothesis are examples of this.

Facit: in mathematics, the limit of knowledge lies with undecidable statements and statements about infinite systems.

Our physical universe is finite (10^{80} nucleons, finite radius and finite age) and discrete (not only energy in QM, but also space-time is discrete in units of Planck length, especially the differential equations of QFT are actually difference equations).

So in principle the universe is (mathematically) "predictable".

Currently, calculations in physics for 3D field calculations of differential equations with FEM grid methods are used (e.g. Navier-Stokes, heat conduction, also GR), in multi-particle systems simulation calculations with minimizations are carried out (e.g. Ising model, astrophysical Star models).

For calculations on the grid (FEM), the computing time increases approximately with $c \cdot N$, for simulation calculations with minimization it increases with c^N (e.g. travelling salesman), where N is the number of grid points or elements.

When computing time reaches the age of the universe, the problem is de facto physically unsolvable.

A second limit is a time limit for the duration of a measurement. The so-called "weak measurement", which is used in quantum computers in order not to destroy the entanglement, works with very low energies and has to be repeated for a long time in order to get a statistically significant result. The lower the energy, the longer is the duration of the measurement.

A third limit is probably the energy to be generated in elementary particle experiments (the realistic limit energy here is presumably several orders of magnitude below the Planck energy).

Facit: in physics the limit of knowledge lies with de-facto non-calculable problems and with measurements that are limited in terms of time or energy.

2 Philosophy of computational science

The traditional approaches to the notion of computational science are:

-**Church-Turing** approach [1] ch.2.1

Four concepts of computability are equivalent: Church's lambda-definability, Kleene's primitive recursiveness, Post's finite combinatory process, and Turing's computability in terms of Turing machines.

As a result, computable is, whatever can be produced by a machine fulfilling Turing's conditions

1. "The behavior of the computer at any moment is determined by the symbols which he is observing, and his 'state of mind' at that moment"
2. "There is a bound B to the number of symbols or squares which the computer can observe at one moment"
3. "The number of states of mind which need be taken into account is finite"
4. "We may suppose that in a simple operation not more than one symbol is altered"
5. "Each of the new observed squares is within L squares of an immediately previously observed square"

-**Gandy's machine** computation

Gandy's thesis: Any function that can be computed by a discrete deterministic mechanical device is Turing-machine computable

Gandy characterizes discrete deterministic mechanical devices in terms of precise axioms, called Principles I–IV, which are an extension of Turing machines.

I *Form of description:* Any discrete deterministic mechanical device M can be described by $\langle S, F \rangle$, where S is a structural class, and F is a transformation from S_i to S_j . Thus, if S_0 is M 's initial state, then $F(S_0)$, $F(F(S_0))$, ... are its subsequent states.

II *Limitation of hierarchy:* Each state S_i of S can be assembled from parts, that can be assemblages of other parts, and so on, but there is a finite bound on the complexity of this structure.

III *Unique reassembly:* Each state S_i of S is assembled from basic parts (of bounded size) drawn from a reservoir containing a bounded number of types of basic parts.

IV *Local causation:* Parts from which $F(x)$ can be reassembled depend only on bounded parts of x .

-**Marr's cognitive** computation

A complete cognitive computation consists of a tri-level framework of abstract-computational, algorithmic, and implementational levels.

The abstract-computational level defines the information-processing task.

The algorithmic level characterizes the representation by calculation elements (e.g., real numbers in decimal representation, or oriented graphs) and the algorithm employed for transforming representations of inputs into those of outputs.

The implementation level specifies how the representations and algorithm are physically realized (e.g. on an electronic digital hardware built of semiconductor logic-gates and flip-flops as memory).

Proposed concept of computation [JH]:

- **the pair** {Church-Turing abstract computation, Marr's cognitive computation} as the valid description of computation.

I think that the Church-Turing abstract computability concept is general enough, which is the current assumption in mathematics. Marr's notion of representation by calculation elements, and physical realization provide the mapping from the abstract into the empirical world.

Those two concepts together are a **minimal description** of abstract-empirical computation.

3 Philosophy of classical and non-classical physics

There are two fundamentally different regimes in our physical world: the quantum regime on molecular, atomic and sub-nuclear scale below $L \sim 50\text{nm}$ (size of large proteins) and the classical regime above this scale.

There are 3 fundamental features, in which those two regimes differ

-orbits in classical regime are **precise functions** $\vec{x}(t)$, orbits in quantum regime are **probability density**

distributions $|\Psi(\vec{x}, t)|^2$, where $\Psi(\vec{x}, t)$ is the wave function

-fundamental variables like location x , time t , energy E , momentum p , angular momentum L are **real numbers** in classical regime; in quantum regime, they are **operators**, which satisfy commutation relations like the

famous $[x, p] = i\hbar$, from which follow uncertainty relations like the well-known Heisenberg relation

$$\Delta x \Delta p \geq \hbar / 2$$

-classical entities are **distinguishable**, they have a non-identical appearance and history and evolve with time, but their **description parameters are approximate**, they lie in a certain interval and have a typical value (mean μ) and a typical deviation (standard deviation σ) with a (in general Gaussian) distribution $P(\mu, \sigma)$, e.g. comets have a typical appearance, size, composition, life-time and orbit parameters;

quantum entities are generally **non-distinguishable**, they have **fixed description parameters** (like mass, charge, spin, structure), have no individual features and no history and do not evolve, entities with half-integer spin obey Fermi-Dirac statistics (e.g. electrons) and have occupation number 1 per state, entities with integer spin obey Bose-Einstein statistics (e.g. photons) and have occupation number arbitrary per state

4 Philosophy of evolution [JH]

4.1 Distinguishable and non-distinguishable entities and evolution

The **classical** physical entities (e.g. comets) are **distinguishable**, they have a non-identical individual appearance and individual history and evolve with time, but all their description parameters including appearance, composition, history have typical values (mean μ) and deviations (standard deviation σ) within a *range characteristic for the type*, they belong to a common (physical) **species**. The species has a place in a hierarchy and has a common origin with other species, e.g. comets, asteroids and planets originate in the protodisk of a star and are part of the star's planetary system.

For example, stars belonging to the class of Red Dwarves are static classical objects described by mass, radius, brightness, radiation spectrum, density-distribution, equation-of-state, composition, all of which lie within a certain range typical for Red Dwarves. Stars are “individuals within a group” and they evolve in time, this evolution is described by the Hertzsprung-Russell-diagramm.

The situation is quite similar in the biological world: individuals in a (biological) species are distinguishable, but share a common typical genotype, phenotype, and behavior. Biological species have an evolutionary hierarchy and an evolutionary history: they evolve from other species. On the other hand, individuals have a personal history.

The **quantum** entities (sub-molecular scale) are **non-distinguishable**, they have no history and do not participate in evolution. They belong to a **species** (e.g. individual CH_4 -molecules belong to the species ‘methane’), but the *parameters which describe the species are identical* for all individuals. The individual atoms/molecules can differ in location and energy-momentum, which do not belong to the describing parameters. The describing parameters are (for molecules) mass, charge, spin, composition, structure. The species belongs to a hierarchy (e.g. atoms are ordered according to their atomic number and have a place in the Mendeleyev scheme), but do not evolve, and have no evolution history: *they are ageless*.

For example, helium nuclei are described by mass, charge, spin, composition (here 2 neutrons and 2 protons). These parameters exactly equal for all helium nuclei and do not change in time, so that these objects are indistinguishable and ageless. However, the location and energy-momentum vectors do change in time, and are in principle measurable, although with an uncertainty (Heisenberg principle), so these objects have an “individual history”. Helium nuclei can also enter an excited state with a higher (discrete) energy, which is also part of their “individual history”.

The **laws** governing **classical species** have parameters with values in a certain range, i.e. they are **approximate**. This is true for static laws (e.g. equation-of-state in a sun-like star) and for evolution laws (e.g. the Hertzsprung-Russell diagram of star evolution).

The same applies to the biological species. The (static) parameters governing the metabolism of an individual of a species vary within a certain range. The (evolutionary) parameters governing the individual history (e.g. aging) also have a range across the species.

The **laws** governing quantum species have **fixed parameters**. E.g. the phase diagram $p(\rho, T)$, the density

$\rho(p, T)$, chemical reaction rate $(r = k[A]^{n_A}[B]^{n_B} \quad k = \frac{1}{T_0} e^{-\frac{E_A}{RT}})$ of a molecular substance like water H_2O , are

precise, and their parameters can be calculated from the molecular structure.

4.2 Evolutionary hierarchy [JH]

Physical world evolution hierarchy:

-Stellar system: stellar(star, planets, asteroids, comets, gas) with constant energy production rate P from nucleosynthesis, scale $L=5 \cdot 10^{12}$ m, typical life-time $T=5 \cdot 10^9$ y= $1.6 \cdot 10^{17}$ s (sun-like), typical char. time $T_0=1$ d (sun activity period)

-Galaxy: galaxy(central BH, stars, gas) with constant energy production rate P from gravitational accretion of central BH, scale $L=1 \cdot 10^{21}$ m (radius), typical life-time $T=1 \cdot 10^{10}$ y= $3 \cdot 10^{17}$ s (Milky Way), typical char. time $T_0=1$ d (sun activity period)

evolution principle

dust gravitational collapse + nuclear H-burning $\rightarrow$ star (gravitation-bound stable radiating mass), goal: none

Biological world evolution hierarchy

-Cell: cell(enzymes, gene-carriers, energy-cycle, membrane), where on Earth: enzymes=peptides gene-carriers=nucleotides energy-cycle=iron-sulfur-reaction or photosynthesis, typical scale $L=1\mu\text{m}$ (bacteria), typical life time $T=20\text{min}$ (division time in bacteria), typical char. time $T_0=1\text{ms}$ (typ. reaction time in bacteria)
 -Multicellular: multicell(organs, feeding, sexual reproduction), scale $L=1\text{cm}\dots 1\text{m}$, lifetime $T=3$ months(insect)...100y (tree)

evolution principle [13]

enzymes (terrestrial: peptides)+controllers(terrestrial: nucleobases) + chemical energy cycle(terrestrial: Wächterhäuser's iron-sulfur reaction) $\rightarrow$ life proto-cycle (terrestrial: proto-cell phospho-lipid membrane in a volcanic pool), goal: survival with Darwinian selection

Intelligence evolution hierarchy

-Biological brain: brain(binary multi-layer Neural Network, electrical signals (ion flow)) with reinforced learning (synapses), with learned and pre-wired representation of environment, scale $L=1\text{cm}\dots 30\text{cm}$, life time $T=1\text{y}\dots 70\text{y}$, char. time $T_0=10\text{ms}$ (neuron activation time)

-Biological society: society(intelligent individuals, rule-controlled learned social behavior), scale $L=100\dots 1000\text{km}$ (human state), life time $T=100\dots 500\text{y}$ (human cultural period)

-Autonomous evolving robot: robot(backprop evolving real-valued Neural Network, electrical signals) with reinforced learning(weights), reinforced flexible structure-mutation, pre-fixed goals, scale $L=1\text{cm}\dots 10\text{cm}$, life time $T\sim 10\text{y}$ (? , mechanical wear, NN-structural leap), char. time $T_0=10\text{ns}$

-Robotic swarm : swarm(robots, rule-controlled learned cooperation)

evolution principle

neurons (output function $\hat{y} = \text{sign}(\sum_{j=1}^d w_j x_j + b)$) + synapses (weights w_j) + voltage $\rightarrow$ learning neural network, goal: pattern recognition success rate

4.3 Life strategy [JH]

Biological beings with a central nervous system have an image of reality acquired by learning from sensorial input, the image is continuously corrected by experience of reality (in animals: purely sensorial experience, in humans: also by verbal communication).

They are guided by built-in goals of biological evolution: survival of individual and survival of species.

In order to achieve these goals, they optimize their behavior, based on prognoses of outcome for behavioral scenarios.

-Image of reality

The reality is physical (material and biological outer world), psychic (inner mental world), and social (inner individual social relation network, and the society of our country with its group structure and its relation network).

The image is

-physical-technological model of the physical reality

-intuitive model of the own psyche and body

-memory of individual history

-model of inner social relation network based on (introspective and learned) model of human character (German Menschenkenntnis, English theory of mind)

-Goals

The goals are intuitive/built-in main goals: corporeal, mental, social well-being

and rational sub-goals: corporeal: fitness,

mental: knowledge technological and of human character,

social: status+ finance+ friendship & love+ security

-Optimal behavior

Life strategy in humans is finding the optimal behavior under given circumstances, based on the image of reality and comparison of prognoses for variants of own behavior.

The prognoses are physical-technological (e.g. handling a machine or computer), personal-social (e.g. dealing with people in daily life). global-social (e.g. analysis and prediction of social and political processes).

-Sense-of-life

Humans are biological beings, and as such they are goal-oriented. The main goal is individual survival, subgoals are reproduction, physical and mental achievement, social status, property, social power.

Humans are the only biological beings on Earth, which use language and with it are capable of symbolic thinking, abstract planning, and symbolic knowledge. As such, they are aware of death and include it in their life plan and common knowledge base (culture).

The main goal of biological evolution is survival of species, the individual survival is a subgoal, which is limited by death; all biological organisms, which reproduce sexually, have a limited lifespan, ageing and dying is a in-built biological process, which no individual can escape.

The concept of goals in life, which is built-in in the human mind, is described as sense-of-life in philosophy.

The obvious biologically enforced impossibility to achieve the main goal, individual survival, generates the fundamental exclusively human dilemma of “absurdity of life”, which is central in all human cultures and religions. This dilemma is solved in religion by the magical concept of (immortal) soul (see ch.10.3).

The other obvious dilemma arising from the physical limits of humans in physical and mental achievement is solved in religion by the magical concept of God (or gods), which is endowed with super-human power and knowledge (see ch.10.3).

4.4 Evolution of societies and ethics [JH]

Biological societies, human and animal, in which individuals cooperate, practice partition of tasks (e.g. gathering food, defense, care for offspring), and are guided by behavioral rules.

Ethics

In human societies, behavioral rules are called ethics. Ethics is conserved in rituals and religion, later in urban societies also (ethical prohibition) by law.

Ethics contains negative rules (interdictions, e.g. killing another human is forbidden), and positive rules: recommended morally good behavior e.g. helping each other in need.

Ethics was from the beginning an important part of philosophy, starting in the antiquity.

There are 3 fundamental views of ethics [14]

-deontology, a rule-based ethics

Kant's view is that moral duties are absolute and innate (moralischer Imperativ), which follows the traditional religious justification

- consequentialism, a results-based ethics

which says the right thing to do is what will have the best consequences, i.e. is 'maximizing happiness for the majority', which is a modern rational view

- virtue ethics, a person-centered ethics

which follows Aristotle, and emphasizes moral character (virtue) rather than acts or their consequences; in this view moral behavior is a positive personal quality (like discipline, cleanliness), which results in more happiness and success in life.

From the scientific point of view, the consequentialism is the correct approach.

Ethics in religious and social context is dealt with in ch.12.2 and ch.12.5 .

5 Causality and arrow of time in science [JH]

The concept of (temporal) causation [1] ch.8 originates in the biological world: a biological agent (animal or human) carries out an action which lasts in time and produces an effect (e.g. a monkey tears at a twig and breaks it off), causation is an **interaction** between two participants at a time t_1 , with a **state-transition in time** at a later time t_2 , which is in general irreversible, because in the biological world **time is directed** from the past into the future. Another kind of causation is **mediated by movement** (e.g. an agent throws an object which causes an effect at its destination):

In physics, the concept of causation as interaction with a state-transition via energy flow can be transferred directly, in classical and quantum physics.

5.1 Causation in physics

In physics, there are two fundamental causation schemes [1] ch.8

-**collision-like processes** (interaction matter-matter)

-**absorption-like processes** (interaction radiation-matter)

In **classical collision** (e.g. two balls colliding), there are two moving bodies with orbit-vectors $\vec{x}_1(t)$ and $\vec{x}_2(t)$, which collide at a time $t = t_0$ where their orbits intersect $\vec{x}_1(t) = \vec{x}_2(t)$ and interact via energy flow. The cause is the state of the two orbits before the collision (moving to each other), the effect is the state of the two orbits after the collision (moving apart). The two states interact by energy flow (or equivalently by the action of a force).

In **quantum collision**, the situation is basically the same, except that the (sharp) orbit $\vec{x}(t)$ becomes the time dependent “fuzzy” wave function $\psi(\vec{x}, t)$.

In **classical absorption** (e.g. light absorption by a body), the energy flow is carried by the incoming wave. The cause is the incoming wave+ body, the effect is the body after absorption (e.g. at increased temperature).

In **quantum absorption**, the process can be interpreted as a collision of a field-quantum (e.g. a photon) and a massive particle: quantum causation is collision-like.

In quantum physics, there are also **spontaneous** processes like radioactive decay or spontaneous light emission. Here, there is no other interacting particle or field-quantum, so these processes are by definition **non-causal**.

Causation in **collective classical dynamical systems** is based on the fundamental collision and absorption processes. In time-evolving dynamical systems like atmospheric ensembles (gases), hydrodynamic ensembles (fluids), solid structures (geological structures like mountains), plasma ensembles (stars), causation consists of a large number of fundamental causal processes.

Causation in **collective quantum dynamical systems** is based on the fundamental interaction processes and spontaneous emission processes. Examples of time-evolving dynamical systems in quantum regime are chemically interacting molecular ensembles and quantum gases (e.g. Fermi electron gas in solids, Fermi neutron gas in stars).

5.2 Arrow of time in classical and quantum regime

In physics. the two classical interactions gravity and electromagnetic, and the color(strong)-interaction are time-symmetric, only the weak interaction is not (CP-violation in weak kaon decay). But the **arrow of time is always present** in statistical phenomena governed by thermodynamics (classical and quantum), because the entropy is non-decreasing (second law of thermodynamics).

In the quantum regime, time is locally reversible on micro-scale because of the fundamental uncertainty relations.

In the classical regime, there is a **spontaneous breaking of time-symmetry** classical in gravitational (and by analogy in classical electrodynamic and in quantum gravitational and quantum electrodynamic) systems [9], so the preferred time direction is taken (the one preferred by CP-violation, i.e. positive). This is an explanation for the observed Boltzmann-effect of **low initial entropy**.

Both classical and quantum **dispersing** dynamical systems are **ergodic** (every state is reached), **entropic** (obey the Second Law), **time-irreversible** (arrow of time).

Breaking of time-symmetry: arrow of time in classical and quantum regime

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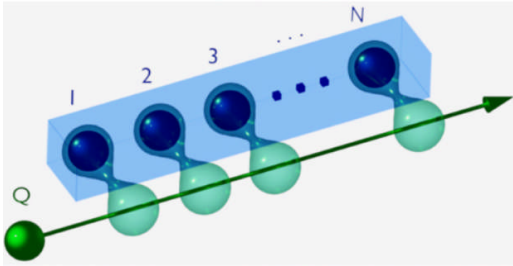
Spontaneous breaking of time-symmetry in quantum and in classical regime

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Emergence of constructor-based irreversibility in quantum systems

Quantum machine [92] works by qubit B moving along qubit-row, interacting into entanglement and out of it. State transformation $B:B1 \rightarrow B2$ is possible, but inverse $B:B2 \rightarrow B1$ has probability $\rightarrow 0$ with $N(\text{qubit}) \rightarrow \infty$.



5.3 Messaging and causation

In physics, causal notions are connected with the **flow of mass-energy**. Every actual process that has causal efficacy can propagate **no faster than light** ($v \leq c$).

The causation by movement is generalized in physics by **messaging** (e.g. using light) and **interaction** (collision in classical, scattering in quantum physics).

The collision with interaction in classical and in quantum physics is reversible: it is time-symmetric.

The messaging with waves (light or sound) in physics obeys the **wave-equation** (hyperbolic partial differential equation (PDE) of second order), solutions of which have a “**domain of dependence**” in the past $t < t_0$, called “light cone” in special relativity. For the other two fundamental types of physical PDE’s: elliptic (potential equation in electrostatics) and parabolic (heat equation) there is no such “domain of dependence”.

That means: the interaction aspect of causation is time-symmetric (cause and effect exchangeable) and the messaging aspect of causation is time-asymmetric (cause and effect non-exchangeable) because of the wave-equation in the Lorentz metric.

5.4 Time and history

Predicting future events and reconstructing past events is typical for research of evolutionary processes (e.g. astrophysics, biological evolution, human history). There is a fundamental asymmetry between past and future:

- the large number of effects that a strong past event (e.g. prehistoric explosion of a volcano) usually creates, leads to a so-called *overdetermination of causes*

- the strong increase of uncertainty in time in prediction of most classical dynamical systems (e.g. numerical weather forecast becomes unreliable for 10 days ahead) leads to *underdetermination of future events*

- typical stability time t_L and characteristic time t_0

The ratio t_L / t_0 is low (100-1000) for chaotic and low-stability systems, and is high ($10^5 - 10^6$) for periodic and high-stability systems:

weather (chaotic): typ. change time $t_0 = 1\text{h}$ weather forecast time $t_L = 10\text{days}$, $t_L = 240t_0$

solar system (periodic): orbit time (Earth) time $t_0 = 1\text{y}$ orbit stability time $t_L = 2\text{My}$, $t_L = 2 \cdot 10^6 t_0$

human DNA (low-stability) : indiv. life expectancy $t_0 = 60\text{y}$ stability $t_L = 40000\text{y}$, $t_L = 470t_0$

mountain (high-stability): typ. change time $t_0 = 1000\text{y}$ life time $t_L = 100\text{My}$, $t_L = 10^5 t_0$

5.5 Indistinguishability and aging

There is a close relationship between indistinguishability and evolution (aging) of physical objects.

Quantum objects of a certain type are described by a few parameters, which are time-independent and *identical for the type* of objects, so that they are *indistinguishable and ageless* (there is no evolution in time). For example, helium nuclei are described by mass, charge, spin, composition (here 2 neutrons and 2 protons). These parameters exactly equal for all helium nuclei and do not change in time, so that these objects are indistinguishable and ageless. However, the location and energy-momentum vectors do change in time, and are in principle measurable, although with an uncertainty (Heisenberg principle), so these objects have an “individual history”. Helium nuclei can also enter an excited state with a higher (discrete) energy, which is also part of their “individual history”.

The non-distinguishability comes in **two forms**:

-bosons have spin $s = n = \text{integer}$, number of particles in one state=arbitrary, statistical average number in one

$$\text{state } N(\varepsilon) = \frac{g(\varepsilon)}{\exp\left(\frac{\varepsilon - \mu}{k_B T}\right) - 1} \quad (\text{Bose-Einstein statistics})$$

-fermions have spin $s = n + 1/2 = \text{half integer}$, maximum number of particles in one state=1, statistical average

$$\text{number in one state } N(\varepsilon) = \frac{g(\varepsilon)}{\exp\left(\frac{\varepsilon - \mu}{k_B T}\right) + 1} \quad (\text{Fermi-Dirac statistics})$$

Classical objects of a certain type are also described by a few parameters, but these are *in a range characteristic for the type*, and change in time: these objects are *distinguishable and they evolve in time*: they age.

For example, stars belonging to the class of Red Dwarves are static classical objects described by mass, radius, brightness, radiation spectrum, density-distribution, equation-of-state, composition, all of which lie within a certain range typical for Red Dwarves. Stars are “individuals within a group” and they evolve in time, this evolution is described by the Hertzsprung-Russell diagram.

5.6 Indistinguishability and entropy

The entropic principle (entropy S is non-decreasing, second fundamental theorem of thermodynamics) is the physical basis of the arrow of time.

Entropy is defined by the Boltzmann formula $S = k_B \log W$ and is computed for a classical gas with N particles with volume V as follows [75].

For each index s , we consider C_s cells in phase-space of volume V bounded by the energies $(\varepsilon_s, \varepsilon_s + \Delta\varepsilon)$ containing N_s particles.

The number of distributions Z_s of N particles over C_s cells is

$$Z_s = C_s^{N_s} \text{ for distinguishable particles}$$

$$Z_s = \frac{(N_s + C_s - 1)!}{N_s! (C_s - 1)!} = \binom{N_s + C_s - 1}{C_s - 1} \text{ for non-distinguishable particles.}$$

The total number of states is then

$$W = \frac{N!}{\prod_s N_s!} \prod_s Z_s V^{N_s}$$

and for distinguishable particles with the Stirling approximation $N! \approx (N + 1/2) \log N - N$ we get for the entropy

$$S_d \approx k_B N \log N + k_B \sum_s N_s \log \frac{C_s}{N_s} + k_B N \log V \quad \text{where } N = \sum_s N_s$$

for non-distinguishable particles we get the entropy

$$S_{nd} \approx k_B \sum_s N_s \log \frac{C_s}{N_s} + k_B N \log V$$

Now entropy S must be extensive in N and V : $S(\lambda N, \lambda V) = \lambda S(N, V)$

and only S_{nd} has this property (using S_d instead causes the so-called Gibbs paradox).

The entropic principle demands that identical objects in a classical or quantum statistical ensemble must be non-distinguishable.

5.7 Causality and Green's functions

Causality means: events at a time t_0 depend only on data at time $t < t_0$, not on future events.

Now physical processes are described essentially by partial differential equations (pdeq) of order two, in time t and space $\vec{x}$. The solution of such pdeq can be expressed by the integral over the corresponding Green's function $g(x, s)$:

$$u(x) = \int g(x, s) f(s) ds \text{ is a solution of the pdeq } Lu(x) = f(x)$$

For pdeq of order 2, its Fourier transform is a quadratic polynomial, and there are two solutions for its Green's function: retarded $g_{ret}(x, s)$ and advanced $g_{adv}(x, s)$. The retarded solution integrates over passed time, the advanced solution integrates over future time. So only $g_{ret}(x, s)$ respects causality, the other solution is discarded as "unphysical".

The same applies to homogeneous pdeq's with inhomogeneous boundary conditions

$$Lu(x) = 0 \quad u(x, t)|_{t=t_0} = f_1(x) \quad \left. \frac{\partial u(x, t)}{\partial t} \right|_{t=t_0} = f_2(x)$$

Harmonic oscillator

The differential equation for the one-dimensional harmonic oscillator is [75]

$$\ddot{x}(t) + \omega_0^2 x(t) = f(t)$$

with the Fourier transformed Green's function

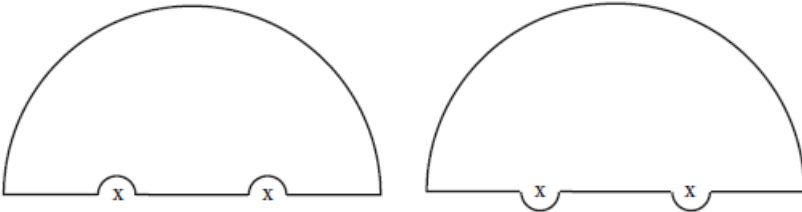
$$\hat{g}(\omega) = \frac{1}{\sqrt{2\pi}} \cdot \frac{1}{\omega_0^2 - \omega^2}$$

the two Green's function in t are

$$g_{ret}(t) = \begin{cases} 0 & t < 0 \\ \frac{1}{\omega_0} \sin \omega_0 t & t > 0 \end{cases} \quad g_{adv}(t) = \begin{cases} -\frac{1}{\omega_0} \sin \omega_0 t & t < 0 \\ 0 & t > 0 \end{cases}$$

here $g_{ret}(x, s) = g_{ret}(t, \omega_0)$

depending on the contours taken around the poles in the complex plane



If we add damping to the harmonic oscillator, we get

$$\ddot{x}(t) + \gamma \dot{x}(t) + \omega_0^2 x(t) = f(t)$$

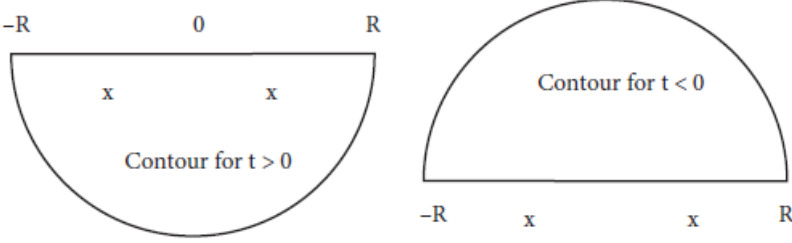
with the Fourier transformed Green's function

$$\hat{g}(\omega) = \frac{1}{\sqrt{2\pi}} \cdot \frac{1}{(\omega_0^2 - \omega^2) - \gamma \omega i}$$

The Green's function becomes

$$g(t) = \frac{1}{2\pi} \int_{-\infty}^{\infty} \frac{e^{-i\omega t}}{(\omega_0^2 - \omega^2) - \gamma \omega i} d\omega$$

and now, there is only the retarded g_{ret} , because the poles are now under the real axis and the upper contour integral is zero



Maxwell equations

Starting with the Maxwell equations

$$\square \varphi = \frac{\rho}{\varepsilon_0} \quad \square \vec{A} = \mu_0 \vec{J} \quad \text{in the Lorentz gauge } \partial_\mu A^\mu = 0$$

we get the retarded potentials

$$\varphi(\vec{r}, t) = \frac{1}{4\pi\varepsilon_0} \int \frac{\rho(\vec{r}', t')}{|\vec{r} - \vec{r}'|} d^3r' \quad \text{and} \quad \vec{A}(\vec{r}, t) = \frac{\mu_0}{4\pi} \int \frac{\vec{J}(\vec{r}', t')}{|\vec{r} - \vec{r}'|} d^3r' \quad \text{with} \quad t' = t - \frac{|\vec{r} - \vec{r}'|}{c}$$

and the advanced potentials with $t' = t + \frac{|\vec{r} - \vec{r}'|}{c}$

The advanced potentials are discarded as causality-violating.

Wave equation

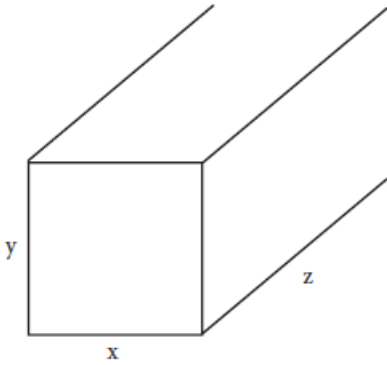
The wave equation is one of the most important equations in physics. It describes the behavior of waves (and messaging), and is therefore the decisive criterion for causality in physics.

The wave equation reads [75]

$$\nabla^2 \psi - \frac{1}{c^2} \frac{\partial^2 \psi}{\partial t^2} = 0$$

with the boundary conditions in time $\psi(x, t_0) = \psi_1(x) \quad \frac{\partial \psi(x, t_0)}{\partial t} = \psi_2(x)$

In a bounded waveguide $0 < x < x_1 \quad 0 < y < y_1$



we get the solution with modes (m, n)

$$\psi(x, t) = A e^{i[\sqrt{\omega^2 - (\frac{m\pi}{x_1})^2 - (\frac{n\pi}{y_1})^2} z + \omega t]} + B e^{-i[\sqrt{\omega^2 - (\frac{m\pi}{x_1})^2 - (\frac{n\pi}{y_1})^2} z - \omega t]},$$

where the first summand is the incoming wave, which is unphysical and has to be discarded.

So here again, we have the retarded solution with $g_{ret}(x, s)$ and advanced solution with $g_{adv}(x, s)$, and the latter is discarded because of causality.

In the case of a lossy wave equation [80]

$$\nabla^2 \psi - \frac{1}{c^2} \frac{\partial^2 \psi}{\partial t^2} - \frac{\mu}{c} \frac{\partial \psi}{\partial t} = 0$$

we get a retarded solution damped in the direction of propagation with the factor $\exp\left(-\frac{\mu}{2}x\right)$, and the same damping for the advanced solution, which eliminates the advanced solution, because it “explodes” in the future.

Facit:

In general, there is a causal retarded solution, and a causality-violating advanced solution, which is discarded. Dissipation introduces a direction of time, and the solution becomes unique and causal.

Abraham-Lorentz force

The Abraham-Lorentz force in electrodynamics is the recoil force on an accelerating charged point-like particle with mass m and charge q caused by the particle emitting radiation.

It is given in SI units as [75]

$$\mathbf{F}_{\text{rad}} = \frac{\mu_0 q^2}{6\pi c} \dot{\mathbf{a}} = \frac{q^2}{6\pi\epsilon_0 c^3} \dot{\mathbf{a}} = \frac{2}{3} \frac{q^2}{4\pi\epsilon_0 c^3} \dot{\mathbf{a}}$$

where F_{rad} is the force, $\dot{\mathbf{a}}$ is the derivative of acceleration.

Its relativistic form is the Abraham-Lorentz-Dirac force

$$F_{\mu}^{\text{rad}} = \frac{\mu_0 q^2}{6\pi m c} \left[\frac{d^2 p_{\mu}}{d\tau^2} - \frac{p_{\mu}}{m^2 c^2} \left(\frac{dp_{\nu}}{d\tau} \frac{dp^{\nu}}{d\tau} \right) \right]$$

For a particle in an external force F_{ext} , we have

$$m\dot{\mathbf{v}} = \mathbf{F}_{\text{rad}} + \mathbf{F}_{\text{ext}} = m t_0 \ddot{\mathbf{v}} + \mathbf{F}_{\text{ext}}, \text{ where } t_0 = \frac{\mu_0 q^2}{6\pi m c}, \text{ for the electron } t_0 = 0.93 \times 10^{-24} \text{ s} = \frac{r_e}{c} \text{ with}$$

$r_e = 2.8 \times 10^{-15} \text{ m}$ = classical electron radius, or integrated

$$m\dot{\mathbf{v}} = \frac{1}{t_0} \int_t^{\infty} \exp\left(-\frac{t' - t}{t_0}\right) \mathbf{F}_{\text{ext}}(t') dt'.$$

Here the acceleration depends on the value of F_{ext} from a time interval approximately t_0 into the future, it violates causality. If we choose the electron to have the finite radius r_e , the causality is restored, and the Abraham-Lorentz force is modified accordingly.

Facit:

Point-like particles violate causality, causality is restored, if we introduce a finite size for them.

5.8 Causality, simultaneity and Kramers-Kronig relations

Cauchy integral formula

For a complex function f analytic in a region D , and a closed continuous curve γ in D , follows

$$f(a) = \frac{1}{2\pi i} \oint_{\gamma} \frac{f(z)}{z - a} dz$$

Cauchy residue theorem:

$$\frac{1}{2\pi i} \oint_{\gamma} f(z) dz = \sum_k \text{Res}(f, a_k)$$

Kramers-Kronig relations

The Kramers-Kronig equations [86] [87] connect the real and imaginary parts of a complex function analytic in the upper half-plane. They are used in physics for the response functions in physical systems.

For stable physical systems, analyticity of the response function in the upper plane is equivalent to the causality of the system.

The Kramers-Kronig formalism is widely used in physics, among others for response functions and for the complex refractive index $\tilde{n} = n + i\kappa$ of a medium.

From the Cauchy integral formula follow the Kramers-Kronig relations.

$$\text{For function } \chi(\omega) = \chi_1(\omega) + i\chi_2(\omega)$$

where $\chi(\omega)$ is analytic in the upper half-plane of ω , then

$$\chi_1(\omega) = \frac{1}{\pi} P \int_{-\infty}^{\infty} \frac{\chi_2(\omega')}{\omega'^2 - \omega^2} d\omega' \quad \chi_2(\omega) = -\frac{1}{\pi} P \int_{-\infty}^{\infty} \frac{\chi_1(\omega')}{\omega'^2 - \omega^2} d\omega'$$

Causality and signal velocity

Causality is not inherently implied in equations of motion, it is introduced as an additional constraint..

This constraint has implications for the response function of a system: the Kramers-Kronig relations and stability of the underlying physical system.

From SR follows that causal efficacy cannot propagate faster than light (which is the information signal velocity).

In QM, massive particles propagate with subluminal velocity, massless particles propagate with light velocity.

In QM, massive particles are described by wave packets, which have group velocity and phase velocity.

The energy of a wave packet propagates with group velocity, which is the particle velocity $v_g = \frac{d\omega}{dk} = v < c$.

The phase of a wave packet travels with phase velocity $v_p = \frac{\omega}{k}$, and this can be locally larger than c (e.g. due to irregularities of the refractive index).

The Kramers–Kronig formalism and response functions.

The response $\chi(t - t')$ must be zero for $t < t'$ since a system cannot respond before it is applied.

Then, by Titchmarsh's theorem, the Fourier transform $\chi(\omega)$ is analytic in the upper half plane, has no poles there, and satisfies the Kramers–Kronig relations, and also $\chi(-\omega) = \chi^*(\omega)$ [87].

A physical system with analytic $\chi(\omega)$ is stable.

From the analyticity of $\chi(\omega)$ follow the simplified Kronig-Kramers relations

$$\chi_1(\omega) = \frac{2}{\pi} P \int_0^{\infty} \frac{\omega' \chi_2(\omega')}{\omega'^2 - \omega^2} d\omega' \quad \chi_2(\omega) = -\frac{2\omega}{\pi} P \int_0^{\infty} \frac{\chi_1(\omega')}{\omega'^2 - \omega^2} d\omega' \quad [87]$$

Simultaneity

Invariance of simultaneity is not absolute in SR, but depends on the observer's reference frame.

$$t' = \frac{t - vx/c^2}{\sqrt{1 - v^2/c^2}} \quad x' = \frac{x - vt}{\sqrt{1 - v^2/c^2}}$$

If two events with equal time t have different values of the x -coordinate, they will have different values of the t' coordinate, so they will happen at different times in that frame. The deviation term is $\frac{v \Delta x}{c^2}$.

In non-relativistic limit, simultaneity is frame-dependent, if the signal velocity is independent of the sender velocity. From the observed frame-invariant simultaneity follows that the maximum signal velocity (=light velocity c) is constant. Constancy of the light velocity is the first Einstein postulate, together with the second postulate (independence of reference frame) follows the Lorentz-invariance, i.e. Special Relativity.

6 Induction in science [JH]

Induction is a method of inference that aims at gaining empirical knowledge by counting observation confirming or contradicting a certain hypothesis (e.g. common flu occurs only in the cold season) [1] ch.9. *Enumerative* induction is based on confirming observations, *eliminative* induction is based on contradicting observations.

Some philosophers, like Hume, rejected induction, because of its lack of certainty.

Proposed position [JH]

Induction is nothing else than a statistical test of a certain hypothesis. In applied test theory, there two common statistical tests:

-test of the probability distribution of a random variable

Here the statistics (probability distribution $P(x, \mu, \sigma)$ with mean μ and stdev σ) of a random variable x is collected and compared to a presumed probability distribution $P_0(x, \mu, \sigma)$ (e.g. the distribution of the IQ measured by standard tests), the test measures the deviation and decides whether the probability of rejection of hypothesis is sufficiently small $P(|P(x, \mu, \sigma) - P_0(x, \mu, \sigma)| > \varepsilon_1) < \varepsilon_2$ for two predefined small thresholds $(\varepsilon_1, \varepsilon_2)$.

-test of truth of an assertion about a random variable

Here the number of occurrences of the true and false results of the assertion $f(x)=x_0$ are counted with parameters in the chosen range, and decided whether the mean logical value of the assertion is sufficiently close to true ($=1$):

$P(|E[f(x)] - x_0| > \varepsilon_1) < \varepsilon_2$ for two predefined small thresholds $(\varepsilon_1, \varepsilon_2)$.

In the case of induction it is the truth of an assertion, which is tested.

The central limit theorem in probability theory **guarantees** that for sufficiently large sample-size $N \rightarrow \infty$ of independent measurements the logical value of the **assertion will be arbitrarily close** to its factual value (i.e. true=1, or false=0).

That means that induction is **certain in the limit** $N \rightarrow \infty$ for the sample-size.

7 Determinism and indeterminism

7.1 Deterministic and prognostic systems [JH] [1] ch.10.2.2

In a *deterministic system*, observation corresponds to an *observation function*, that is, a function $\Phi : M \rightarrow M_0$ where $\Phi(m)$ is the observed value. Because the observation has a finite precision Δm , the number $N(M_0)$ of values (measurement intervals) in M_0 is *finite*. Classical Newtonian (energy preserving) systems are of this kind, e.g. orbit of a planet $r(\varphi)$ = sun distance in dependence of the orbit angle φ : $\Phi(a, e) = r(\varphi)$, where a is the large elliptical half-diameter and e the eccentricity.

A *prognostic indeterministic system* is a stochastic variable vector $Z(\vec{a})$ of a parameter vector $\vec{a}$, which is a prognose of $\vec{a}$ at the time t_i for the next time t_{i+1} . An example is the weather forecast $\vec{a}' = \Phi(\vec{a})$ for day t_{i+1} based on the weather data $\vec{a}_i = (p_i, T_i, u_i, D_u T_i, D_u p_i)$ for day t_i , where p , T , u , $D_u T$, $D_u p$ are pressure, temperature, wind velocity, gradient T in u -direction, gradient p in u -direction. Assuming a finite measurement precision Δ , we have a finite number of values for the parameter vector $\vec{a} : M = \{\vec{a}_i | i = 1, \dots, N\}$

The prognose Φ is an assessment of a random variable parameter vector $Z(\vec{a})$ with transition probabilities $P(\vec{a}_i \rightarrow \vec{a}_j) = P_{ij}$ from state $\vec{a}_i$ to the state $\vec{a}_j$ at the next time point, i.e. the system is a Markov system with states M and probabilities P_{ij} .

The prognose Φ is *observationally equivalent*, if it is with confidence $1-\varepsilon$ for the measurement precision Δ , i.e. if we have $P(|Z(\vec{a}_i) - \Phi(\vec{a}_i)| > \Delta) \leq \varepsilon$ for $i=1 \dots n$, i.e. for a given precision the stochastic values agree with the prognose within confidence of, say $c(2\sigma)=0.95=1-\varepsilon$.

In classical physics, there are purely stochastic systems:

- *Bernoulli systems* representing a sequence of identically distributed random experiments, independent of each other, as for a sequence of coin tosses
- *Markov systems* representing a sequence of identically distributed random experiments, where the next outcome depends only on the previous outcome, i.e. with transition probabilities $P(\vec{a}_i \rightarrow \vec{a}_j) = P_{ij}$

7.2 Regular, chaotic and non-causal classical and quantum systems

In classical physics dynamical systems have point-like trajectories, in quantum physics trajectories are probability densities (wave functions) with a certain width Δx .

Both classical and quantum dynamical systems show two fundamentally different behaviors: regular and chaotic, quantum systems can also be non-causal.

-non-dispersing (regular)

In these systems trajectories are regular (there is a fixed pattern), non-ergodic (only a small part of possible states are reached), non-mixing (trajectories do not come arbitrarily close), time-symmetric.

Examples: regular classical and quantum billiards, simple mechanic systems (pendulum with or without friction), laminar flow in fluids, 2-body gravitational systems

-dispersing (chaotic)

In these systems trajectories are chaotic (no fixed pattern), ergodic (all possible states are reached), mixing (trajectories come arbitrarily close), entropic (entropy is maximized, Second Law of thermodynamics valid), velocity follows a probability distribution, there is time-irreversibility and arrow-of-time.

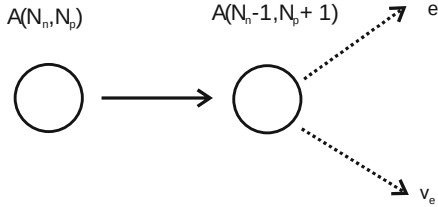
Examples: dispersing classical and quantum billiards, classical ideal gas (Maxwell distribution), quantum Fermi gas (Fermi-Dirac distribution), quantum Bose gas (Bose-Einstein distribution), multi-body gravitational systems with $N > 2$

-non-causal

Spontaneous decay quantum systems like radioactive nuclei are **non-causal**: it is principally impossible to determine when a specific nucleus will decay, and there is no apparent cause of the decay (whereas e.g. in collision processes there is a cause). Radioactive nuclei have an exponential probability distribution and a well-defined mean life-time τ , and decay rate $\lambda = 1/\tau$

$$N(t) = N_0 \exp(-\lambda t)$$

nuclear beta-decay



7.3 Determinism and randomness in classical and quantum mechanics [JH]

Classical mechanics is deterministic and classical observables are sharp (in principle arbitrarily precise numbers).

In quantum mechanics, quantum observables are non-commutative (matrices) and their values are random variables with a non-zero width (standard deviation). A quantum orbit (location in time) is $\rho = |\psi|^2$, a probability density, where $|\psi|^2$ is the wavefunction, the fundamental description of a particle orbit.

In this context, there are several basic notions, which are clarified below.

Notions of determinism and randomness

1 Locality

Locality in physics means that an object (particle) can only be influenced by its immediate surroundings, the influence (interaction) propagates no faster than with speed of light.

2 Hidden variables and randomness

In quantum mechanics, a location measurement causes the probability distribution of a particle described by its wavefunction to randomly collapse to a single position. Based on this, Albert Einstein argued in the famous EPR paper in 1935, that quantum mechanics must be incomplete, and inherently deterministic, by introducing deterministic “hidden variables”, which determine the outcome of a measurement.

3 Instantaneous action-at-a-distance

In quantum mechanics, with two entangled particles (e.g. two entangled electrons with total spin zero) there is the possibility of a measuring particle P1 (e.g. $S_z(P1)=+1/2$) and immediately determining the outcome of measurement of P2 ($S_z(P2)=-1/2$). This is described as “instantaneous action-at-a-distance”, which apparently contradicts the principle of locality. There seems to be a flow of information, which is instantaneous.

But this is an imprecise interpretation of statistics: $S_z(P1)$ and $S_z(P2)$ are dependent random variables, which satisfy the relation $S_z(P1)+S_z(P2)=0$, there is no additional increase of information from $S_z(P2)$ after the measurement of $S_z(P1)$.

4 Classical apparent action-at-a-distance

A classical gedanken-experiment, which illustrates the apparent action-at-a-distance, is the following.

Alice and Bob carry out measurements by tossing a cubic dice on a glass plate. A measurement consists of reading the upper and lower face of the dice, the sum of the face numbers is always 7. Alice reads the top face looking from above, Bob reads the bottom face looking from below. When Alice sees the result 1, she knows immediately that Bob sees the result 6. Surely, no one would speak here of an instantaneous action-at-a-distance, it makes no sense classically.

This makes clear that the instantaneous flow of information is an illusion, also in quantum regime.

7.4 Bell's theorem

Bell's theorem [95] sets up inequalities, which are valid for a quantum measurement and for a measurement with classical hidden variables. It shows that the classical hidden-variables inequality for the averaged sum of observables C_h is violated in quantum regime.

The conclusion is that **quantum mechanics is inherently random**, and a hidden-variables classical deterministic interpretation is incompatible with measurements.

The reason for the different averages of C_h in the classical and the quantum case, is the **non-commutativity of quantum** observables, which are an exclusive characteristic of quantum mechanics, from which arise the quantum uncertainty (e.g. Heisenberg uncertainty relation $\Delta x \Delta p \geq \hbar / 2$ from the commutation relation

$$[x, p] = i\hbar).$$

Proof [JH]

Alice and Bob carry out measurements in separated locations on a pair of particles: P1 and P2.

Alice measures particle P1, Bob measures particle P2.

Alice chooses randomly to perform one of two possible measurements, A0 and A1, which have possible values +1 or -1 .

In analogy, Bob chooses randomly to perform one of two possible measurements, B0 and B1

First, let us consider the situation for **hidden variables**: a0 for A0, a1 for A1, b0 for B1, b1 for B1.

Consider the combination

$$C_h = a_0 b_0 + a_0 b_1 + a_1 b_0 - a_1 b_1 = (a_0 + a_1) b_0 + (a_0 - a_1) b_1$$

The variables can take on values +1 or -1, so either $a_0 = a_1$ or $a_0 = -a_1$, therefore one of the terms will be zero and the other will be ± 2 .

Using angle brackets to denote averages, we obtain on average

$$|\langle A_0 B_0 \rangle + \langle A_0 B_1 \rangle + \langle A_1 B_0 \rangle - \langle A_1 B_1 \rangle| \leq 2$$

Now, consider the situation for a quantum measurement.

The particles are in the entangled state with particle wavefunctions p_1, p_2

$$\psi = \frac{(p_1, p_2) - (p_2, p_1)}{\sqrt{2}} = \frac{(p_1 - p_2, p_2 - p_1)}{\sqrt{2}} = \frac{(\Delta p, -\Delta p)}{\sqrt{2}}, \Delta p = p_1 - p_2$$

where p_1 and p_2 are the eigenstates of Pauli matrix σ_z

ψ is normalized: $|\psi|^2 = \langle \psi | \psi \rangle$, therefore $|\Delta p|^2 = 1$

The Pauli matrices are

$$\sigma_1 = \sigma_x = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} \quad \sigma_2 = \sigma_y = \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix} \quad \sigma_3 = \sigma_z = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}$$

The Pauli matrices have the properties

$$[\sigma_j, \sigma_k] = 2i\epsilon_{jkl}\sigma_l$$

The observables are

$$A_0 = \sigma_z \quad A_1 = \sigma_x$$

$$B_0 = -\frac{\sigma_x + \sigma_z}{\sqrt{2}} \quad B_1 = \frac{\sigma_x - \sigma_z}{\sqrt{2}}$$

$$A_0 B_0 = -\frac{(i\sigma_y + 1)}{\sqrt{2}} \quad A_0 B_1 = \frac{(i\sigma_y - 1)}{\sqrt{2}} \quad A_1 B_0 = \frac{(i\sigma_y - 1)}{\sqrt{2}} \quad A_1 B_1 = \frac{(-i\sigma_y + 1)}{\sqrt{2}}$$

We calculate the expectation values

$$\langle A_0 B_0 \rangle = \langle \psi | A_0 B_0 | \psi \rangle = \frac{1}{\sqrt{2}} (-1 + (\Delta p)^2 - (\Delta p)^2) = -\frac{1}{\sqrt{2}} \quad \langle A_0 B_1 \rangle = \langle \psi | A_0 B_1 | \psi \rangle = -\frac{1}{\sqrt{2}}$$

$$\langle A_0 B_1 \rangle = -\frac{1}{\sqrt{2}} \quad \langle A_1 B_0 \rangle = -\frac{1}{\sqrt{2}} \quad \langle A_1 B_1 \rangle = \frac{1}{\sqrt{2}}$$

and obtain the result

$$C_h = A_0 B_0 + A_0 B_1 + A_1 B_0 - A_1 B_1 = \frac{1}{\sqrt{2}} (-4 + 2i\sigma_y)$$

$$\langle \psi | C_h | \psi \rangle = \frac{1}{\sqrt{2}} \langle (\Delta p, -\Delta p) | (-4 + 2i\sigma_y) | (\Delta p, -\Delta p) \rangle = \sqrt{2} (-2 - (\Delta p)^2 + (\Delta p)^2) = -2\sqrt{2}$$

$$|\langle \psi | C_h | \psi \rangle| = |\langle A_0 B_0 \rangle + \langle A_0 B_1 \rangle + \langle A_1 B_0 \rangle - \langle A_1 B_1 \rangle| = 2\sqrt{2},$$

which violates the classical inequality with hidden variables.

7.5 Dispersing and non-dispersing classical systems

In classical physics, transition in time from one state to another is mostly described by differential equations [1]

ch.10.3.1. For differential equations, a condition for existence and uniqueness of solutions is *local Lipschitz*

continuity. Intuitively speaking, a local Lipschitz continuous function is limited in how fast it can change. More formally: a function $F(r)$ is *locally Lipschitz* continuous when, for every initial state x in the domain, there is a neighbourhood U of x such that for the restriction of F to U it holds that for all r, s in U :

$$|F(r) - F(s)| \leq K|r - s|.$$

The Picard-Lindelöf theorem states that if the force F is locally Lipschitz continuous on its domain, then there is a unique maximally extended solution to the equation of motion (cf. Arnold 1992), i.e. such a system is *non-dispersing* : two neighboring trajectories do not diverge, the system is deterministic.

A *dispersing* classical system is one, in which two neighboring trajectories diverge exponentially.

Classical billiards with a convex table boundary are dispersing [24]: a small difference in initial conditions (bowl position and velocity) between two trajectories $\vec{x}_1, \vec{x}_2$ results in change in trajectory, which *grows exponentially* with number n of collisions:

$$\|\vec{x}_1(t_n) - \vec{x}_2(t_n)\| \geq c_1 \text{Exp}\left(n c_2 \|\vec{x}_1(0) - \vec{x}_2(0)\|\right)$$

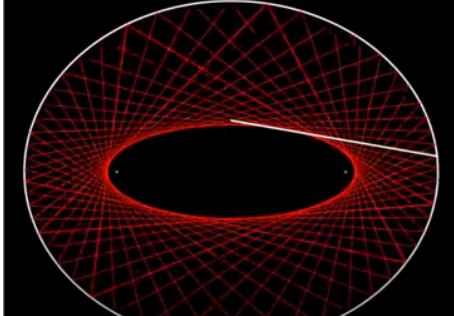
Such a system becomes unpredictable (deviation in trajectory becomes larger than the table) after a number $n_0(\vec{\Delta x})$ of collisions, no matter how small the initial change in trajectory $\vec{\Delta x}$ is, i.e. it is a random classical system.

It has been shown that convex billiards [53]

- are ergodic: all possible states of the system will be reached over time
- are mixing: different trajectories come arbitrarily close to each other over time
- have an increasing Kolmogorov entropy: the Second Law of Thermodynamics is satisfied
- have an exponential decay of correlations: two trajectories of the system become statistically independent over time

This can be generalized to the statement that dispersing classical systems *obey all rules of classical thermodynamics*.

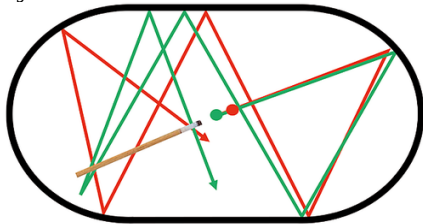
Elliptic billiards are regular [54]



Elliptic billiard with initial condition

Stadium billiard

An example of a dispersing system is the *Bunimovich stadium billiard*, which is a well-known random classical system.

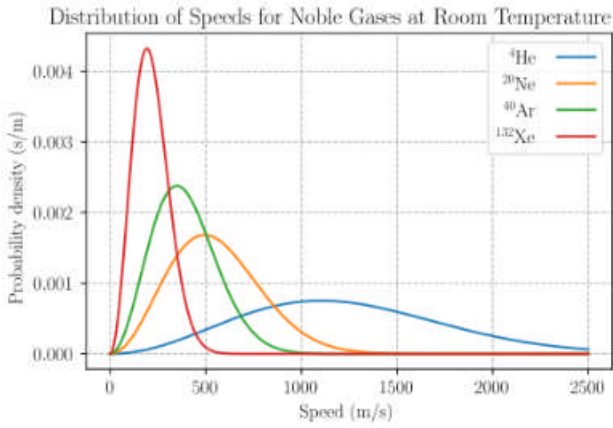


Ideal gas

Another well-known example is the hard-sphere model of ideal gas with Maxwell distribution in the classical kinetic gas theory.

Ideal gas Maxwell probability density of velocity v

$$f(v) = \left(\frac{m}{2\pi kT} \right)^{3/2} \exp\left(-\frac{mv^2}{2kT} \right)$$



[83]

7.6 Dispersing and non-dispersing quantum systems

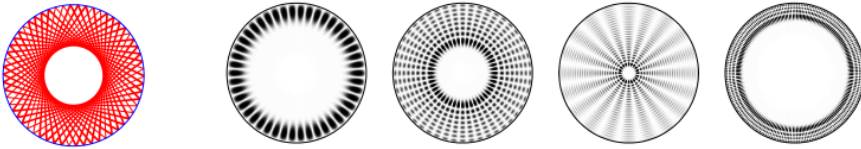
Quantum billiards

In quantum billiards dynamical systems trajectories correspond to wave function solutions of the Schrödinger equation [54]:

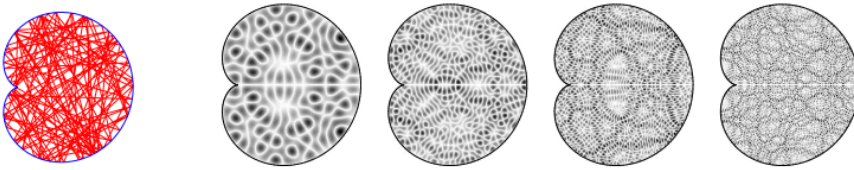
$$-\Delta\psi_n(\mathbf{q}) = E_n\psi_n(\mathbf{q}) \quad , \quad \mathbf{q} \in \Omega \quad \text{with zero boundary conditions } \psi_n(\mathbf{q}) = 0 \text{ for } \mathbf{q} \in \partial\Omega.$$

Quantum and classical billiard show analogous regular and chaotic behavior for circular and cardioid billiard

Regular billiard



Chaotic billiard



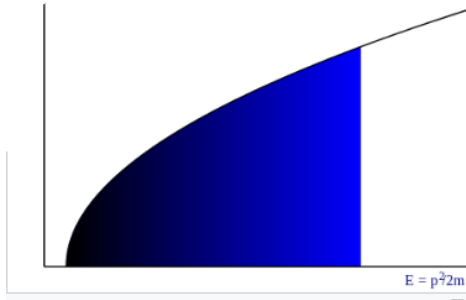
So quantum dynamical systems, like the classical ones, show dispersing (chaotic) and non-dispersing (regular) behavior.

Fermi gas [83]

The Fermi gas a dispersing ergodic quantum system. It has the state density $g(E) = \frac{2}{\hbar\pi} \sqrt{\frac{m}{2E}}$,

the occupation limit Fermi energy $E_F = \frac{\hbar^2}{2m} \left(\frac{3\pi^2 N}{V} \right)^{2/3}$

and the equation-of-state $P = \frac{(3\pi^2)^{2/3} \hbar^2}{5m} \left(\frac{N}{V} \right)^{5/3}$



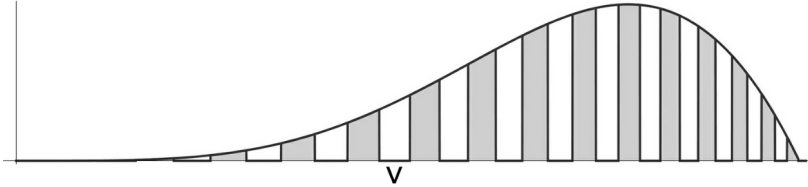
State density in Fermi gas

Random classical system: wheel-of-fortune

Random results can arise from a series of deterministic values under certain conditions [1] ch.10.4.1.

Consider a simple wheel of fortune painted with equal-sized white and grey sections. The wheel is spun with a certain initial velocity, and when it comes to rest a fixed pointer indicates the outcome (white or grey). It is clear from everyday experience that the probability of white and grey are $p_1=p_2=1/2$: the wheel is a simple Bernoulli system, although it is governed by deterministic equations.

Why is it so? The outcome (grey or white) depends on the initial velocity v , which varies randomly within a certain interval:



It is immediately clear, that the outcome is stochastic with the above equal probabilities, if two conditions are satisfied:

-the number of areas N within the variation interval of v is large $N \gg 1$

-the area of consecutive areas Δ_{1i} (white) and Δ_{2i} (grey) is nearly equal $|\Delta_{1i} - \Delta_{2i}| / \Delta_{1i} \leq \delta \leq \frac{1}{N}$

We can calculate the difference of the two probabilities where $\Delta_i \leq \frac{1}{N}$ and total probability=1

$$\sum_{i=1}^{N/2} (\Delta_{1i} + \Delta_{2i}) = 1:$$

$$|p_1 - p_2| \leq \frac{N}{2} \min(\Delta_{2i} - \Delta_{1i}, i = 1, \dots, N/2) \leq \frac{N}{2} \min(\delta \Delta_{1i}, i = 1, \dots, N/2) \leq \frac{1}{2N}$$

so the difference of the two relative occurrence numbers is equal in the limit $N \rightarrow \infty$, and we get $p_1=p_2=1/2$.

8 Consciousness

8.1 Concepts of brain functionality

Humans, like all biological beings have a *representation of reality*, in order to act appropriately within this reality, i.e. live and survive. This representation is the model of reality in our *inner world*, which is the *functionality of the brain*: information processing working with symbols.

These symbols are representations of

- outer-real entities: abstract-physical (heat, temperature), abstract-mathematical (numbers, geometrical forms), personal-historical (memorized personal events), living beings (humans, animals), general-biological (a tree, a horse), general-physical (a lake, a stone)
- inner-real entities: general emotions (fear, anger), personal emotions (memorized emotions in a specific event), personal sensorial images (a memorized sound, a memorized scene image, a memorized face)

There is no doubt, that the biological brain (and specifically the human brain) is basically a binary (neuron firing=1 or quiet=0) neural network. Based on this, there are currently four main concepts of functionality of the human brain:

-Memory is an inner representation of reality based on a spatial map (E. Moser)

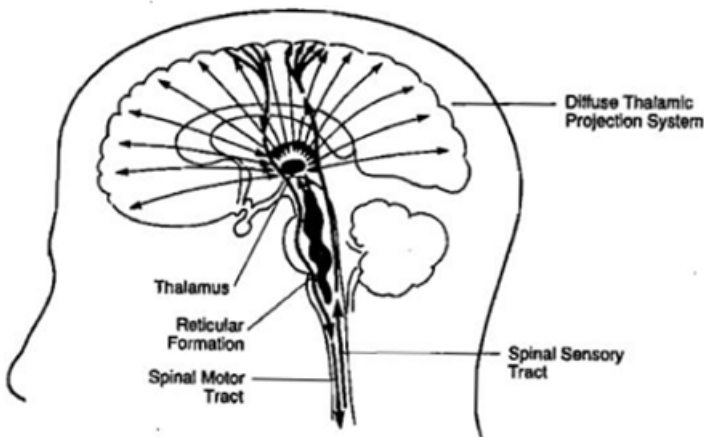
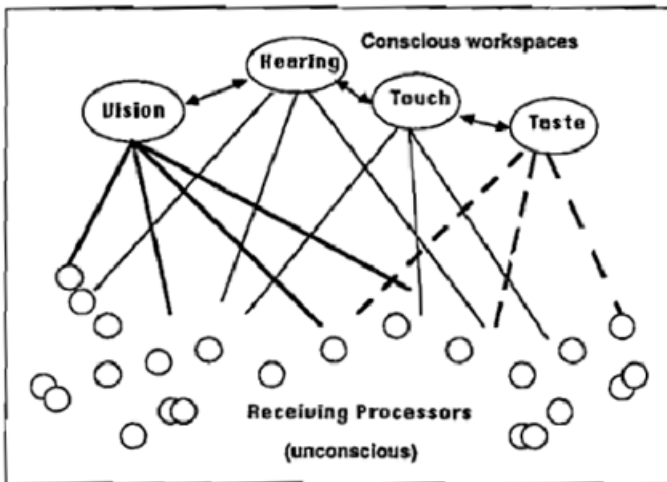
Emerging evidence suggests that the brain encodes abstract knowledge in the same way that it represents positions in space, which hints at a more universal theory of cognition [5] [6].

The underlying principle of general memory is a spatial, temporal and symbolic representation of reality, which includes a representation of the inner world of instincts, emotions, personal history.

-Dynamics consciousness is the Global Workspace (B. Baars [7])

GW is a *mutually inhibiting group of Mental Senses*. The Mind's Eye is the domain of visual imagery (Kosslyn, 1980), and by analogy one may speak of the Mind's Hearing, Touch, or Taste. Each of these defines a domain of conscious experience, which often tends to exclude the others.

The interaction between the agents works via messages with spatio-temporal meaning (i.e. a map, like in the representation concept).



Brain structures most closely associated with conscious experience include the Reticular Formation of the brain stem and midbrain, the outer shell of the thalamus, and the set of neurons projecting upward diffusely from the thalamus to the cerebral cortex. Together these structures can be labeled the "Extended Reticular-Thalamic

Activating System" (ERTAS), since stimulation of a number of neurons throughout this system causes cortical activation.

-Multi-layered personaliy (A. Damasio [4])

In *The Feeling of What Happens*, Damasio laid the foundations of the "enchainment of precedences": "the nonconscious neural signaling of an individual organism begets the protoself which permits core self and core consciousness, which allow for an autobiographical self, which permits extended consciousness. At the end of the chain, extended consciousness permits conscience.

Protoself, located in the brain stem, is an integrated collection of neuron network patterns, which map the inner structure of organism: physical, hormonal, basic-emotional.

Core-self, located in the frontal and parietal cortex, and the learned and remembered patterns of interaction between proto-self and an internal or external object, it functions as an active agent, which controls the focus of "attention".

Autobiographical self, located in the cingulate cortex, thalamus and claustrum, controls the personal event, verbal, pictorial and emotion memory and interacts via memories with the proto-self and the core-self.

High-level consciousness is located in the frontal cortex (especially mPFC, responsible for symbolic concept management and planning) and the language Broca and Wernicke areas. It encompasses: language skills, strong sense of both past and future, strong sense of autobiographical self and memory, conscience, creativity.

-Functionality via feedback-loops (M. Kaku [3])

The personality agents and the GW-agents act via feedback-loop to inputs.

The agents react to input by symbolic messages and actions (e.g. pattern recognition, memory recall,...). The agents's output is goal-oriented and is carried-out according to learned and innate rules. The effect of the output is evaluated and checked against the goals, and weighted accordingly (feedback-loop).

Proposed synthetic concept

Research in neurology and experimental psychology supports the *inner representation* as the model of general memory, the *Global Workspace* as the model of the dynamic conscious process, and the *three-level-personality* as the structure of personality. The 3 models describe areas of functionality and do not contradict each other, so it is natural to establish a *synthesis of the 3 models* as the valid description of the brain's functionality.

8.2 Multi-layered personality [JH] [4]

The evolution stages based on multi-layered personality are as follows:

Name of Layer	Inner Representation	Typical Life Form
Higher Extended and Objective Consciousness	representation of physical-biological environment and inner states, perception of self as an actor, communication audio in symbolic language, symbolic representation of non-real entities: phantasy (lion-man), prognosis (tomorrow the weather will be sunny), a fictitious story (we chased antelopes)	Modern Humans
Extended Consciousness	representation of physical-biological environment and inner states, perception of self as an actor, communication with others in non-symbolic language reflecting reality (there is a lion by the river) or inner states (I am hungry), communication in audio or gestures	Neanderthals
Limited Consciousness	representation of physical-biological environment and inner states, perception of self as an actor, fully learning	Chimpanzees, Dolphins (Mirror Test)
Core Consciousness	rough representation of physical-biological environment based on sensory input and fixed algorithms, restricted learning (Pavlov-type)	Higher Mammals

Damasios mind structure [JH] , [4:8] , [4:9]

Protoself body ↔ protoself

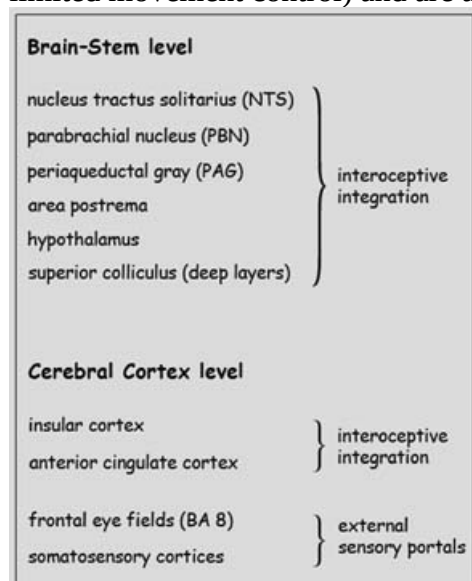
Protoself maps sensory signals (visual, auditory, olfactory, tactile) from the body and *motoric and chemo-static* (hormones) control signals to the body. Protoself forms *primordial feelings* (primary emotions) as *mental images* and communicates them to the core-self.

Protoself is located in

hypothalamus: control homeostasis by hormones

mid-brain: processing of raw sensory data visual, auditory, whole-body chemo-sensoric and tactile information

Hydranencephalic (deprived of cortex) individuals have normally functioning bodies and sensors (except a limited movement control) and are able of all primary emotions [4:3].



The main components of the protoself [4:8.5]

Core-self protoself ↔ core-self

Core-self emerges as procedures (dispositions) establishing relationships between the *protoself* and any map that represents an *object-to-be-known*. The relation between protoself and object is a narrative sequence of images, some of which are feelings.

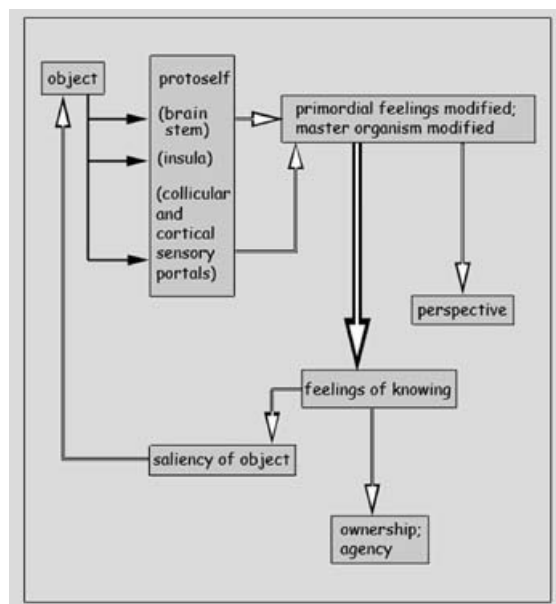
Core-self (core consciousness) maps

primary emotions from protoself as *emotional mental images*

external objects, humans, animals, as *individual mental images*

Core-self has short-term and long-term memory

Core-self is located in superior colliculus (control of behavior toward objects), thalamus (control of awareness), cingulate cortex (emotion formation and processing) [40]



Schematic of core self mechanisms [4:8.7]

Autobiographical self core-self ↔ autobiographical self

Autobiographical self (extended consciousness) [41] emerges as dispositions linking objects in ones' biography with dispositions of core-self into a coherent pattern.

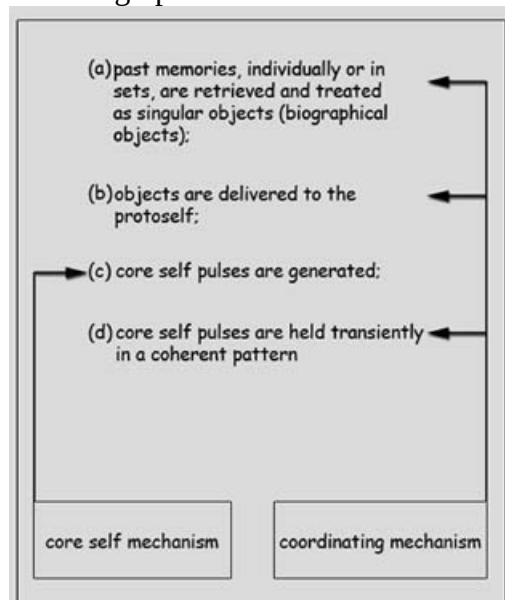
Autobiographical self *enables recognition of oneself* as a person, it passes the mirror-test.

Human children show self-recognition in the mirror test when aged 18 months, chimpanzees and gorillas as adults.

Language capability and sense of personal history are limited, roughly at the level of great apes [32,33] limited language: sign language up to 1000 words, max. 3 words per sentence, no higher abstraction (no generalization).

limited sense of autobiographical history, limited sense of both past and future

Autobiographical self controls the visual, spatial. auditory, cortex



High-level consciousness autobiographical self ↔ high-level consciousness

High-level consciousness has the full capability of the human mind, it encompasses:

possession of complex language skills (recursive sentences, arbitrary abstraction levels), strong sense of both past and future, strong sense of autobiographical self and memory, conscience (personal and social ethics, a precondition for socio-cultural homeostasis), substantial artistic and scientific creativity: the basis for the evolution of memes and techs, i.e. cultural and techno-scientific evolution [34]

High-level consciousness is located in the frontal cortex (especially mPFC, responsible for symbolic concept management and planning) and the language Broca and Wernicke areas.

Consciousness coordination and PMC

The 12 CDR regions are competing for conscious focus, the (left and right) posteromedial cortices (PMC) are the coordinators of conscious focus [4:9.5].

PMC's activity varies in the different brain states:

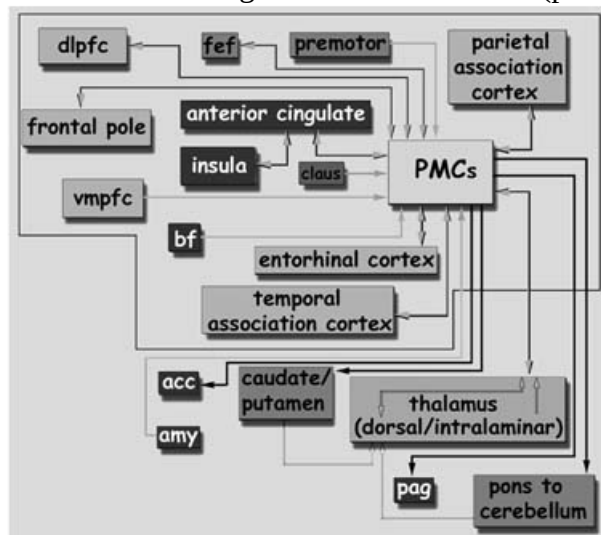
- active in some attention states (salience, executive control), non-active in sensory attention and in dorsal attention state
- increased in DMN mode
- low in REM-sleep (with dreams)
- non-active in slow-wave-sleep (non-REM, dreamless)
- non-active in somnambulant sleep (here cingulate cortex is active [46])
- active in unconscious wakefulness during epileptic absence
- non-active in anesthetized state

PMC, DMN and attention modes

The main DMN network consisting of medial prefrontal cortex, PMC and the angular gyrus, controls self-referenced brain activities: autobiographical memory, anticipation of future, daydreaming, moral judgment. In this mode, PMC shows normal or increased activity.

In focus-attention modes (visual, auditory, executive) PMC shows normal activity.

The DMN activities are non-verbal and self-referenced, therefore they can be attributed to the autobiographical self (presumably left PMC). The focus-attention modes are in general verbal and symbolic, so they can be attributed to the high-level consciousness (presumably right PMC).



The pattern of neural connections to and from the posteromedial cortices (PMCs), as determined in a study conducted in the monkey. Abbreviations: dlPFC = dorsolateral prefrontal cortex; fef = frontal eye fields; vmpfc = ventromedial prefrontal cortex; bf = basal forebrain; claus = claustrum; acc = nucleus accumbens; amy = amygdala; pag = periaqueductal gray [4: 9.5].

The three locations of consciousness [4:10.2]

-Brain stem

The brain stem (PAG) is the primal part of protoself, which controls wakefulness

-Thalamus

The thalamus is essential for wakefulness, bridges brain stem to cortex, and brings in the inputs with which cortical maps can be assembled. The thalamus is the non-cortical part of core-self.

-Cortex

The insular and somatosensory cortex is the cortical part of protoself.

The cingulate cortex (emotion formation and processing, connection with maps) is the cortical part of core-self.

The PMC is the coordinator of consciousness, the left PMC is the center of autobiographical self and the right PMC is the center of high-level consciousness.

Qualia and maps [4:10.6]

Qualia I are sensory maps (visual images, music and sounds) and corresponding emotions.

Qualia II are neural and physical event maps (sequences of events, sequences of movements, personal and non-personal stories) with corresponding emotions.

Studying the mind [JH, 4:1]

Knowledge about the mind can be gained by self-inspection, studying human behavior, physical brain examination, study of mind in animals and human children

-Self-inspection

Self-inspection is to observe one's own mind functionality as recorded by Autobiographical self. Here one has to take into account the filtering by the higher-level mind instances in order to assess the functionality on the protoself and the core-self level.

-Studying human behavior

Studying human behavior, means to apply our innate capability of "emulating" behavior of others in ourselves, commonly known as "human insight". In this category falls also the study of mind functionality after brain lesions.

-Physical brain examination

Physical brain examination uses the modern physical measurement techniques applied to the brain: imaging of brain in action (MRT, PET, EEG, magneto-encephalography), direct electrical neuron stimulation and reading.

-Study of mind functionality in animals and human children

Here are to mention the remarkable research results with primate language learning [32, 33], also in comparison with human children [33].

8.3 Maps as reality representations [JH] [52] [4]

Biological value and homeostasis [4:2]

Biological value is a measure of well-being of an animal/human. It evaluates the deviation of life-parameters from the optimal range (physical parameters like temperature, pressure, concentrations of body liquids, hormone levels, concentration of metabolic reactants) and achievement of goals (sexual reproduction, food supply, security) .

An animal/human is rewarded or punished accordingly by special hormones and feels pleasure or pain.

Preconditions for measuring biological value is interoception (cognition of inner state parameters via hormones and neurotransmitters) and exteroception (sensory cognition).

Measuring homeostasis functions by

- cognition of current inner state
- (pre-defined) knowledge of desirable state
- comparison of the two

Unconscious regulation of homeostasis works via automatic chemical feedback loops .

Conscious regulation of homeostasis works via goal mechanism guided by instincts.

Regulation of social homeostasis is achieved on a basic levels via emotions, on an advanced level via moral, behavioral rules, and justice.

Maps as representations [4:3]

Maps are representations of internal states and external objects and events made by the brain.

Raw sensory data are stored in dedicated regions of the mid-brain: visual images in *superior colliculus*, auditory images in *inferior colliculus*, whole-body pain/satiety information in *parabrachial nucleus*, whole-body chemo-sensor and tactile information in *nucleus tractus*, corresponding *primary feelings* are processed in *periaqueductal gray (PAG)*. The PAG also controls some primary behavior patterns (defensive, copulatory, maternal).

The deep superior colliculus combines visual, auditory and whole-body sensory information into a *primitive map*, which can guide *automatic half-conscious behavior* via PAG .

High-level processing takes place in the cortex: visual resp. auditory images are processed in the *visual cortex* resp. *auditory cortex*, primary feelings are processed in the right and left *insular cortex* and somatosensory cortex.

Recalling objects of a map proceeds via synchronously firing brain regions (40Hz range) , and uses recursive processing.

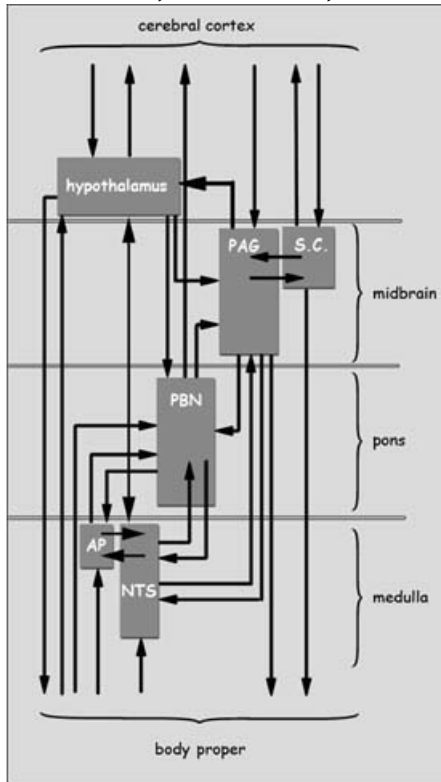
Varieties of Maps (images)	Source Objects
I maps of the organism's internal structure and state (interoceptive maps)	the functional condition of body tissues such as the degree of contraction / distension of smooth musculature; parameters of internal milieu state
II maps of other aspects of the organism (proprioceptive maps)	images of specific body components such as joints, striated musculature, some viscera
III maps of the world external to the organism (exteroceptive maps)	any object or event that engages a sensory probe such as the retina, the cochlea, or the mechanoreceptors of the skin

Varieties of maps (images) and their source objects. When maps are experienced, they become images. A normal mind includes images of all three varieties described above. Images of an organism's *internal state* constitute *primordial feelings*. Images of other aspects of the organism combined with those of the internal state constitute specific body feelings. Feelings of emotions are variations on complex body feelings caused by and referred to a specific object. Images of the external world are normally accompanied by images of varieties of I and II. Feelings are a variety of image, made special by their unique relation to the body. Feelings are spontaneously felt images. All other images are felt because they are accompanied by the particular images we call feelings.

Body-to-mind mapping [4:4]

The sensory information from the body: skeleto-muscular and visceral-muscular sensors, smell and taste mucosae, the tactile elements of the skin, the ears, the eyes and the chemo-sensory information, are pre-processed in mid-brain and stored in the cortex. The cortex *generates conscious (secondary) feelings* (sensory body images), but it can also *simulate* body states.

The brain-to-body signals are motoric (skeleto-muscular and visceral-muscular) and chemical (via hormones, like cortisol, testosterone, and estrogen).



Schematics of key brain-stem nuclei involved in life regulation (homeostasis). Three brain-stem levels are marked in descending order (midbrain, pons, and medulla); the hypothalamus (which is a functional component of the brain stem even if it is, anatomically, a part of the diencephalon) is also included. Signaling to and from the body proper and to and from the cerebral cortex is indicated by vertical arrows. Only the basic interconnections are depicted, and only the main nuclei involved in homeostasis are included. The classic reticular nuclei are not included, nor are the monoaminergic and cholinergic nuclei.

The involved structures such as the NTS (nucleus tractus solitarius) and PBN (parabrachial nucleus) do transmit signals, from body to brain but not passively. These nuclei, whose topographic organization is a precursor of that of the cerebral cortex, respond to body signals, thereby regulating metabolism and guarding the integrity of body tissues. Moreover, their rich, recursive interactions (signified by mutual arrows) suggest that in the process of regulating life, new patterns of signals can be created. The PAG (periaqueductal gray), a generator of complex chemical and motor responses aimed at the body (such as the responses involved in reacting to pain and in the emotions), is also recursively connected to the PBN and the NTS. The PAG is a pivotal link in the body-to-brain resonant loop. The deep superior colliculus (SC) combines visual, auditory and whole-body sensory information, which can guide automatic half-conscious behavior via PAG. The area postrema (AP), is a paired structure in the medulla oblongata of the brainstem, is a circumventricular organ having permeable capillaries and sensory neurons that enable its dual role to detect circulating chemical messengers in the blood and transduce them into neural signals and networks.

In the process of regulating life the networks formed by these nuclei also give rise to composite neural states. The word feelings describes the mental aspect of those states [4:4].

The brain *simulates* body states via the so-called *as-if-body-loop*, which is realized via mirror-neurons. In this way, the brain performs the simulation in the brain's body maps, of a body state that is not actually taking place in the organism.

Emotions and feelings [4:5]

Emotions are complex, largely automated programs of actions. The actions are complemented by a cognitive program that includes certain ideas and modes of cognition, but the world of emotions is largely one of actions carried out in our bodies, from facial expressions and postures to changes in viscera and internal milieu. Feelings of emotion, are composite perceptions of what happens in our body and mind, the world of feelings is one of perceptions executed in brain maps.

Emotions are triggered by images of objects or events that are actually happening.

There are three ways of generating an emotion

- perception of a change of body state caused by the emotion
- perception of the corresponding as-if-body-loop, i.e. the simulation of the emotion
- feeling an altered transmission of body signals to the brain, e.g. by alcohol

The time interval between the stimulus of an emotion and its feeling is about 0.5s, according to magneto-encephalography measurement by Rudrauf.

The primary, evolutionary old emotions are fear, anger, desire, sadness, pain, pleasure, love, disgust, joy.

The secondary socially motivated emotions are compassion, embarrassment, shame, guilt, contempt, jealousy, envy, pride, admiration.

Memory architecture [4:6]

Mental maps are stored as configuration (synaptic weights) of brain neural networks (map memory), and recalled by dispositions (action recipes) .

Memory of an object/event is a composite of sensory, motoric and mental activities:

- audio-visual image (shape, movement, color, sound)
- sensorimotor pattern (e.g. eye movement)
- tactile pattern
- previous patterns pertinent to the object
- pattern of triggering emotions and feelings

The evolutionary predecessor of this map memory is the disposition memory. A disposition is an action recipe invoked by a direct external effect (like a direct hit on the body causing the action “move in opposite direction for a fixed time”). The disposition memory in humans and higher animals is used to manage basic life functions: the endocrine system, reward/punishment, triggering and execution of emotions.

Memories are distributed, a damage to the anterior brain regions compromises the specificity of a memory, but not of its general contents, e.g. a patient with anterior brain damage may describe a birthday party in detail, and yet he may forget that it was his birthday party.

There is a degree of complexity corresponding to a memory: unique-personal entities and events are the most complex, then come the less complex unique-nonpersonal, then nonunique-nonpersonal ones.

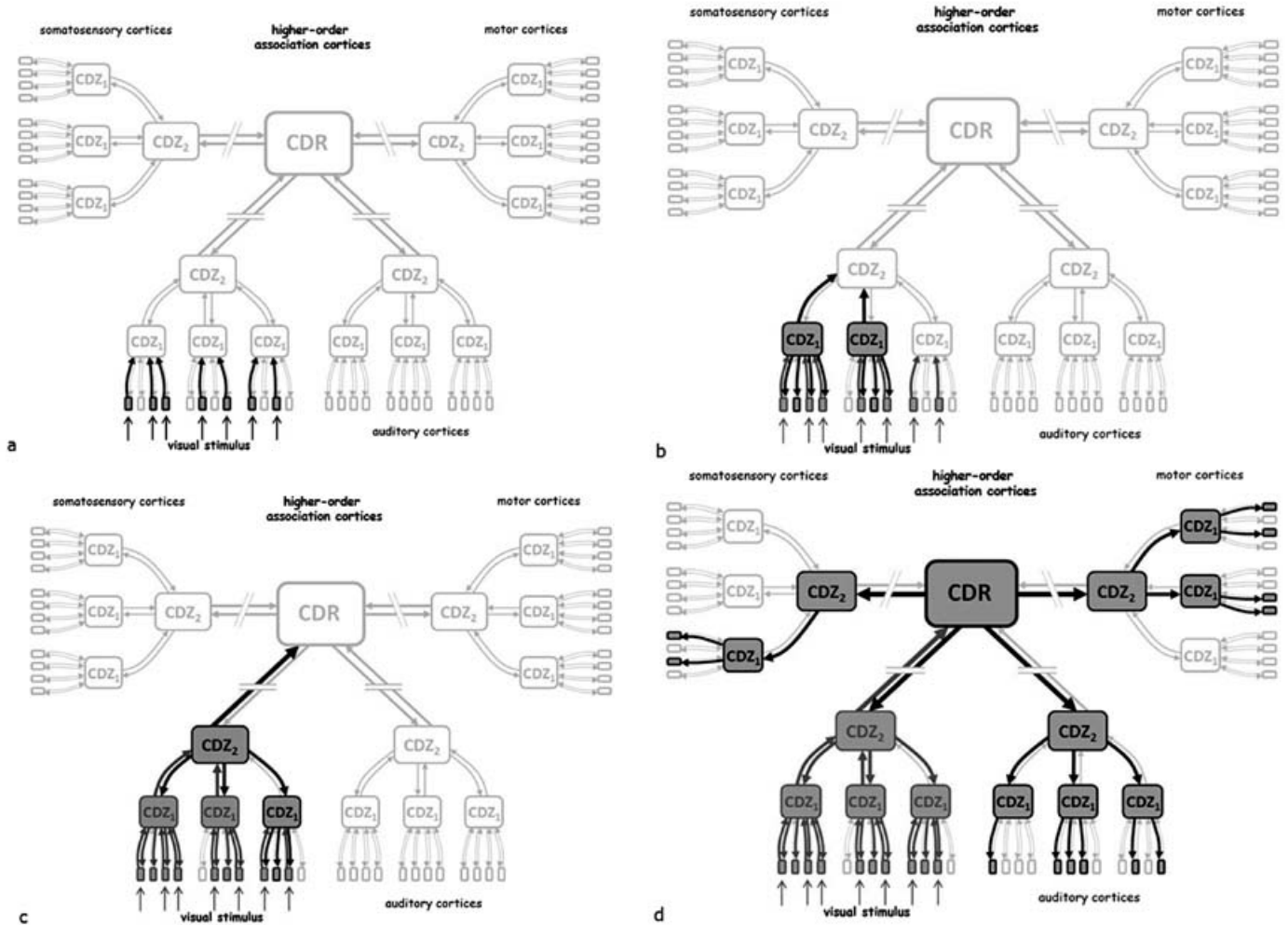
Furthermore, there is a distinction between factual (static) and procedural (in time) memories.

In human/animal brain, dispositions are stored in neural networks to recall map memories.

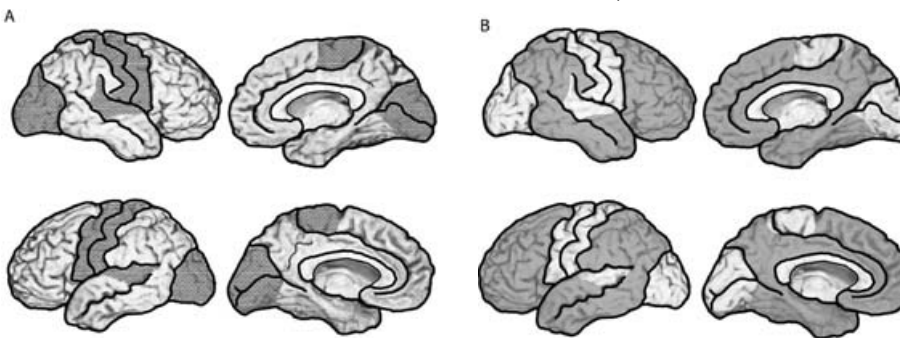
Memory is organized in many-level micronodes convergence-divergence-zones and convergence-divergence regions functioning as central hubs.

A convergence-divergence zone (CDZ) is a microscopic ensemble of neurons which form a feedforward neural network, CDZ's recreate approximately synchronous perceptions with a certain time-window.

CDRegions are macroscopic macronodes, which function as network-hubs. CDZ's number in many thousands, CDR's number in the dozens.



Using the CD architecture to recall memories prompted by a specific visual stimulus. In panels a and b, a certain incoming visual stimulus (selective set of small filled-in boxes) prompts forward activity in CDZs of levels 1 and 2 (bold arrows and filled-in boxes). In panel c, forward activity activates specific CDRs, and in panel d, retroactivation from CDRs prompts activity in early somatosensory, auditory, motor, and other visual cortices (bold arrows, filled-in boxes). Retroactivation generates displays in “image space” as well as movement (selective set of small filled-in boxes) [4:6].



The image space (mapped) and the dispositional space (nonmapped) in the cerebral cortex. The image space is depicted in the shaded areas of the four A panels, along with the primary motor cortex. The dispositional space is depicted in the four B panels, again marked by shading [4:6].

Modal conceptual representation

According to new research [43], aspects of complex concepts are stored in corresponding brain regions and interconnected, and the whole concept is invoked by activation of an aspect (e.g. the concept “telephone” by its sound in the auditory cortex). An aspect can be sensory, motoric or purely abstract (amodal).

The anterior temporal lobe (ATL) is the main hub for amodal concept processing.

There is evidence for **embodied abstraction** view, i.e. multimodal conceptual processing in left posterior inferior parietal lobe (pIPL), posterior middle temporal gyrus (pMTG), and medial prefrontal cortex (mPFC).



8.4 Consciousness coordination [JH] [52] [4]

Wakefulness and consciousness

Wakefulness is a state of a human, in which sensory cognition and muscular motoric (including purposeful movement) is working, as opposed to sleep [4:7].

During **REM-sleep**, there is very limited sensory cognition and muscular motoric, although the brain is partly active producing images (dreaming in REM-sleep) (low PMC activity).

During **non-conscious wakefulness** sensory cognition and automatic movement is possible (during epileptic absences automatic movement is possible, e.g. fetching an empty cup and trying to drink), but there are no visible emotions, no (verbal or non-verbal) communication, no planning, no sense of personal identity. Apparently, during non-conscious wakefulness automatic behavior is controlled by periaqueductal gray (PAG) in tegmentum (protoself) and subconscious emotions are controlled by deep superior colliculus, with complete shutdown of the cortex. As a consequence: conscious feeling requires a functional cortex (insular cortex, somatosensory cortex).

During **somnambulant episodes** the brain is in slow-wave sleep (non-REM), PMC is not active, but there is activity in motor, sensori-motor and cingulate cortex [46]. Furthermore, motoric and sensoric activity is much more advanced than in PAG-controlled non-conscious wakefulness and (unconscious) speech occurs. That means, this happens under non-conscious core-self control.

According to new brain research, consciousness has two modes:

- non-focussed mode under control of **default mode network (DMN)** (autobiographical self?)
- attention mode under control of **dorsal and ventral attention networks (DAS, VAS)** (high-level consciousness?)

Consciousness functions as a global workspace with CDR's as agents competing for focus, under the coordination of PMC (DMN-modus) and DAS or VAS (attention mode).

Taking this into account, we can plausibly describe consciousness and wakefulness:

consciousness is a state of awareness of self and surroundings, including previewing and planning of future

wakefulness is a state of awareness of surroundings and automatic movement control.

consciousness has two modes: non-focussed (DMN) and attention mode (dorsal and ventral attention networks)

consciousness functions as a global workspace with CDR's as agents competing for focus, under the coordination of PMC (DMN-modus) and DAS or VAS (attention mode)

Consciousness can be rated by its scope:

- minimal: drinking a cup of coffee, thinking of nothing
- medium: daydreaming (watching an internal flow of images) , or recalling personal episodes and impressions of persons from the past
- high: in a dialogue with a friend or relative

This differentiation can be used to locate the different levels of consciousness, specified above:

- subconscious: protoself
- minimal-conscious: core-self
- medium-conscious: autobiographical self
- high-conscious: high-level consciousness

The function of the current "consciousness manager" (which will we passed between main cortex regions) is basically:

- select "valuable" images out of the huge flow by evoking varying degrees of emotion as marker ("gut feeling")
- organize them into a coherent narrative and bring this into focus in the scarce "focus display space"
- use evaluation criteria: anticipation of situations, preview of possible outcomes, navigation of possible future, invention of management solutions

Ingredients of consciousness to build a conscious machine [37]

- 1 attention
- 2 attention schema
- 3 library of patterns

Default node network DMN

In neuroscience, the **default mode network (DMN)**, is a large-scale brain network primarily composed of the orbital frontal cortex, the lateral temporal cortex (LTC), the medial prefrontal cortex (mPFC), posteromedial cortex (PMC) and angular gyrus (AG) [38, 39].

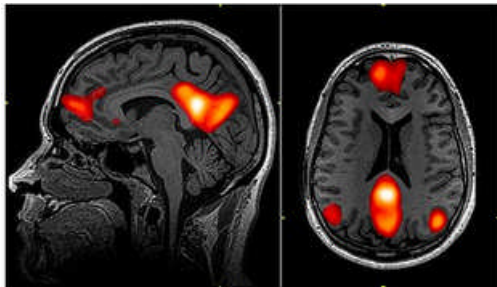
It is active when a person is not focused on the outside world and the brain is busy in self-reference: autobiographical memory, thinking about others, thinking about oneself, remembering the past, anticipation of future, daydreaming, moral judgment.

DMN is also highly active in meditation [41] and when enjoying art [40].

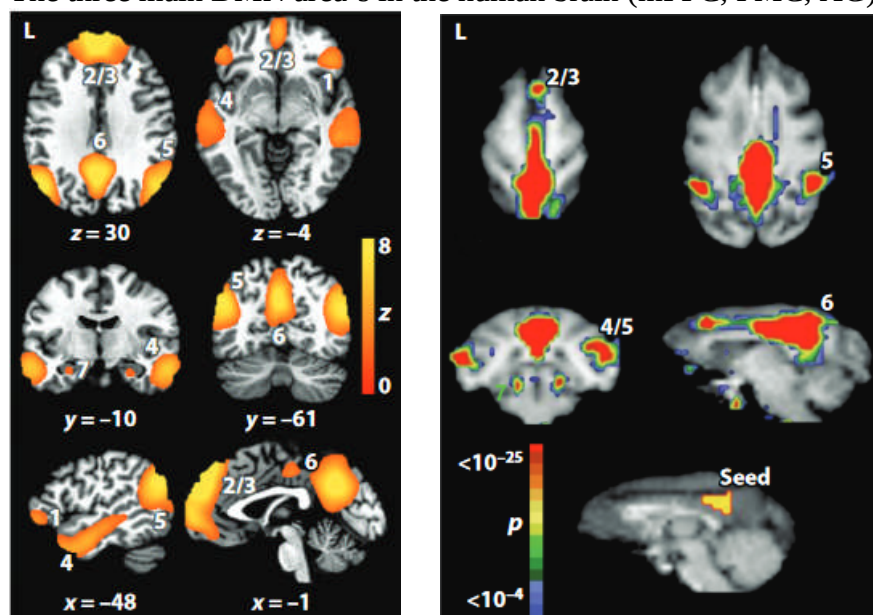
DMN in humans shows low activity in infants and evolves to full functionality in adults [38].

DMN has been shown to be negatively correlated with attention networks in the brain.

In monkeys there is a similar network of regions to human DMN, PMC is also a key hub in monkeys, but the mPFC is smaller and less well connected [38].

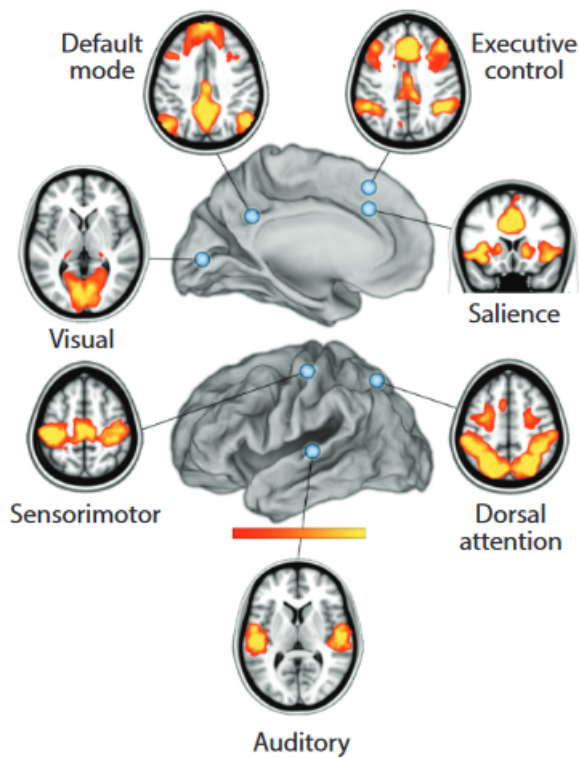


The three main DMN area's in the human brain (mPFC, PMC, AG) [38]



Human DMN left [38]: . significant clusters include 1, orbital frontal cortex; 2/3, medial prefrontal cortex/anterior gyrus; 4, lateral temporal cortex; 5, inferior parietal lobe; 6, posterior medial (PMC)/retrosplenial cortex; 7, hippocampus/para-hippocampal

Monkey DMN right [38]: 2/3, dorsal medial prefrontal cortex; 4/5, lateral temporoparietal cortex (including area 7a and superior temporal gyrus); 6, posterior medial(PMC)/precuneus cortex; and 7, posterior parahippocampal cortex



Global brain networks and their functions [39]: Default Mode (DMN), Central Executive Control (CEN), salience (or ventral) attention system (VAS), dorsal attention systems (DAS), and the three sensory systems visual, sensorimotor, auditory.

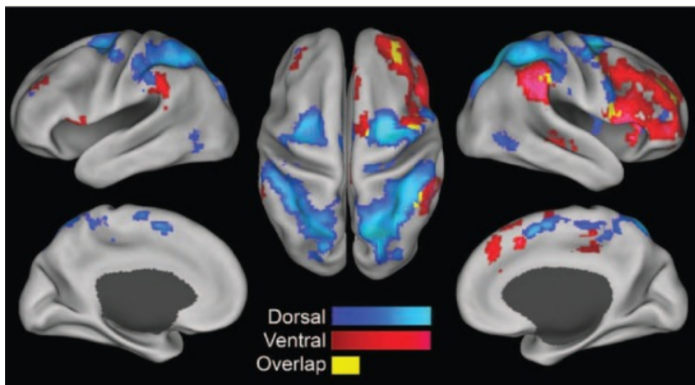
Attention networks

Attention networks are sensor-oriented networks (visual, auditory, sensorimotor), executive control network CEN, the attention-controlling dorsal DAS and salience (or ventral) networks VAS as *supramodal attention systems* [32].

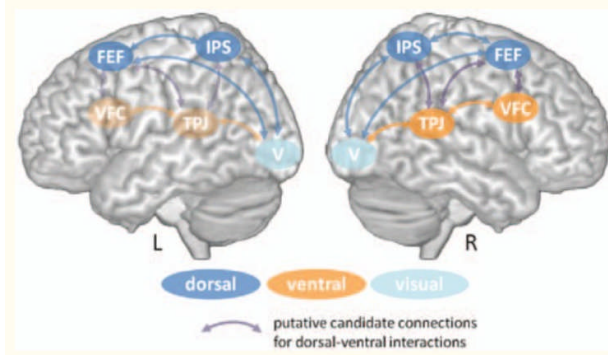
The **dorsal attention system** (DAS) controls the top-down biases of sensory areas [42].

The **salience or ventral attention system** (VAS) is typically recruited by infrequent or unexpected events that are behaviorally relevant, and for sensory filtering [42].

The VAS network facilitates switching between the CEN and DMN [42].



Functional connectivity maps for dorsal seed regions (IPS/FEF, blue) and ventral seed regions (TPJ/VFC, red) during fMRI resting state [42]



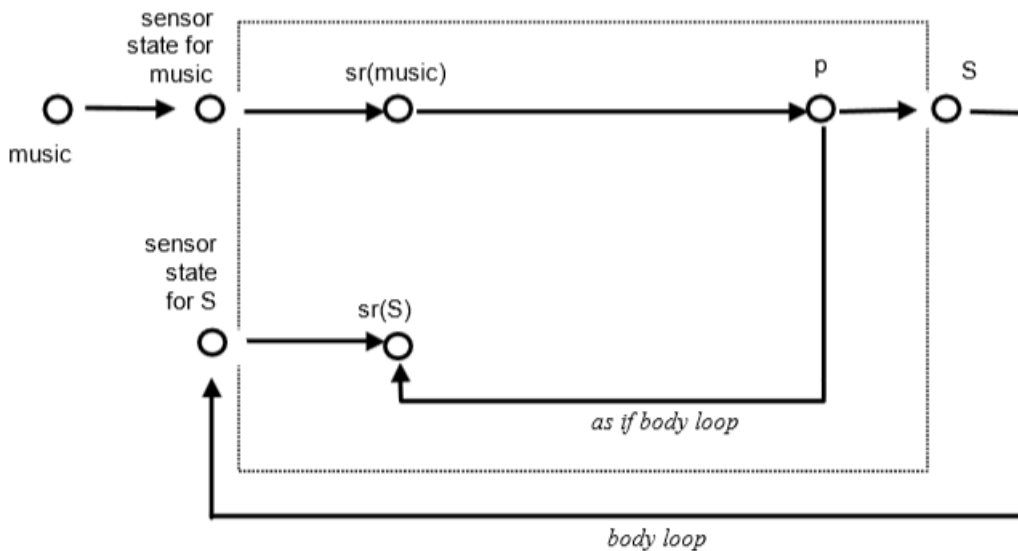
Interaction of DAS and VAS [42]

Simulation model of mind behavior [35]

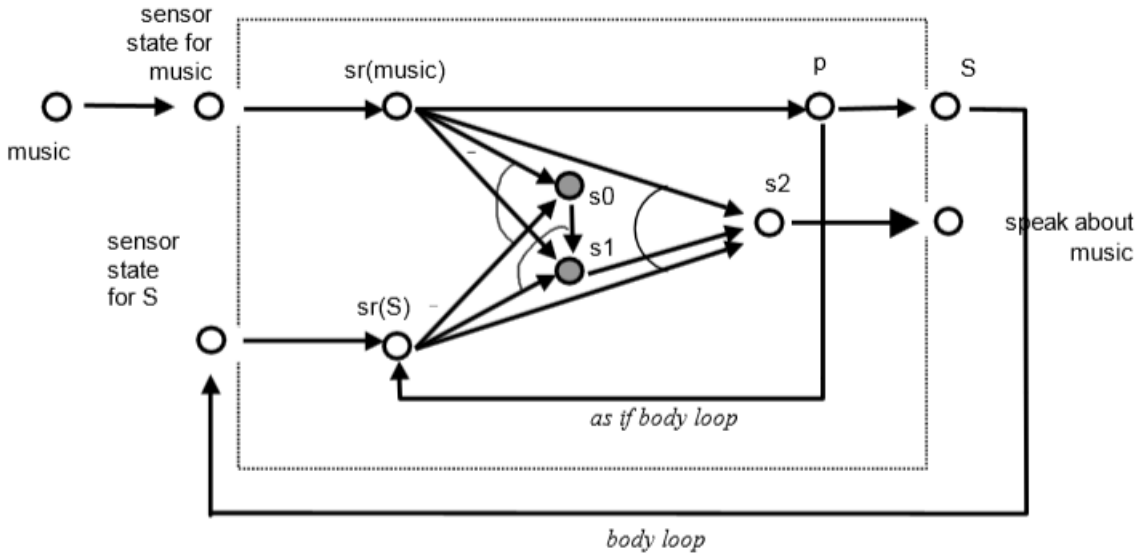
The above consciousness model can be formulated with the brain as a *state-machine*, with constant transition time and fixed *transition rules*.

Three important concepts in this theory are 'emotion', 'feeling' and 'feeling a feeling' (in core consciousness). The two mechanisms by which a feeling can be achieved as distinguished by Damasio have been incorporated in the model:

- (1) via the body loop, the internal emotional state leads to a changed state of the body, which is then represented in sensory body maps in protoself.
- (2) via the as if body loop, the state of the body is not changed. Instead, a changed representation of the body is created directly in sensory body maps and produces the same feeling as with a genuine sensory stimulus.



The “feeling a feeling” is a second-order representation of the mind state S , here S =feeling the music, $sr(\text{music})$ is the sensory map in protoself. The “feeling a feeling” of music means sensing S as sensory input (see diagram below).

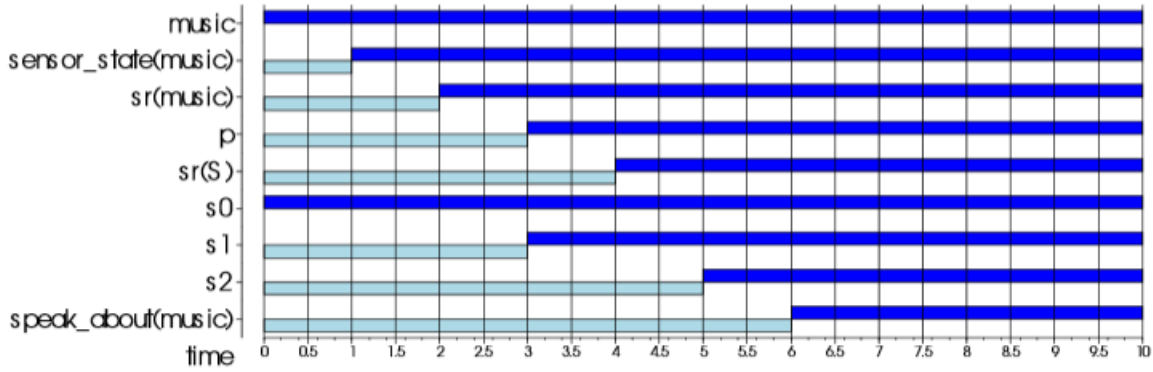


The transition rules for the above example are

$$\forall t1, t2 \ [\ t1 \leq t2 \ \& \ \text{state}(\gamma, t1, EW) \models \neg S \wedge \text{music} \ \& \ \text{state}(\gamma, t2, EW) \models S \] \\ \Rightarrow \ \exists t3 \geq t2 \ \text{state}(\gamma, t3, \text{internal}) \models \text{sr}(S) \]$$

$$\forall t3 \ [\ \text{state}(\gamma, t3, \text{internal}) \models \text{sr}(S) \\ \Rightarrow \ \exists t1, t2 \ \ t1 \leq t2 \leq t3 \ \& \ \text{state}(\gamma, t1, EW) \models \neg S \wedge \text{music} \ \& \ \text{state}(\gamma, t2, EW) \models S \]$$

The simulation with special software [36], which generates simulation traces like the one for the as if body loop



The traces are a verification tool, with which one can check,

8.5 Classification of living beings based on feedback loops [JH] [52] [3]

-Level 0 consciousness

The lowest level of consciousness is Level 0, where an organism is stationary or has limited mobility and creates a model of its place using feedback loops in a few parameters (e.g., temperature).

Example: a flower with ten feedback loops (which measure temperature, moisture, sunlight, gravity, etc.), would have a Level 0:10 consciousness.

-Level I consciousness

Organisms that are mobile and have a central nervous system have Level I consciousness. One example of Level I consciousness would be reptiles. They have so many feedback loops that they developed a central nervous system to handle them. The reptilian brain would have perhaps one hundred or more feedback loops (governing their sense of smell, balance, touch, sound, sight, blood pressure, etc., and each of these contains more feedback loops).

-Level II consciousness

Next we have Level II consciousness, where organisms create a model of their place not only in space but also with respect to others (i.e., they are social animals with emotions). Forming allies, detecting enemies, serving the alpha male, etc., are all very complex behaviors requiring a vastly expanded brain, so Level II consciousness coincides with the formation of new structures of the brain in the form of the limbic system. As noted earlier, the limbic system includes the hippocampus (for memories), amygdala (for emotions), and the thalamus (for sensory information), all of which provide new parameters for creating models in relation to others. The number and type of feedback loops therefore change.

We define the degree of Level II consciousness as the total number of distinct feedback loops required for an animal to interact socially with members of its grouping.

Example: if a wolf pack consists of ten wolves, and each wolf interacts with all the others with fifteen different emotions and gestures, then its level of consciousness, to a first approximation, is given by the product of the two, or 150, so it would have Level II:150 consciousness.

-Level III consciousness

Level III consciousness creates a model of its place in the world and then simulates it into the future, by making rough predictions. Level III human consciousness is a specific form of consciousness that creates a model of the world and then simulates it in time, by evaluating the past to simulate the future. This requires mediating and evaluating many feedback loops in order to make a decision to achieve a goal.

By the time we reach Level III consciousness, there are so many feedback loops that we need a CEO to sift through them in order to simulate the future and make a final decision. The point of running simulations is to evaluate various possibilities to make the best decision to fulfill a goal. This occurs in the prefrontal cortex, which allows us to simulate the future and evaluate the possibilities in order to chart the best course of action. Precisely how does the brain simulate the future? The human brain is flooded by a large amount of sensory and emotional data. But the key is to simulate the future by making causal links between events—that is, if A happens, then B happens. But if B happens, then C and D might result. This sets off a chain reaction of events, eventually creating a tree of possible cascading futures with many branches. The CEO in the prefrontal cortex evaluates the results of these causal trees in order to make the ultimate decision.

measure of the level of consciousness III :

Let's say that a person is given a series of different situations like the one above and is asked to simulate the future of each. The sum total number of causal links that the person can make for all these situations can be tabulated. (One complication is that there are an unlimited number of causal links that a person might make for a variety of conceivable situations. To get around this complication, we divide this number by the average number of causal links obtained from a large control group. Like the IQ exam, one may multiply this number by 100. So a person's level of consciousness, for example, might be Level III:100, meaning that the person can simulate future events just like the average person.)

8.6 Comparison intelligent animal, intelligent autonomous robot [JH]

Intelligent animal

An animal is *an evolved biological goal-oriented mobile intelligent system*. As a biological being, it evolved from the first terrestrial life proto-cycle with energy cycle, catalyzing enzymes(=peptides), controlling genes (=nucleotides, DNA). It is a hierarchical system: animal→ organs→ cells, behavior-controlled by the brain. The brain consists of discrete (0-1) feed-forward neural networks (NN).

The *behavior is goal-driven* (goals: self-preservation, reproduction) and is based on the inner representation of reality (*knowledge*) as *NN-patterns* (personal memory, behavioral memory, spatial-temporal-orientation), which is partly hard-wired, but mostly acquired by reinforced learning via pattern recognition.

Animals communicate within their species and community via audial, behavioral and olfactory signals. Their *structure and behavior* (but not its knowledge) is *coded in its genotype and passed on* to the next generation via sexual reproduction.

goals

self-preservation (feeding, danger-avoiding)

reproduction (preservation of species)

goal-guiding

reflexes automatic movement, automatic sequence of movements

enzyme-control e.g. dopamine, insuline

basic emotions e.g. hunger, anger, fear

control

knowledge = internal representation of reality, partly hard-wired, partly acquired by learning

learning

learning by *local discrete (0-1) recurrent transformer-type spiking neural networks*

behavior

inherited behavior e.g. bee dance

learned behavior e.g. predator learns catching prey

physiological mechanism

energy production : physical food processing (guts), chemical processing (enzymes), energy transport (blood)

sexual reproduction

movement control muscles, nerves

learning, prediction, behavior control: brain, nervous system sensory system

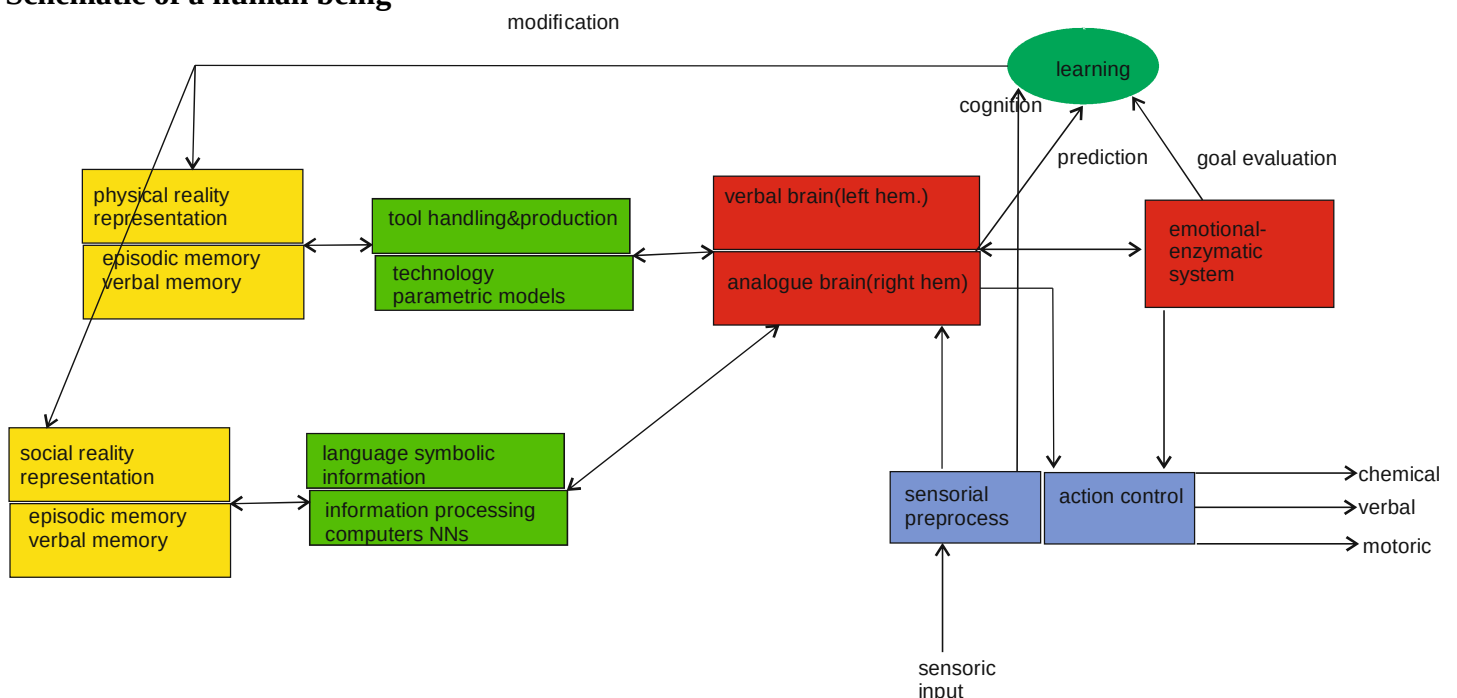
physiological structure bottom-up = cell networks

level1: cells, autonomous biological entities maintaining life cycle via chemical feed-back loops, and reproducing

level2: *function-dedicated networks of cells =organs*

level3: *control system*: brain, nervous system, sensory system

Schematic of a human being



The schematic of the learning process in a human being is shown above.

The significant brain centers are shown in red: the verbal-processing left cortex hemisphere, the pattern-processing right cortex hemisphere, the emotion-processing and chemical-controlling brainstem/ midbrain.

The storage centers in yellow are the verbal-symbolic memory (reality representation), and the episodic memory. In green are shown the two mediating processes : *tool management* for interaction with the physical environment and *language* for interaction with the social environment.

The cortex processes the sensorial information, and generates an *action response and a prediction*.

In the learning process, the incoming sensorial input and the prediction are compared, evaluated by the emotional system, stored in episodic memory, and potentially used for *modification of the episodic and the verbal memory*.

The two mediating processes are a specifically human accomplishment, which distinguishes us from all other biological beings. Their evolution ran in parallel, and the language and motoric centers are closely related and situated and at short distance in the cortex.

They evolved in two levels: basic level1, which developed over ca 2 million years, and the machine level 2, which came with the industrial and the computer revolution.

- tool management

level1: manual production of tools and weapons in stone, wood, leather, metals, ceramics;

motoric ability to handle tools as an extension of the biological motoric apparatus

level2: mechanic and electronic machines as motoric extension;

electronic, optic, acoustic devices as sensorial extension

- language management

level1: symbolic language with complex grammar and generic semantics evolved from 2 word-sentences [96] into a powerful medium of communication, organization, and information storage via scripture

level2: natural language is transformed into programming language for computers, which is a logical-analytic-calculation extension of the brain;

humanoid autonomous robots equipped with transformer-type neural networks process and produce natural language as humans and are an extension of human behavior and thinking as a whole.

Autonomous intelligent robot

A robot is a *designed technical goal-oriented mobile intelligent system*. It is a hierarchical electronic system: robot→ (sensors, actors)→ (hardware, firmware), behavior-controlled by Central Control Unit (CCU).

CCU consists of CPU-array for algorithmic functions, of a global back-propagation continuous neural network for learning and classification, electronic storage (fast dynamic memory and slower non-volatile flash-memory), input-output control.

Their sensorial equipment are audio input-output, HD-camera, infrared and ultrasound distance sensors, their motion is driven by electrical step-motors or DC-motors (wheel- or leg-movement), their power supply are high-capacity accumulators, which they reload at dedicated power stations.

Robots communicate with other robots and with their control center via broadband wireless.

Robot hardware is replicated externally from its design by automatic production. Robot firmware (program, memory, NN learned content) can be transmitted by the robot to its control center.

Robot behavior is controlled by pre-programmed goals (tasks, e.g. driving a car from start to final position), proficient behavior is acquired in a *learning phase* by reinforced learning (goal oriented) or unsupervised learning (classification knowledge acquisition). It is based on the inner representation of reality (*knowledge*) as *NN-patterns* (personal memory, behavioral memory, spatial-temporal-orientation) and as *pre-programmed database*.

goals

tasks e.g. driving a car from start to final position

goal-guiding

programmed optimization of goals e.g. time, security

boundary conditions e.g. speed , area

control

knowledge = internal representation of reality, mostly pre-programmed, partly acquired by situation-learning

learning

learning by algorithm, and by *global recurrent transformer-type continuous neural networks*

behavior

programmed algorithm

learned algorithm (neural network learning)

physiological mechanism

energy control e.g. battery supervision

movement control: motors, control electronic, FPGA

behavior control: microcontroller, wired connection, wireless connection

physiological structure top-down:hierarchical & modular, decreasing complexity

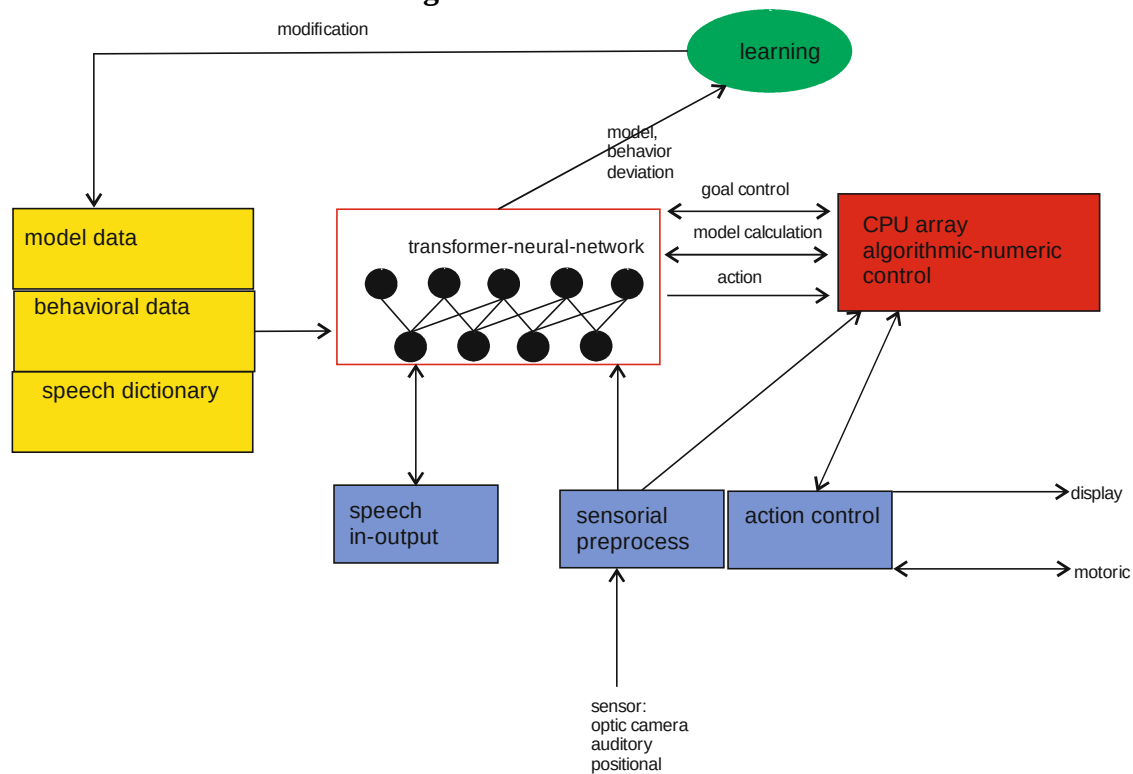
level1: actors mechanic grabbers wheels, propellers , *actors electronic* motors, artificial muscles

level1: sensors optical cameras, GPS+laser location sensors, auditory sensors, tactile sensors

level2: sensorial evaluation processors, actor control processors

level3: central control parallel processing real-time operational system on processor array, neural network, storage

Schematics autonomous intelligent robot



An intelligent robot processes data with two methods

- pattern control, processed by transformer neural network hardware (TNN)
- algorithmic-numeric control, processed by CPU array (CPUA)

The internal-external world representation is stored in model & behavioral data.

TNN takes input from model & behavioral data, speech dictionary, sensorial preprocessor, model numerical calculation (from CPUA), and generates a prediction in physical external data (model data) and action (behavioral data). CPUA performs model numerical calculation, controls the goal model and behavioral data. Finally, the deviation in goal and prediction data generates a modification of the world representation (learning process).

Speech input (commands and information) and speech output (information) is managed by TNN using the speech dictionary. In speech-learning mode, the speech dictionary is also modified.

Example: a humanoid robot drives a vehicle to a given address.

Sensorial data are actual location and velocity, surrounding traffic data.

Applicable model data are city map, traffic rules.

Applicable behavioral data are car movement control parameters: velocity, direction, position, distances, acceleration.

Applicable goal data are destination address, velocity and time goals, traffic rule boundary conditions, security conditions.

TNN generates in real time a position-direction-velocity (action) prediction, CPUA performs numerical calculation and goal control.

8.7 Biological memory and concepts [JH]

[52]

The biological brain is basically a binary neural network (NN) (see above), therefore its basic functionality is pattern recognition and classification.

Memory storage in animals and humans, according to recent research, can be roughly described by patterns (stored in NN “columns” in the brain), classified images (stored in image classification NN’s), classified sounds (stored in auditory classification NN’s), spatial and temporal maps, and sensory impressions (stored in visual, auditory and olfactory cortex).

-Sensory impressions

These are preprocessed sensory data, which are stored in the corresponding sensory cortex, e.g. preprocessed image stored in the visual cortex, which is preprocessed to show contour, contiguous areas and structure (e.g. straight lines). The most significant of them are stored in long-term memory and remembered as “scenes”.

-Spatial and temporal maps

Research with animals shows that topological data with related features are stored in a spatial map in the brain[5]. The same apply probably to notions in humans with their relational connections.

Temporal event sequences are also stored in maps [5, 6].

-Classified images and sounds

Unsupervised neural networks are capable of spontaneous *structure-finding and classification* [29] in *unsupervised learning*. In *supervised learning* e.g. in *backpropagation NN’s*, *classification* is learned by enforced learning [29]. Similarly in the brain, *conceptual features* (e.g. triangle, face scheme, bird) are extracted by classification and structure-finding in *classification NN’s*, and stored in long-term memory.

-Patterns

Individual patterns (e.g. faces, individual behavior, melodies) are *learned by normal NN’s* (columns) in the brain and stored permanently, apparently even as *elementary patterns* in single neurons.

A plausible hypothesis formed on this basis is the distinction between “*memorables*” falling into one of the above categories and *pure qualities of memorables*.

Normal “*sharp*” *concepts* like individuals, species (e.g. bird, mountain), general qualities (e.g. form patterns) are *memorables*.

Those concepts, which are solely *qualities of memorables*, are “*fuzzy*”: form qualities (e.g. size), psychic qualities (e.g. angry), events, temporal qualities (e.g. duration).

It seems, that qualities used as *fundamental parameters* in extracting memorables from experience, play a the role of Kantian “*pre-defined concepts*”:

-in maps: space, time, number

-in classified concepts and patterns, fundamental sensory features like: color, brightness, acoustic frequency and intensity, contour, contiguous area, straight line, arc.

8.8 Dual brain

The Parkins-Adolphs-Kuo-Squire-Yordanova (PAKSY) model of procedural vs declarative representation and processing in the brain, which is introduced in [65: P2-1.3] describes the information processing and representation in the brain in terms of the duality of procedural-declarative or intuitive-analytic processing. The distinction between procedural and declarative process is the same as the distinction between automatic skills and controlled processing (Adolphs, 2009), between implicit and explicit knowledge (Yordanova, 2008), and between analytic reasoning (slow, controlled, and effortful) and intuition (fast, emotional, effortless, and creative) (Kuo, et.al. 2009; Rhodes, 2012).

Lateralization of functionality within the brain [65: P3-8]

Information and processing associated with left cerebral hemisphere functionality:

The left cerebral hemisphere plays a major role in processing of speech, verbal information, language. It is concerned with feature extraction, abstract concepts, and logical-analytical processing, it works sequentially. The left hemisphere is involved in the process of active vigilant attention, and it controls focal attention.

It has been suggested that only the left hemisphere has the underlying brain organization that allows for high-level consciousness (Nierbauer et.al., 2002).

From this one can conclude: the left cerebral hemisphere is responsible for the **analytic/declarative (abstract)** information representation and processing, and its function can be identified with Damasio's **high-level consciousness**.

Information and processing associated with right cerebral hemisphere functionality:

The common types of information that is processed by the right cerebral hemisphere is spatial, the other is the perception and production of emotional information.

One quality of the right cerebral hemisphere is holistic/global information processing. It processes information quickly, responding more quickly than the left hemisphere.

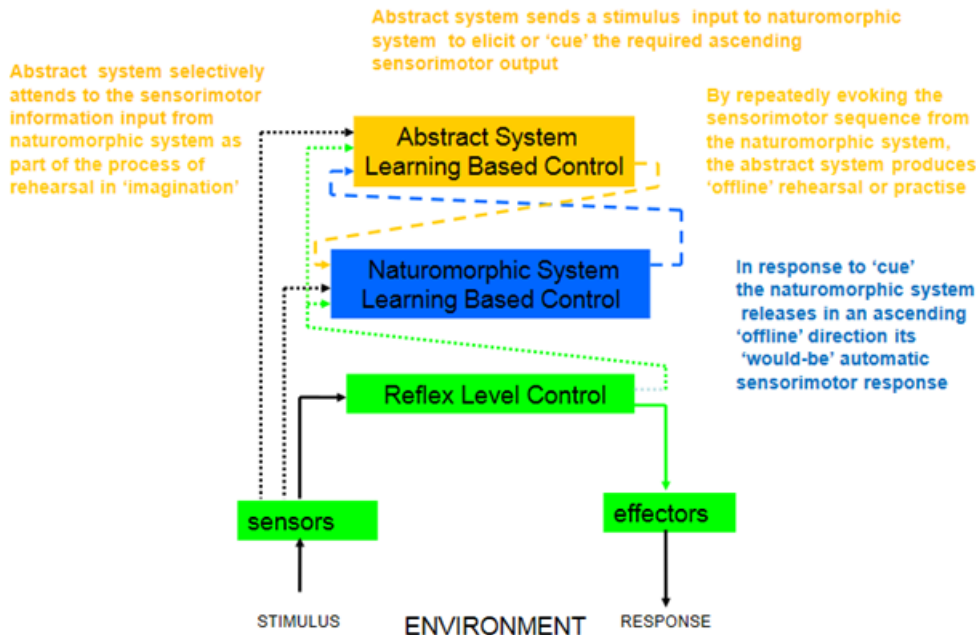
Other features of the right cerebral hemisphere are parallel processing, analog perceptual representation, and implicit information processing (i.e. through a relation network, as opposed to explicit through an expression or formula).

It has been pointed out that the infant relies primarily on procedural memory systems during the first 2-3 years of life (Schore, 2000). Accordingly, we can assume that from the evolutionary point of view, the procedural functionality is an **earlier development stage** than the declarative functionality.

From this one can conclude: the right cerebral hemisphere is responsible for the **intuitive/procedural (naturomorph)** information representation and processing, and its function can be identified with Damasio's **autobiographical self**.

Functionality of the left and right cerebral hemisphere

	Left Brain Hemisphere	Right Brain Hemisphere
Functions	Speech and language, Mathematical computations, Rational reasoning, Logical analysis	Intuition, Spatial awareness, Music, Creativity, Facial recognition, Art, Rhythm
Personality	Logical, Attention to details, Analytical	Artistic, Creative, Open-minded
Traits	Rational decision-making, Linear thinking, Reality-oriented	Random thoughts, Non-verbal processing, Holistic thinking, Fantasy-oriented
Thought process	Verbal and sequential	Non-verbal random thoughts
Problem-solving ability	Solve problems in the most logical way	Solve problems in the most intuitive way
Overall thinking	Detail-oriented	Holistic approach
Strengths	Language verbal and written, Mathematics and analytics, Sequencing, Reading, Writing, Spelling	Arts, Music, Coordination, Multi-dimensional thinking, Remembering a place, faces, or events
Difficulties	Visualization, Abstract thinking	Organizing a huge body of information, Difficulty in following a sequence, in remembering names
Parts of the body being controlled	It controls the right side of the body.	It controls the left side of the body.
Effects on the body when damaged	Not able to understand both spoken and written words, Can't see or perceive things on the right side of the body, Slow movements	Visual perception is impaired, Can't see or perceive things on the left side of the body, Short attention span, Poor decision-making, Slow learning process, Impulsiveness



Communication between the abstract and naturomorphic learning [65:P2-2.4]

Basic features of abstract functionality

Basic abstract logical functionality: simple arithmetic, simple logical conclusion, simple grammatical schemes (like subject-predicate (SP), subject-verb-object (SVO))

Basic abstract semantic functionality: using/learning concepts, using/learning metaphors

Concept: is a set of related objects, sensorial images, motoric actions, emotions, events

Metaphor: is a description of a concept in terms of another concept, which is better understood, and taken from physical, social, or psychic experience [74]. E.g. metaphor "TIME IS MONEY" has the realization "You're *wasting* my time".

Basic features of naturomorph functionality

Basic naturomorph functionality: pattern recognition (e.g. face recognition), automatic structure finding, event-prediction from time-series of events, evaluation of similarity, analogy reasoning, pattern-reconstruction (filling-in of missing features).

All these functionalities are characteristic for different types of neural networks [73].

Brain evolution [65:P3-10]

According to MacLean there are three evolutionary layers to the mammalian brain, which are described as the reptilian brain, the paleo-mammalian brain, and the neo-mammalian brain (MacLean, 1973) .

- reptilian brain: brainstem and the basal ganglia
- paleo-mammalian brain: limbic system
- neo-mammalian brain: neo-cortex

As the limbic system is related to Damasio's core-self, and the brainstem is related to Damasio's protoself, we can conclude, that from evolutionary point of view, the development goes from protoself to core-self, and then to the cortex-based autobiographical self and the high-level consciousness.

9.1 Collection of data**Collection of unstructured data (CuD)**

CuD's are sets of events or objects, which are unstructurable, e.g. human history, climate, life evolution, cosmic history, geography of Earth, geography of planets, geography of a stellar planetary system, geography of a galaxy. They are events over time (inherently diffuse, because only indirectly measurable from 'traces') or landscape over space at a certain time (then precisely measurable). In both forms they are basically unrepeatable and only very roughly subdivided in types, e.g. mountains in a landscape, periods in history. Conscious structuring proceeds by unsupervised learning in (biological) neural networks, on the basis of similar properties (e.g. hardness, color, surface of a stone) and spatio-temporal coherence (localization in space and constancy in time of a stone).

Collection of data (object groups) with structure (CoDS)

CoDS's are data with structure (pattern), e.g. living organisms on Earth. They can be classified in a structure tree (living organisms on Earth in class, order, family, genus, species).

There is a 'structure plan' for classes (like structure plan for classes: mammal, insect, flat-worm and for cells of multicellular organisms). Individuals of a species have a statistical deviation, the structure has a statistical 'fuzziness'.

Other CoDS's are human societies, animal herds, insect societies.

Collection of state-groups (phenomena) with structure (CoSS)

In medicine, psychology: CoSS's are physical or mental states of a living individual, classified in related states: e.g. human or animal illnesses, mental states of a human being.

9.2 Models**Mathematical models (MM)**

Mathematical models are realizations of a mathematical or physical theory, e.g. a certain group (cube rotational group) is a realization of (axiomatic) group theory, a neutron is a realization of quark chromodynamics. They are precise (or precise within an error bar in physics), quantifiable, and the structure is determined (the structure is precisely defined, there is no 'fuzziness' like in CoDS's). In this sense also the quantum mechanics is determined (although not deterministic), because it is operating with a mathematically precisely defined wave function.

The realization is based on a set of elements with relations of the model, the model has a set of axioms (principles).

The number of elements can be infinite (analysis/analytic function theory), very large but finite (physics), or small and finite (algebra-geometry).

The underlying background structure can be a continuous field ($\mathbb{R}$, $\mathbb{C}$) in analysis, a set of statistical variables (wave functions, operators) in physics, a finite-dimensional vector-space or finite group in algebra- geometry. A physical MM is tested against the experimental data and has the precision of a typical experiment (usually $3\sigma=0.3\%$, in particle physics $5\sigma=1-0.4 \cdot 10^{-4}$).

Behavioristic models (BM)

Behavioristic models are intuitive (in-brain) parameterized models of a society dynamics. BM contains a small number of actors (persons or groups) which act on the others and bring the society into a new state.

The behavior of an actor is the entirety of its actions and their rules depending on the actual state of the society. The properties of the actors and actions are fuzzy values like "strong, medium, weak".

All the actors and their behaviors constitute the BM.

BM is the inner representation of the social environment of a human individual.

An example: personal relationship environment of an individual with family members, partners, friends, enemies, colleagues, acquaintances, with their emotional, physical, financial, informational relations to oneself, and within a time-frame (i.e. personal event history).

Another example: the personal picture of the large-scale socio-political environment in a modern liberal industrial society, e.g. government, justice institutions, parties, religious groups, syndicates, military, police, administration units, influential persons, with their strength (number of supporters/adherents) their actions,

mutual relations, and their evaluation for the person (good/bad , friendly/opposed, ...). This BM is the so-called “political view” of an individual.

Simulation models (SM)

A simulation model is a structural model of a dynamical statistical system with numerical parameters and functions, which control the evolution of the system in time. It contains parameter-dependent random variables, which are usually Gaussian with mean value m and standard deviation (std) σ , e.g. individual daily consumption in an economical model.

Example 1: physical SM of a star is the spatial concentration c_i distribution of elements (H, He, C,...) in time with the corresponding equation of state $p(c_i, T)$.

Example 2: behavioristical-economical SM of a human society in time is a BM with numerical-valued group parameters (e.g. percentage of support of a group, its force of influence, its actions and action rules) , plus global parameters of the society (income distribution, economical production distribution, education index, infrastructure quality, technology index, administration quality,...).

Global parameters are random variables over time with a small std in 1% range. Actions of an individual are random variables dependent on situation parameters with a broad probability distribution like human IQ (mean $m=100$, std $\sigma=15$). Therefore the predicted values have a broad relative error margin, e.g. $\Delta_r(IQ)=\pm 15/100$ with probability of 67% .

A physical SM is tested against the experimental data and fitted in its parameters, until a desired precision is reached (typically $\sim 3\sigma=0.3\%$).

A behavioristic economical or political SM is fitted in its parameters in comparison with real economical or historical data, until a desired precision in global variables is reached (typically $2\sigma=5\%$).

There are currently dozens of economic behavioristic models, which predict medium-term (years) economic development with a satisfactory accuracy.

There are also some political-historical behavioristic models, which are fitted on historical data and reach an astonishing degree of accuracy [26].

In this sense, one can speak of an *economical or political reality independent of time*, because a correct SM can describe a *virtual history*, which would happen, if some event in history had been changed (e.g. the course of American history if Donald Trump had been elected for the second term).

9.3 Biological data

Biological species

Structure, elements and visual impression of a typical individual of a species (plants or animals) constitute the human representation of the living world.

Biological actions

In animals, sequences of actions (movements, communication sounds) are passed-on genetically or by learning (imitation) or by combinations of both (fixing by learning of variable intermediate sequences, while others are inborn).

In humans, sequences of actions are passed-on mostly by learning and by group-specific rituals, e.g. hunting techniques.

9.4 Technology and tools

Technology

Technology is a collection of algorithms (quantitatively described sequence of actions (e.g. flattening with a hammer)) with the goal of creating materials (e.g. pure iron) or objects (e.g. glass cup) with a defined geometrical form and composition.

Technology is passed-on by imitation or verbally-pictorially (including scripture) by *recipes* in *system-2* (verbal-intuitive) paradigm.

Technology is passed-on by quantitative and formula-mathematical *algorithmic description*.

For instance, producing iron from iron-ore in antiquity was passed-on by imitation, and pictorial-verbal “fuzzy”, i.e. non-quantitative recipe. In modern times, it is passed-on as exact quantitative description, including machine-algorithms(software) and physical-mathematical description of the system-behavior over time.

In modern technology, computer software is recorded in computer languages, electronics in design-formats like VHDL and EDIF, geometric-mechanical design in 3d-CAD formats like DWG.

Tools

Tools in general are objects created or used with a purpose: a bed is an object built for sleeping, a house is an object built (a log cabin) and used (a natural cave) to stay in, for shelter and comfort.

9.5 Actions and actors

General actions

An action is a purposeful behavior of a living organism or a machine.

-Unconditional action

An unconditional action is genetically fixed (in an organism) or programmed (in a machine). The action is evoked if a certain pattern of objects and events is met within a similarity margin .

Example: a bee stings, if attacked

-Conditional action

A conditional action in an organism is learned from others or by experience (success guided learning).

A conditional action in a neural-network-machine is the output of a recognized pattern learned in the learning phase of the neural-network (NN).

Example: a dog follows an odor on command, because he is trained to do so (by reward-guided training).

-Planned action

A planned action is the result of a simulation in a representation of the environment. The simulation is performed by an intelligent being (an intelligent organism or an AI-robot) in order to reach a goal.

Example: a human “calculates” how a trap must be like in order to catch a hare, he simulates the behavior of a hare in a certain trap in his imagination (=representation of the environment and the hare’s properties and behavioral patterns).

Intelligent actors

Intelligent actors are organism or AI-robots, which have a *representation of the environment* (objects and acting organisms) and can plan, i.e. simulate a pattern of events in this environment, including oneself as an acting subject (consciousness).

9.6 Inner representation and language

Inner representation

A representation is a mapping of the environment *entities* (objects, actors and events and their properties) within an intelligent actor. An entity is mapped into a *symbol*. Entities are linked by relations (a hand is a part of a body) or actions (a dog is pursuing a hare).

Brain research tells us that the human brain memory organizes objects on a fixed (hexagonal) lattice in space for orientation, and events on a time line, generalized on a space-time lattice [5].

The human inner representation is nothing other but the *semantics of the human language*.

Humans are biological and social beings, their inner representation is twofold: representation of physical-biological environment (landscape, buildings, plants, animals) and of social environment (BM of the personal relationship environment and BM of the large-scale society).

Language

In intelligent groups, a representation is made transferable through communication by a group-understandable coding into a *language*.

Simple *self-explaining* languages are not group-specific (species-universal).

Example:

picture-language=symbols coded in their image : hare coded as its image.

gesture language= symbols coded with gestures: a running hare described by moving fingers.

Abstract coded language: for humans the sound-coded proper language with grammar, expressing relations between symbols, which achieves a larger information density.

Human languages are group-specific and must be learned within a group: they are not species-universal.

Proto-language

Singing and music as its extension is probably a proto-language used to express emotions and states of mind in general by humans, but also by mammals and birds. In humans, music has its own esthetics based on frequency ratios, and related to emotions (chords have emotional types, rhythm reflects emotions and movement patterns).

Proper language is recorded by scripture, music is recorded by note-scripture.

Recorded language

Language transfers one representation into another (in humans: from brain to brain).

Sound language is made recordable by scripture.

A human scripture can be pictorial=coding the sound (sequence of phonemes) of an entity by a pictogram, e.g. in Chinese character 人 represents the syllable ren2 with its meaning 'man'.

Most modern human scriptures are alphabetical= coding of sound-elements phonemes into alphabetical characters, the Latin alphabet.

9.7 Art

Literature

Stories (originally as fables and myths) and poem-songs described originally fundamental experiences and event-patterns in life. They evolved into (fiction) literature and poetry, which are a sort of “simulated life” for modern humans. Their esthetics is based on realistic representation and emotional esthetics.

Pictorial art

Artistic representation of reality in form of drawing, painting, and sculpture, were produced by humans from the beginning. They are a sort of “simulated perception”, which obeys a canon of geometric and color esthetics, based on the principle of maximum information and minimal complexity according to Doerner [10].

9.8 Symbols

Symbols in human natural language can be divided into four categories

1 mathematical-physical entities : algebraic group, physical variable temperature, geometric triangle, physical ensemble gas , mathematical set natural numbers, chemical substance water; they are defined precisely in the mathematical-physical formal language and are therefore fundamental and non-created in the sense of Platonian ideas.

2 entities and products of the (terrestrial) biological world , which are species of living organisms, their parts, products , and communities

-biological entities : kingdom bacteria, species homo sapiens

-biological communities: forest (trees), bee hive

-biological products: dog's fur, snail's shell

3 entities of the (terrestrial) geographical world, which are small- and large-scale structures of Earth surface

-geographic structures: mountain, lake, marsh

-material fragments: stone (piece of rock= geometrically localized ensemble with common qualities: color, hardness), drop of water

4 entities and products of the (human) intelligent world, which are elements of the human mental world, human spiritual and moral entities, human-produced tools and objects

-human tools: table, saw, ship, house

-human behavior: running, eating

-human spiritual entities: god, ghost, soul

-human moral-social qualities: good, evil, treacherous

-mental/sensorial entities: hunger, pain, love, fear, dream

10.1 Popper and Kant**Popper's Three-worlds theory**

In the philosophy of the mind, Popper opposed both classical mind-body dualism and reductionist theories, such as behaviorism. He proposed a mental division of the world into three areas [11], namely:

- World 1, that is the physical world
- World 2, the world of individual perception and consciousness
- World 3, the world of spiritual and cultural content that can exist independently of the individual consciousness, e.g. For example, the contents of books, theories and ideas.

Kant fundamentals [12]: space and time are prerequisites of sense-learnable (sinnlich) ideas; Copernican turn: we do not recognize the 'thing in itself' (Ding an sich), but only its appearance or the 'thing for us' (Ding für uns).

Kant's Categories Table

Quantity, quality, relation and modality are the four functions of the mind according to which categories are formed.

Quantity	Quality	Relation	Modality
Unity	Reality	Substance & Accidens	Possibility
Multiplicity	Negation	Cause & Effect	Existence
Allness	Limitation	Interaction	Necessity

Quantity & Quality: logical quantors

Unity: it applies to exactly one, multiplicity: it applies to several, allness: it applies to all

Reality: there is one, negation: there is none, limitation: if there is something there is one

Relation & modality: physical relations

Accidens: ensemble of identical objects (e.g., gas, liquid, solid)

Cause and effect a, b: temporal change of state of an ensemble, temporal change of 2 ensembles through interaction

Interaction: interaction energy, described by Hamiltonian

Possibility: physically possible, e.g. Star with a certain mass > 13 Jupiter masses, e.g. Max. Jump height for a human

Existence: physical realization, e.g. an electron

Necessity: laws of conservation and symmetries (coupled by Noether's theorem)

Kant's classification of judgments

a priori analytic: logically derived expectation, World 4 statements

a-priori synthetic: innate / learned disposition, representation of World 4 in World 2 (Psyche)

a-posteriori synthetic: observed, innate / learned decoding mechanism of the senses (World 2)

a-posteriori analytic: technology / science / applied mathematics, representation of World 4 in World 3

10.2 Four-world concept: extension of Popper's concept

World 1: Our universe = particular reality in geometry and physics

model with a specific parameterization: fundamental constants, parameters of the standard cosmological model, parameters of the Standard Model of elementary particles.

Subworld1: biological cell world : self-organizing, reproducing systems based on self-catalyzing metabolic cycle with catalyzers-enzymes (peptides and information-storing synthesizers (poly-nucleins) in a cell.

Subworld2: biological organisms world : information-processing and acting goal-oriented multi-cellular organisms with a neural-network-processor (brain) ; it forms a representation of reality (animal consciousness) , ultimately with the self as acting agent (human consciousness) and symbols

World 2: Subconsciousness: emotional states; memory; consciousness: information acquisition, planning, calculation; speech processing: speech and speech comprehension in biological beings.

Generalization2.1: Autonomous learning robots with neural networks

Generalization2.2: Subconsciousness, consciousness, speech in non-terrestrial biological beings.

World 3: Communicated and recorded verbal knowledge of humanity: literature scientific, religious, philosophical, belletristic; all linguistic utterances

Generalization3: Programming languages and information theory: all coded programs

World 4: General physics and mathematics

Geometry of our universe: Euclidean geometry of the Euclidean background spatial metrics

Algebra of our universe: field= complex numbers $\mathbb{C}$ and quaternions $\mathbb{Q}$, Lorenz group, Lie groups= Lie groups of the four fundamental interactions: $SU(2)_{\text{ext}}$, trivial $SU(1)$, $SU(2)$, $SU(3)$

Physics of our universe: physics fundamentals=(minimum principle for action and lagrangian and derived pdeq's , interactions: four long-range and quantum gauge-invariant QFT's, statistical mechanics, two phenomenological models: Lambda-CDM (macrocosm) and Standard Model of Elementary Particles (microcosm))

Generalization4.1: Realization of other universes (e.g. metric $SO(2,2)$ physics universe)

Generalization4.2: Entire Mathematics: Algebra, Geometry, Topology, Graphs, Set Theory and Logic, Analysis, Functional Analysis, Statistics

Representations of the 4 worlds in one another

Art: Representation of W2 in W1

Technical devices: representation of W3 in W1

Perception & Memory: Representation of W1 in W2

Particular Reality: Representation of W4 in W1

Technology / Science: Representation of W4 in W3

Geography / Astrophysics / History (phenomenological exploration): Representation of W1 in W3

Reading, Listening, Watching: Representation of W1 in W2

Individual world view: representation of W4 in W2

Theory of speech / Communication: Representation of W3 in W4

10.3 Metaphysical concepts: basic questions

Consciousness / Soul: Mental Default Network

Natural gods: anthropomorphic explanation of physical nature

Creator-God: anthropomorphic explanation of the formation of the world

Ethical God: idealized, supernaturally powerful human being as a moral instance

Morality: code of conduct between people in a society (mathematical game theory shows that cooperative behavior under normal ('happy') conditions is beneficial over purely selfish behavior).

Intelligent being: a living being (biological automaton), who through learning / logical-analogical deduction can plan the future and act accordingly (for example humans)

Non-intelligent being: a living being acting only through innate behavioral patterns (e.g., bee)

Free will: The ability of a thinking being to compare and select one of the different patterns of action is guided by innate emotional drives, e.g. fear, anger, love, hate, hunger, pain, lust, lust for power

Goal: physical: undefined, biological: a condition that an automaton wants to reach, e.g. to satisfy hunger / thirst in living beings, to reproduce oneself, to be healthy = ward off disease (immune system)

Meaning of life: extrapolation of biological patterns of behavior on biological existence, biological meaning of life is the preservation of the species (not the self-preservation).

Eternity: physical: meaningless, our reality is limited in space and time; biological: very long survival of the species (> 100 million years)

Immortality (persistence on earth): Sexual beings are mortal, including protozoa and plants. Bacteria that multiply by germination are potentially immortal. Reproduction occurs by fusion of germ cells based on the chromosome / gene / DNA mechanism. In humans, there is the passing on of information to the next generation via genes (as with other living beings), via memes (memories, history) and techs (technical procedures, behavioral prescriptions).

Form / matter (meso-physics):

Matter: Atoms / molecules with constant composition (fluctuation typ. 1%)

Form: individual objects, composed of individual unified matter and held together by forces (physical / chemical) so that they move and act as a whole.

Shape / matter (macro-physics): objects separated by vacuum and acting as a multi-component system, e.g. a star

Form / matter (micro-physics): objects of identical elementary particles, these are waves (stay according to probability distribution) with different parameters (for example, energy, rest-mass, spin, angular momentum, radius, charges ...)

Randomness / determinism: In micro-physics (quantum mechanics) the objects have a probability distribution and are fundamentally stochastic. In classical physics (meso-physics) the processes are deterministic, but complex systems can show chaotic behavior and thus become quasi-stochastic. Generally, the individual processes in micro, meso and macro physics are not deterministic and can only be predicted statistically.

Past / future: In physics, the time is symmetrical, the associated maintenance size is the energy. CP symmetry is violated with 0.2% (K0-Zefall), as well as T (time). The past is just as fuzzy / unpredictable as the future if it is not recorded (by thinking beings). Life causes here, as elsewhere, a local entropy decrease (information) at the expense of total entropy. In macro-physics, e.g. planet orbits and continental drift recognizable over millions of years in the past and future. The biological world, especially human history, however, being locally entropy-violating, is clearly time-unbalanced.

Space-time: space-time: 4d, curved (embedded in 5d); Lorentz metric (time: +, space);

space: 3d curved (embedded in 4d), cyclic, finite (sphere or icosaedron);

partial world event horizon, time: deSitter universe cyclical with rebound (without singularity);

Our space-time anti-deSitter ($\Lambda > 0$): semi-cyclic (repeated in a parameter-identical parallel universe) finite, beginning= Bing-Bang & inflation & large entropy, end= cold temperature death, time-lapse below the uncertainty relation, small entropy.

11 Philosophy of language and intelligence [JH]

JH 28.8.2018

11.1 Human language

A *human language* is a (second order algorithm) in *communication between autonomous beings*.

Its *syntax* (grammar) is a set of rules about *flexion and order* to enable the extraction of meaning.

Its *semantics* is the *basic symbolic knowledge* acquired by a child during the language-learning process, which is basically the same in all human communities. The semantics is extended by further (mainly verbal) learning until adulthood. The basic symbolic knowledge encompasses notions like mother, fire, run, pain etc.

The semantics is nothing else as the internal representation of reality in humans (and general in biological beings).

Elements (basic semantic elements)

noun= {object, person}

verb=action

adjective=predicate(object)

adverb=predicate(verb)

Evolution of language

Language evolved in parallel (and coupled) with brain evolution, probably originally as gesture language [16]. Atkinson's "best fit" model states that language originated in central and southern Africa between 80,000 and 160,000 years ago [16].

The basic functionality of language is communication (question, imperative: type 3,4) and passing of information (description, action: type 1, 2). The communication aspect has as its purpose support of cooperation, the information aspect has the purpose of developing the internal representation of reality (knowledge).

Fundamental phrase structure

There are three fundamental phrase structures: S, SP, SVO [15]

S (subject) is the simple *indication*: (e.g. child saying dog), which is also used by primates using sounds and gestures [16].

SP (subject-predicate) is a *description* of a static scene (e.g. sky with clouds), or an inner state (e.g. pain).

SVO (subject-verb-object) describes an *action* (e.g. dog chases a rabbit)

Apes can form phrases in non-vocal language with up to 3 different-meaning words, and can have a passive vocabulary up to 2000 words, active vocabulary up to 1000 words (e.g. the gorilla Koko using gesture language and understanding spoken language [32]). Their potential language ability are roughly at a level of a 2-years old human child (bonobo Kanzi [33]).

Human language uses *recursion* in SP and SVO phrases (i.e. sub-phrases), apes are unable to use recursion [33].

The logic of language is *fuzzy* (i.e. in general not bi-valued true-false), e.g. big-small has a fuzzy transition, no sharp boundary.

Ape language has only *one-to-one* correspondence between words and external objects [33].

Humans use *symbols* in language and in knowledge, which represent classes characterized by some predicate (e.g. animals, trees, triangles, numbers).

Acquisition of language

Acquisition of *native language* (in children aged ≤ 3 years) works by *pattern-recognition of real concepts* in parallel with pattern-recognition of *language phrases*: the phrase gives the syntax pattern, the mapping phrase $\rightarrow$ real concept gives the semantics. E. g. the phrase "dog chases a rabbit" maps to the actual real action seen by the child. The *semantics of language* is the fundamental human knowledge, which is basically the same in all human societies. Children which grow up without language cannot learn to speak later (both the medieval monarch Frederick II and Akbar have carried out such experiments with children [16]).

Native learning proceeds in principle by reinforced learning [17].

Learning a non-native language by an adult by *learning the correspondence* native language $\rightarrow$ learned language (the semantics is already fixed).

Functional type of phrase

type1 description: predicate(object)=value (e.g. "sky is blue")

type2 action: subject verb object (e.g. "a dog chases a rabbit")

type3 question: ask for element of type1 or type2-phrase, e.g.

predicate(type1)=? e.g. "what color is the sky?"

verb(type2)=? e.g. “what does the dog do to the rabbit?”

type4 imperative:

verb(type2) != x (e.g. “let person_x leave the room!”)

Learning primitives

Learning by relations [15]

1. COORDINATION dog is the same as hound
2. DISTINCTION a white dog is not the same as a brown dog
3. OPPOSITION a black dog versus a white cat
4. COMPARISON this dog is bigger than that dog
5. SPATIAL that dog is on the left, the other dog is on the right
6. DEICTIC (similar to spatial but in terms of the perspective of the speaker) I am in front of that dog but behind the other
7. TEMPORAL I fed the dog before I fed the cat
8. HIERARCHICAL a dog is a sort of mammal, which is a type of animal
9. CAUSAL if the dog bites me, I will punish it

Flexion (optional, language-dependent):

flexion=relations coded in grammar

verbs: me-thou-he, we-you-they

substantives:

genitive: belonging to, dative: subordinated goal (I gave him money), accusative: direct goal (I hit him),

ablative: subordinated goal (I am using something to...), locative. spatial determinator (on, by something),

vocative: talking to...

Function of human language

-Technical information

Passing technical information (e.g. material properties) or behavioral information (teaching swimming) belong to this category

-Psychic information

Informing about emotions, personal memories and inner states fall into this area.

-Ritual function

Small talk and gossip belong to this category (Wittgenstein calls it “language games” [14])

-Behavioral function

Language, like physical action, and mimics, is part of purposeful behavior in humans, e.g. talking to someone with the purpose of influencing his behavior.

11.2 Evolution of human language

Language evolved in humans as a powerful method of communication to promote cooperation and passing of information, in parallel and in mutual influence with the evolution of brain functionality [55].

Based on DNA-genetic (FOXP2 gene), paleontological, and primate-learning research we can assume, that homo erectus probably possessed limited vocal and mental language capability on the level of stage2 (modern human child aged 1.5 years). Furthermore, Sapiens and Neanderthals have basically the same FOXP2 gene, apart from an intron insertion, which happened very early in Sapiens [59]. From this and FOXP2 mutation studies in modern humans [59] follows, that Neanderthals probably had the language capability of stage3 (modern human child aged 3 years), whereas Sapiens probably from the beginning (~300ky ago) had the language capability of stage4 (modern human child aged 5 years), which gave them an evolutionary advantage over Neanderthals.

Stage5 (symbolic language and thinking) emerged probably around 50-70ky ago [2] [55], and caused a leap in cultural evolution and the second migration of Sapiens to Europe, South Asia and Australia.

Languages obey laws of Darwinian evolution. Darwin treated languages like species, and indeed, languages mutate with time-constant rates, they exchange words, they can merge, undergo selection and extinction.

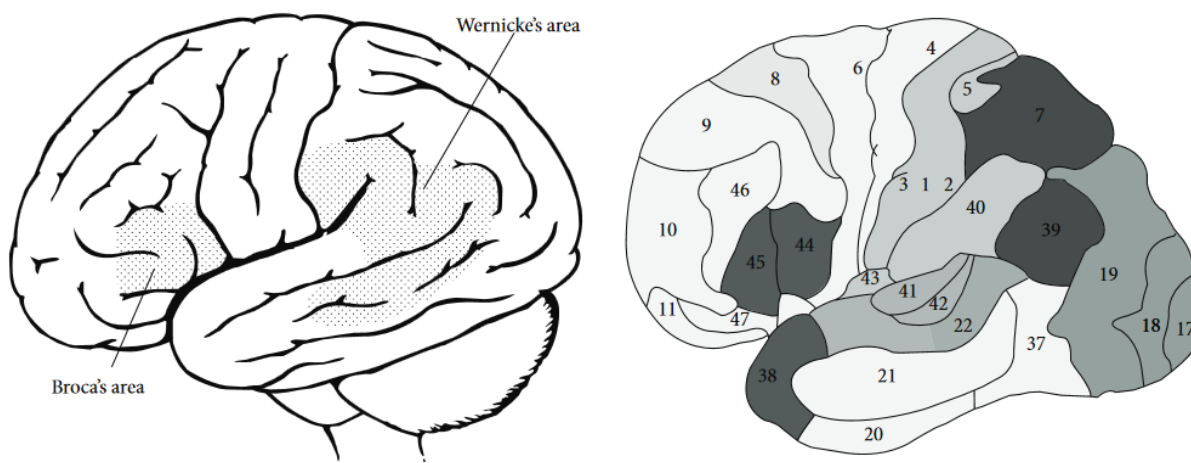
There is an evolution tree for languages, like the biological evolution tree, and extinct parent languages can be reconstructed, e.g. Proto-Indoeuropean (~7ky), Eurasiatic (~12ky). There are fundamental similarities among all languages, so it is plausible that there was once a simple common original language, perhaps similar to the oldest known language of Kho-San (~150ky).

In regard to the origin of language in hominins, there are several hypotheses, the most plausible, and probably effective in parallel are [55]:

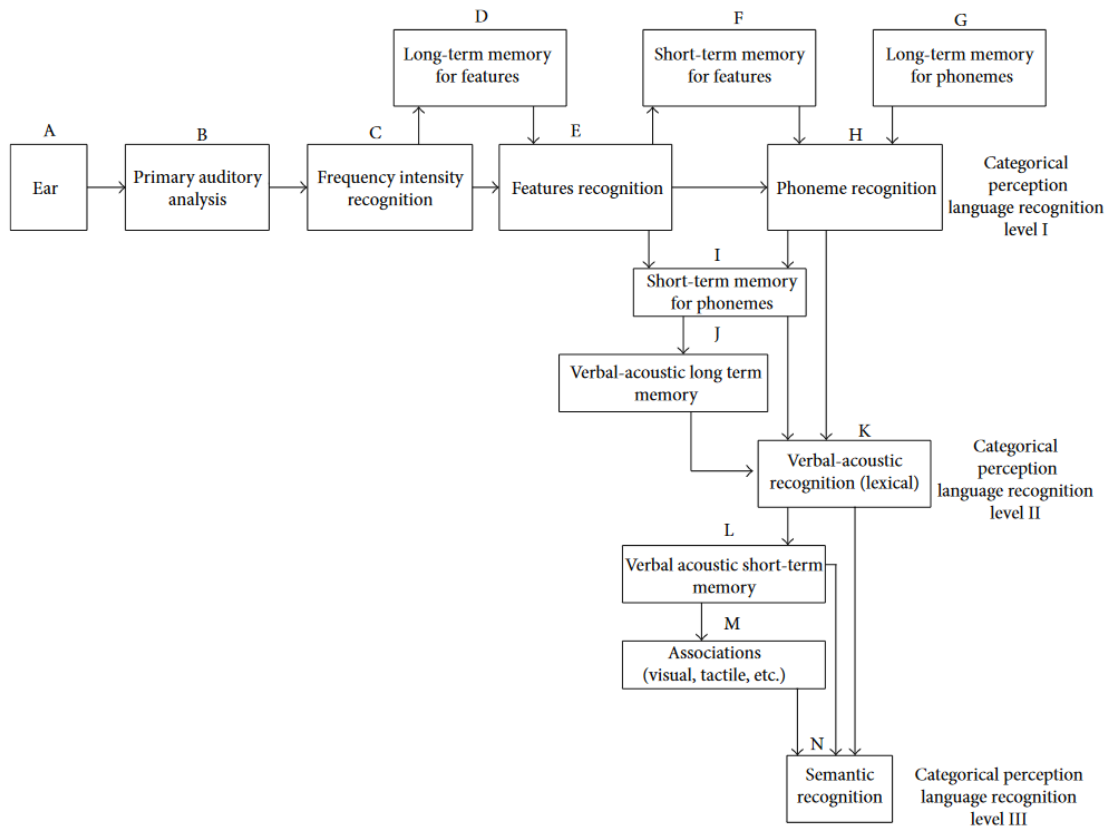
- Language began as imitations of natural sounds, which is supported by the fact that this is even today an important source of new words. Furthermore, there exists “phonetic symbolism” in most languages, e.g. small, sharp, high things tend to have words with high front vowels in many languages (e.g., /i/ in “little”), while big, round, low things tend to include back vowels (e.g., /a/ in “large”).
- Gestures are at the origin of language, and body movement preceded language, and indeed gestures continue playing a significant role in contemporary human communication under certain particular conditions
- Language arose from rhythmic chants and vocalisms uttered by people engaged in communal labor, hunting, or dancing.

Fundamental structure

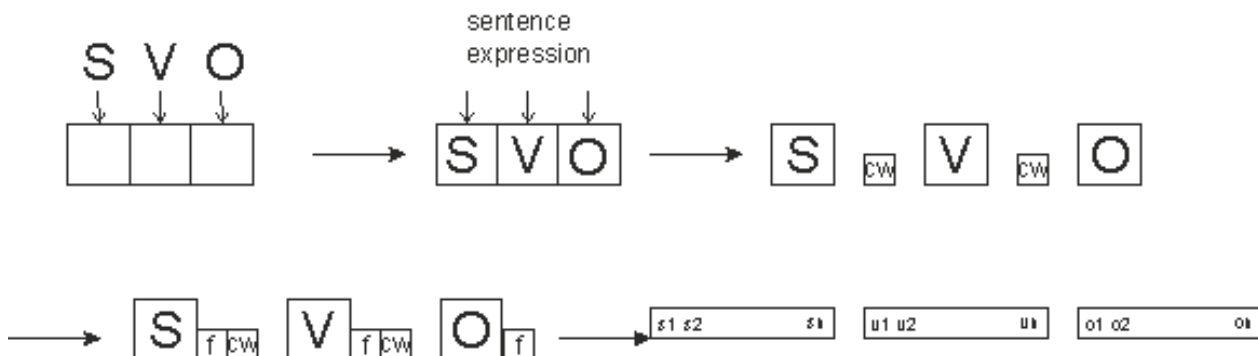
Language is processed by two independent brain processes : lexical/semantic located in the Wernicke area, and grammatical/audio-motoric located in the Broca area .



There are two major areas involved in language: frontal Broca area (BA44, BA45) and temporal Wernicke area (BA22, BA21, BA37, BA39) [55].



Processing of language perception in 3 stages: phoneme recognition, verbal-acoustic recognition, semantic recognition [55].



Processing of language generation in 5 steps: inserting semantic symbols into slots for subject-verb-object, replacing SVO by nested sentence or expression, adding connection words (cw) to express relation, transforming words by inflection (f) according to grammar, sequencing words into phonemes $s_1, \dots, s_n$ $v_1, \dots, v_n$ $o_1, \dots, o_n$ for vocal output [JH]

As was shown by research in neurology of lesions and genetic defects in humans, the Wernicke area is responsible for lexical analysis and semantics (meaning) of words, while the Broca area is responsible for the grammar, syntax, relations between words, and for the vocal combination of phonemes into words during speech generation.

The basic structures of human language is

-subject-predicate (SP) sentence e.g. the man (subject) is big (predicate)

-subject-verb-object (SVO) sentence, e.g. the dog (subject) chases (verb) the hare (object)

where all parts can have local predicates (adjective for noun, adverb for verb) and form a compound

(elementary part+ predicate), and are connected by connecting words, which express their relations. Apart from this, language of stage5 (symbolic) is recursive, i.e. every elementary part, predicate and compound can be replaced by a sentence or by an expression (connected by 'and' 'or' etc.) .

There are main word classes: noun, verb, adjective, adverb, and there are connecting word classes: pronoun (she), preposition (after), conjunction (and), determiner (those), exclamation (oh), particles (look up).

There are grammatical categories: tense (past, present, future), number (singular, dual, plural), gender (masculine, feminine, neuter), noun classes (animated, humane,...), locative relations (cases, particles), persons (I, you), aspects (progressive, non-progressive), modalities (active, passive).

Stage1: primitive communication

Without question, initial human language was similar to the communication systems observed in other hominid primates, such as chimpanzees, orangutans, gorillas, and gibbons.

Chimpanzees use a diversity of gestures (including facial expressions) to communicate, in addition, they have a limited repertoire of vocalizations (they produce about 12 different vocalizations) that can be used for communication purposes with other chimps. Also, chimpanzees can learn some artificial languages (such as using tokens or gestures) and close to about 200 words. Kanzi the human-raised bonobo, has an active token vocabulary of 200 words [33]. Still, primates are unable to learn grammar, and can form sentences of only 2 words with different meaning.

Vocalization is very much present in modern language: people in everyday life frequently use a diversity of noises (vocalizations) to say “yes,” “no,” to express different emotions, to make emphasis, and so forth.

Gestures are equally important in modern communication, so we can assume, that the basic communication for early hominins (*Australopithecus*) took place in the same way as it does for chimps: by gestures and vocalization.

Stage2: initial language 2-word sentences

It was proposed by Bickerton [55], that a protolanguage developed from the original chimp-like gesture-vocalization language, and was used already by *Homo habilis* (~2.4My ago), and later in a refined form (two-word sentences) by *Homo erectus* (~1.8My ago).

This protolanguage corresponded to a certain definite development stage in children aged about 18 month [57] [56].

At around 18 months, children refer to themselves by name.

Those children understand:

familiar phrases like ‘Give me the ball’

simple instructions like ‘Stop that’

very simple explanations like ‘The sun is out, so we need our hats’.

The children know and use **20-100 meaningful words**.

At this stage there is a basic set of phonemes [55] : a o i e g/k n m p/b .

Children use one- or two-word sentences.

Stage3: simple language with SVO-structure, 4-word sentences

At the age of 3 years, another definite stage in the child language is reached [55] [58]. This was probably approximately the language level of Neanderthals and Denisovans.

At this age, children speak in sentences of 3-4 words with SVO or SP structure and are getting better in pronunciation (extended set of phonemes + b l).

In their language there is a basic vocabulary [55] :

pronouns (I), quantities (more), adjectives (big), human distinctions (father), animals (fish), natural phenomena (sun), colors (red).

Children start using words like ‘more’ and ‘most’, as well as words that make questions, like ‘who’, ‘what’ and ‘where’.

Children start to say ‘me’, ‘mine’ and ‘you’, understand the difference between ‘mine’ and ‘yours’.

They start to use grammar and more structured sentences. For example, instead of ‘I go’, the child might say ‘I’m going’. The child uses the past tense – for example, ‘walked’, ‘jumped’, and starts using plurals like ‘cats’ or ‘horses’.

Irregular syntax is still missing. For example, the child says ‘foots’ for ‘feet’, or ‘goed’ instead of ‘went’.

A child can participate in a simple conversation like:

the child says ‘I go shop’, the adult responds, ‘And what did you do at the shop?’ , the child replies ‘Buy bread’.

Children start playing with language through rhyming, singing and listening to stories.

Stage 4: relational language, 9-word sentences

The next definite stage in the child language is reached at the age of 5 years: they use relational language, i.e. the full set of **connecting words**. This was probably approximately the language level of early Sapiens.

At this age [58], children begin to use:

connecting words, like 'when' and 'but'

words that explain complicated emotions, like 'confused', 'upset' and 'delighted'

words that explain things going on in their brains, like 'don't know' and 'remember'

words that explain where things are, like 'between', 'above', 'below' and 'top'.

more adjectives e.g. 'empty' and 'funny'.

They use long sentences of up to **nine words**.

They use increasingly complex sentences by joining small sentences together using words like 'and' or 'because'.

Children begin to use many different sentence types.

For example, they say both 'The dog was chasing the cat' and 'The cat was chased by the dog' to mean the same thing.

They use different word endings. For example, the child can add 'er' to the ends of words, so that words like 'big' turn into 'bigger'.

But they still make some grammatical mistakes – for example, 'They wants to go' instead of 'They want to go'.

They start using past and future tense, and they get better at using the past tense, as well as irregular plurals like 'mice' and pronouns like 'them', 'his' and 'her'.

By this age, children understand and use words that explain when things happen, like 'before', 'after' and 'next week', they start to understand figures of speech like 'You're pulling my leg' and 'They're a couch potato'.

A child will follow directions with more than two steps. For example, 'Give your ticket to the man over there, and he'll tear it. Then we can go to the movie'.

There are still mistakes in pronunciation, like for example, saying 'fing' for 'thing,' or 'den' for 'then'.

Children engage in more sophisticated conversation:

'I went to Max's and we had cake and Max is from my preschool'.

Children begin to use language to tease and tell jokes.

Stage 5: symbolic word representation

Symbolic language and thinking was probably the reason for a leap in cultural evolution and the second migration of Sapiens around 50-70ky ago [2] [55] . At this time, the first objects of art and first symbols (e.g. geometric figures) appear.

This stage corresponds roughly to the literalization stage in modern children at the age of 6-8 years.

At this stage, children learn to map phonemes into letters, and words into written words (which **symbolize** the vocal word).

In languages with pictorial characters (like Mandarin), children learn to represent words by their corresponding characters (again, the pictorial character **symbolizes** the vocal word). In particular, in Mandarin words are syllables. which carry meaning and are represented by pictorial characters (kanzi) and the vocal value consists of one vowel with one or two consonants and a tone (one of 5): the word kǒu (mouth) is pronounced in the falling-rising tone k+o+w and corresponds to the character 口 .

At 5-6 years, children know some or all of the sounds that go with the different letters of the alphabet [58]. At this age, children also learn that single sounds combine together into words. For example, when you put the 't', 'o' and 'p' sounds together, they make the word 'top'.

By six years, children start to read simple stories with easy words that sound the way they're spelled, like 'pig', 'door' or 'ball'. They're also starting to write or copy letters of the alphabet, especially the letters for the sounds and words they're learning.

By eight years, children understand what they're reading. By this age children can also write a simple story.

11.3 Other languages

Computer machine language

A computer control language (first order control algorithm) corresponds to the *neural control* algorithm in an animal.

Elements

load_memory(reg), save_memory(reg), read_sensor, write_actor

log_operate(reg) *logical operation*

jump(reg) *jump to address in register*

arith_operate(reg) *arithmetical operation*

conditional clause if <cond> then <action>

Overall program structure

check inner state, check outer state,

evaluate goal_x (e.g. control_value=temperature)

for goal_x (e.g. constant temperature): if (deviation>threshold) stabilization_procedure(parameters)

Animal neural control

Elements

read_sensor (e.g. auditory) , write_actor (e.g. muscle)

store_memory(experience)

get_memory(experience)

learn_step(neural_network_x)

exec_step(neural_network_x)

check_goal_value(goal_x) (goal= hunger, pain, sex, sleep, curiosity,...)

Overall control structure

for goal_x (e.g. hunger): if (value>threshold) satisfy_goal(parameters) (e.g. look for food)

if <known subgoal> get_memory(experience, parameters) (e.g. crack a nut:if known recall procedure)

if <new subgoal> experiment_learning(parameters) (e.g. crack a nut: experiment to crack)

Animal swarm language

type5 swarm action: e.g. “swarm of fish swims in direction_x”

swarm_action (individual_behavior, parameters)

(here a swarm is a group of *identical* autonomous beings, which is never the case with humans: in a human group *there is always a hierarchy*)

Logic calculus & arithmetic & set theory

logical calculus: atom, subject=name(object), predicate=predicate(object), functor=function(object),

logical operators $\neg \wedge \vee \exists \forall$

set theory language: set, set operators $\cap \cup \subset \in$

arithmetic language: integer , operators + *

Algebraic structure language

group theory: group element, operation *, inverse, unit, operation satisfies group axioms (e.g. associative, inverse)

field: field element, operations * +, unit, zero, negative, inverse, operations satisfy field axioms (e.g. field= rational numbers Q)

Mathematical function language

function f: K->K K field (mostly K=real numbers R or complex numbers C), continuous, differentiable,

solution=zeros of function

Classical mechanics language

classical physical object= {geometry, position, material parameters (e.g. density, elasticity), environment parameters (temperature, pressure), orbit}

Hamiltonian =total energy, variation from minimization principle yields the *Hamiltonian movement equations*

Quantum field language

boson: vector wave function, carrier of interaction, integer spin, vector, normally massless, wave equation

fermion: spinor particle wave function, exerts interaction, spin 1/2, spinor, massive, Dirac equation

interaction described by a Lie-group with commutation relations

Lagrangian density L , equation for wave function from minimization of action $\delta S = 0, S = \int L d^4x$

11.4 Comparison natural language – program language

JH 30.11.2018

11.4.1 natural language

grammar

varying with or without *flexion*, context dependent, diverse *position*

syntax

scheme SVO <subject><predicate subject ><verb><predicate verb ><object><predicate object>

e.g. the dog hunts the hare

scheme SO <subject><predicate subject >

e.g. the mountain is high

semantics

phrases normal, if-clause, question, command

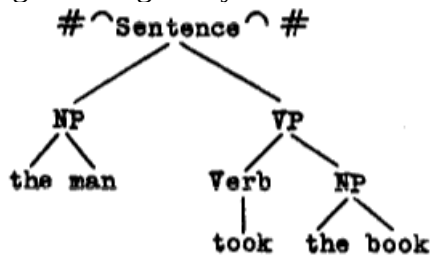
Semantics is learned in childhood (basic life experience) in parallel with language acquisition and is *universal* for humans (as opposed to language, which community-dependent)

processing

[48, 50]

word-analysis from morphemes

parsing: building the syntax tree from the grammar



e.g.

semantic analysis: lexical semantics (find meaning in database), named entities recognition (recognize proper names), relationship extraction (e.g. who is married to whom), word sense disambiguation

goal

information receiving, information sending,

initiation of action,

description of reality,

description of psyche

objects

representation of *reality data* (e.g. animal, mountain)

representation of *mental data* (e.g. emotions, moral qualities, human behavior, human tools)

representation of *ideas* (e.g. velocity)

11.4.2 program language

grammar

context independent

syntax

rule controlled productions (e.g. Backus-Naur form of Algol [47])

semantics

machine-oriented: action(source,destination) e.g. load reg from memory, write reg to storage

function-oriented: function(params)->return_value

processing

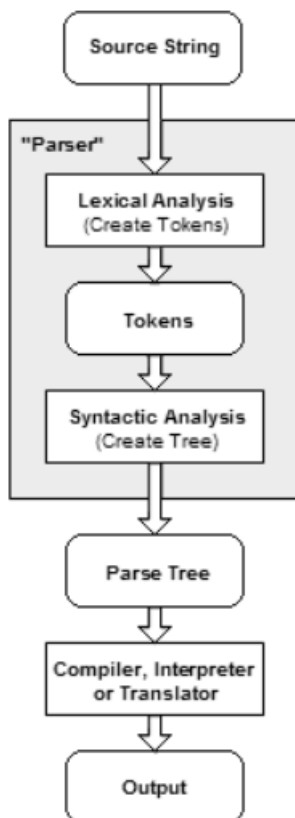
[49]

lexer: extracts words from text

parser: forms syntax tree= representation of procedure call

e.g. c=Plus(a, b)

compiler: generates machine code for procedure



goal

operation(object): search, calculation, input/output

objects

structure(table, list, text, image), *element*(number, logical, character)

11.4.3 neural network language

grammar

context independent

syntax

output=operation(input)

semantics

phases: learning, recognition

operations: input, output, forward to next layer, activation function, update weights

objects

pattern, *image*, *fuzzy-value*

goal

pattern recognition

12 Philosophy of society and ethics [JH]

12.1 Societies as biological communities

A society in a general sense is a community of biological individuals with a behavioral model and a goal. Biological communities compete with each other with regard to the adaptation to the environment and evolve under natural selection. The behavioral model is a set of rules determining the interactions, and the goal is the “fitness” criterion which is to be optimized.

Basic types of biological communities are:

Multicellular organism

A multicellular organism consists of cells with identical genotypes, but different functionalities (grouped as organs) controlled by biochemical (enzymes) and electrical (nerves) signals. The goal is maximum reproduction of the organism. The behavioral model is the interaction of organs within the organism determined genetically by its genotype (DNA).

Species

A species is an ensemble of genetically similar, but slightly different biological individuals, which can interbreed sexually. The behavioral model is inter-species interaction (mating, offspring care, rivalry and cooperation), the goal is survival and evolutionary fitness of the species.

Animal groups

An animal group is an ensemble of animals of the same species, which live together. The behavioral model consists of (mostly genetically fixed) rules of cooperation, rivalry, submission and domination. The goal is increased survival time and evolutionary fitness. Example: a chimpanzee clan.

Human society

A human society is a community of humans, which cooperate, speak a common language (usually) and consider themselves an entity separated from other societies. It has a *goal* (surviving and evolving in competition with other societies) and an organization (*social structure* and a behavioral model=*ethics*). Furthermore, it has a *judicial framework* (in modern societies: a constitution and a civil and penal law) and a *social ideal* (an ideal social model to strive for).

The fitness (well-being and competition strength) of a society (modern: nation) shows in the course of history, when a “fitter” society influences, subdues and possibly absorbs the less fitter ones. In order to assess the fitness, a short time criterion, a *valuation*, is needed. In modern sociology/economics, different valuations are used: economic performance, political stability, freedom index, contentment index. Of these, the contentment index, or simply “the average happiness” seems to be the best candidate. It is measured with sufficient reliability via opinion polls.

12.2 Society models and ethics

First, the most important *ethics models* (behavioral models) are presented [51]. The list is by no means complete, of course, and is only a rough characterization of main types.

Tribal ethics

The tribal ethics is the fundamental human behavioral model. The basic rules are:

loyalty and solidarity within the group, adherence to the traditional rites and customs, physical and sexual violence within the group is forbidden, special cooperation and love within the family, violence and aggression towards other non-allied groups is allowed and even demanded.

The Islamic ethical model is arguably extended tribal ethics, where the notion of the group is extended to the whole believer community (Arabic *umma*).

Christian ethics

The Christian ethic is the moral canon of the Christian Gospel plus the Ten Commandments. It demands: love for the neighbor, forgiveness and non-violence.

Buddhist ethics

The Buddhist ethics is the moral canon of the Buddhist Eightfold Way. It demands: self-restraint and discipline towards oneself; trust, respect, pity, absolute non-violence towards others.

Confucian ethics

The Confucian ethics is the moral canon of China during most of its history. It influenced also Japan, Central Asia and South-East Asia. It extends the original family ethic to the whole society: respect and obedience for parents and superiors, cooperation and care for those in need, control of emotion and aggression, esteem for and pursuit of knowledge.

In the following several *society models*, historical, modern and current ones are presented. The two historical models represent the past only very roughly, but for our epoch, only the modern and current ones are important [18].

Historical: tribal society

The tribal society is the social model of the hunter-gatherer society, i.e. the first social model in the history of our species. The tribal/clan group is led by a *chief*, basically elected. There is a common language and a set of characteristic rites, customs, and myths (*traditional knowledge*) supervised by a *priest/shaman*, which are to be followed and passed on to future generations.

The *ethics* of this group is the fundament of human ethics in any human society. The basic rules are: loyalty and solidarity within the group, adherence to the traditional rites and customs, a ban on physical and sexual violence within the group, special cooperation and love within the family, violence and aggression towards other non-allied groups is allowed and even demanded. The *social ideal* is: control of resources and successful defense/expansion, successful reproduction/growth of the group, stable social structure and continued traditional culture.

Historical: hierarchical class society

The hierarchical class society is the social model of the early urban communities, continued in an extended form up to the Middle Ages. The social structure is the caste system: warriors, priests, merchants/artisans in the cities, peasants in the countryside. It has a (originally polytheistic) religion and a legal system (originally unified religious, penal and civilian law).

The *ethics* is basically the tribal ethic plus the religious and legal rules.

The *social ideal* is: stable social structure and behavior according to the ethics, submission of other societies and expansion outside.

Modern totalitarian: fascist society

The fascist society (mostly in Europe and South America in the first half of the 20th century) is a hierarchical dictatorial society which suppresses minorities, enforces obedience by coercion (secret police), promotes military-like discipline. The fascism is aggressive towards non-allied neighbor societies, in the economy it promotes technological progress, state-supervised market economy and respects private property. The *ethics* is basically the tribal ethics. The *social ideal* is a homogeneous disciplined military-like society which subdues neighbors and expands by military power.

Modern totalitarian: communist society

The communist society emerged as a reaction to the conflict between the bourgeoisie and the industrial workers in Europe and America in the second half of the 19th century, became the ruling social model in Eastern Europe, Soviet Union and Asia, the socialist nations formed the powerful Eastern Block in the middle of the 20th century. After its downfall in the 1990's the communist societies transformed into social-market democracies or into market-autocratic societies (Russia, China), except some relics like North-Corea and Cuba.

It is an egalitarian dictatorial society, with state-controlled economy and restricted private property; it promotes technological progress and mass education. Loyalty to the regime is enforced by secret police.

The *ethics* is basically the tribal ethics with enhanced solidarity and loyalty to the community. The *social ideal* is a utopian strictly egalitarian, disciplined society without private property, and a new type of citizens, who put the community interest above personal interest.

Traditional-totalitarian: Islamic society

The totalitarian Islamic society was established or strengthened in many Islamic countries after the Iranian Islamic Revolution of 1979 as a reaction to the post-colonial oppression by Christian US and European countries, combined with the traditional Muslim aversion to the Christian West.

It is a religious-dictatorial society with sexual restriction, suppression of women, minorities, and other religions. Loyalty to the regime is enforced by religious police. The Islamic society is not actively supportive towards education and technological progress. The valid law is the Islamic (penal) *Sharia-law*, the economy is basically the Islamic model of *bazaar-economy*.

The *ethics* is basically tribal with addition of Islamic religious practices. The *social ideal* is a religiously homogeneous disciplined society with strictly religiously controlled behavior inside the society, and outside with submission and religious conversion of non-Islamic societies.

Modern: social-market-democratic society

The social-market-democratic society emerged after the Second World War in democratic European countries as a variant of the original capitalist society of the late 19th century with the addition of a social-security-system. It is a representative democracy with several political parties, with independent jurisdiction, free media

and guaranteed freedom of speech. The valid law is rooted in the constitution and complemented by a penal, civil and economic legal framework.

The economy is a free-market economy with public social insurance, public healthcare, public education and transport system. The *ethics* is basically the Christian ethics (Europe) or the Buddhist ethics (Asia). The *social ideal* is a democratic society with real tolerance and freedom of speech, lack of corruption, low crime-rate, high education and economic success. The political parties have political programs, which shift this social ideal in the direction socialist-state-controlled or conservative-private-controlled.

Modern: private-market-democratic society

The private-market-democratic society is the original capitalist society of the late 19th century, which basically continued in the US until today, without public social security and healthcare, and largely privatized infrastructure and partly privatized education. It is a presidential representative democracy with two main political parties, with independent jurisdiction, free media and guaranteed freedom of speech. The valid law is rooted in the constitution and complemented by a penal, civil and economic legal framework.

The economy is a free-market economy with private social insurance, private healthcare, public and private education and private transport system. The *ethics* is basically the Christian ethics. The *social ideal* is a democratic society with real tolerance and freedom of speech, lack of corruption, low crime-rate, high education and economic success, with minimum state intervention. The main political parties are more or less Christian-conservative by European standards.

Modern: market-autocratic society

The market-autocratic society emerged in the 1990's in the post-communist China and Russia as a market-economy ruled basically by an oligarchy. It has basically a one-party political system, with a partially state-supervised market economy, with state-controlled social security, healthcare, education, infrastructure. Political dissidents are isolated and persecuted, there is a systematic electronic supervision of the population, especially in China. In spite of the lack of democracy, the economy is performing well, especially in China.

The *ethics* is basically the Christian ethics (Russia) and the Confucian ethics (China). The *social ideal* is a benevolent-autocratic society with lack of corruption, moderate income gap, security, broad political consensus and economic success.

12.3 Social dynamics in human societies

Obviously, the dynamics in human societies and in politics is a statistical phenomenon, *individual social variables* like income, life expectancy, crime rate, educational index, contentment index, health index, are random variables (not necessarily independent) with a distribution (mostly gaussian), an average and a standard deviation.

Furthermore, there are *economic global parameters* like tax rate, wealth advantage, debt coefficient, and *social class parameters*: class distribution of average individual social variables, class dominance index, class permeability index [27, 28].

Also, abrupt changes in a society: social unrest, civil war, violent takeover of power, are similar to phase transitions in a physical system, e.g. freezing of water, and can be described by the same mathematics: an important parameter (physical: temperature, social: average income) reaches a critical value, and an abrupt transition to a new state takes place [25].

In economics, there are behavioral-statistical models of a society, which successfully explain the time behavior of key economic variables (e.g. wealth distribution), with a few economic global parameters (e.g. *affine wealth model* with 3 global parameters: tax rate χ , wealth advantage ζ , debt coefficient κ [25])

Similar behavioral-statistical models with parameters like those above, can simulate socio-political development of societies across history with good results [26]. The values of global economic and social parameters and distribution of individual parameters are extracted by fitting to the known data in the past. These can then be used to make a prognosis for different socio-political strategies.

12.4 Individual action within a human society

As outlined above, a human society is a statistical dynamic system with a large number of individuals, so individual action has only small effect on the system.

From this point of view, individual action can only be effective

- by participating in an important social group, e.g. in a political party
- if the individual has a high 'influence index' (political power or influence in the media)
- by entering and amplifying a socio-political 'trend' near a critical global parameter value, e.g. the role of the Bolsheviks in the October Revolution in Russia in 1917

12.5 Religion and society

Religion is a “built-in” part of our psyche, therefore a powerful factor also in social behavior [51].

Religion is a *primeval explanation of reality* and a guideline in social behavior, with a *dogmatic approach* to both the physical and the psychic-social world. In this approach there is no check against reality, this is even forbidden, because religion asserts *divine superhuman authority*, which must not be challenged within religion. The rational approach, with its continuous *verification of assertions against reality*, is completely contrary to it, so the two approaches are in permanent conflict, with the religion retreating more and more into the less explored aspects of reality, e.g. psychology, brain functionality, ethics, aesthetics.

Religion has basically three aspects

-Ethics

Ethics is a norm of social behavior and psychic self-control, which every religion contains, and for which it claims divine authority. Archeological evidence shows that religious ethics developed in the urban communities of the agricultural revolution about 10000 years ago [2], based on the ancient tribal ethics of the hunter-gatherer societies. The universal religions Buddhism, Tao-Confucianism and Christianity with their high-level ethics originated in the classic antiquity 500BC-100 AD .

Modern research in sociology and psychology mostly supports the positive influence of religious ethics in both areas, and there is also no intersection and therefore no conflict with the physical-rational worldview.

-Concept of the world

Every religion contains an *interpretation of the world*, e.g. Christianity has its heaven, purgatory and hell (with physical locations), Buddhism has its Nirvana and the transmigration of souls. Some religions encompass also an *interpretation of the world origin*, e.g. Judaism with the Old Testament, and in general all natural religions of hunter-gatherer societies.

Most religions, among them also Christianity, contain as well a *supernatural version of history* with wonders, direct spiritual interaction with reality, etc.

Both the religious interpretation of the physical world, and supernatural version of history are in *direct conflict with the physical* concept of reality and are incompatible with the physical-rational worldview.

-Spiritual reality

Another basic aspect of religion is its spiritual belief: it is an early *interpretation of internal (psychic) and external reality*.

On the one hand, it contains the concept of a *superhuman non-material power*, which interacts with the material reality (*God or gods*). On the other hand, it contains the concept of a *non-material immortal soul*, located in every human.

Both concepts are *primeval explanations of reality*.

The first concept of God is one of *extended anthropomorphic (intelligent) designer and creator of complex physical and natural phenomena* and, in fact, of the complex reality itself. It is extended in the sense of elimination of physical and psychological limits: immortality, omniscience, omnipotence etc. which lead immediately to physical-rational, but also to logical contradictions (e.g. Russel paradox about the set of all sets).

The second concept of soul arose firstly probably as an *extended anthropomorphic projection of human consciousness*, which is continuous and (apart from sleep) life-long. It is extended in the *sense of elimination of the time-limit* of biological existence. Current research in human and primate brain functionality and consciousness indicates that only humans among the primates are aware of the inevitableness of death [32, 33]. It arose secondly probably as a simple interpretation of the *high superiority of humans* with their intelligence, language and social organization, as compared to all other biological organisms.

Both concepts (God and soul) are part of the traditional concept of *spiritual-material dichotomy* of the world, originating in the Cartesian philosophy of the 17-th century, but both are in fact very ancient (at least 70000 years with the emergence of symbolic thinking and sophisticated culture [2]), as we can infer from archeological and ethnological research.

Both concepts require an *interaction between the material and the spiritual world*, which must

- either be connected with a flow of energy, and would be detectable, which is not supported by evidence
- or is undetectable but active, and therefore in contradiction to physics

Therefore the whole concept of *spiritual reality is incompatible* with the physical-rational worldview.

13 Outer and inner world

JH 08/2023

Humans are biological beings, subjected to the laws and goals of evolution.

The laws are the basic functionality of terrestrial life on cellular and multicellular level [13].

The goals are the goals of the Darwinian evolution: survival of species, survival of individuals, reproduction.

Humans, as all higher animals, possess a brain and a nervous system, functioning on the principle of neural networks, and functioning as the control system to ensure homeostasis and attaining the evolution goals.

The brain is basically a state-automaton, which is operating in two worlds: the external world of the physical reality, and the internal world of sensorial images, motoric actions, emotions (goal-oriented valuation of sensorial images), and psychic states [52].

13.1 World description

Outer physical world

The **outer physical** world is described by the mathematical models of theoretical physics [8]: minimization principles (of the corresponding action=integral over Lagrangian density), resulting equations of motion (classical Euler-Lagrange-equations, quantum Dirac equation, Einstein equations, Navier-Stokes equations, heat flow equation): those are partial-differential equation of order 2, Lie-group theory describing gauge fields in the Quantum Field Theory, mathematical statistics in thermodynamics.

Inner neural world

The **inner neural** world is described by the mathematical models of discrete-output spiking recursive generative transformer (GPT) neural networks [73] [89] [90].

The functionalities are:

-conscious verbal(declarative/analytical) process

This process follows the structure and semantics of language sentences.

action SAO sentence: subject(predicate) action(predicate) object(predicate)

description SP sentence: subject predicate

-half-conscious procedural/intuitive pattern-oriented process

This process is recalling patterns (visual, audial), searching for similar patterns, and completing partial patterns

-half-conscious procedural/intuitive episode-oriented process

This process is recalling episodes, comparing episodes, imagining new episodes

GPT neural networks like LaMDA [89] [90] are capable of human conversation in natural language, and pass the Turing test for human-like intelligence. They are also capable of human-like emergent analogical reasoning [91], in other words, they reproduce human conscious verbal processes.

GPT neural networks have also conventional pattern-recognition and hierarchy-formation capabilities of conventional neural networks [73].

These functionalities are a sufficient foundation for the emergence of procedural/intuitive and declarative/analytical processes in the human cortex [52].

The entities of the inner neural world are

-emotions

-symbols, with predicates: sensorial(red), physical(stone), social(friendship), emotional(hatred), spatial-geometrical(triangle), arithmetic(three), temporal(year)

-persons, with predicates: face, behavior, personal relation

-episodes, with predicates: location, time, environment, involved persons

-goals, with predicates: status, power, security, wealth, work skills, social skills, erotic-emotional happiness

The entities belong to networks and hierarchies:

symbol-class (hierarchy) -> symbol -> network(related symbols)

person -> network(related persons, related episodes)

episode -> network(related episodes, related persons, related environments)

Table of entities and functionalities

neural function	function predicate
verbal action SAO	subject, subject-predicate, action , action-predicate, object, object-predicate
verbal description SP	subject , predicate
intuitive pattern-oriented	recalling, searching , completing patterns
intuitive episode-oriented	recalling, comparing, imagining new episodes

neural entity	entity predicate
emotions	
symbols	sensorial(red), physical(stone), social(friendship), emotional(hatred), spatial-geometrical(triangle), arithmetic(three), temporal(year)
persons	face, behavior, personal relation
episodes	location, time, environment, involved persons
goals	status, power, security, wealth, work skills, social skills, erotic-emotional happiness

Outer social world

The outer social world is defined by the behavioral network of human society, specifically by the contact group of an individual, which consists of ca 150 persons (about the size of a primeval human group). It is described by statistical-behavioral models, which cover patterns of behavior with their statistics, i.e. behavior and communication patterns in family environment, at workplace, in leisure activities. Interaction in social context happens exclusively by written or spoken communication in a language.

13.2 World context

The context of a mathematical model are the elements, variables and the functions of the model, e.g. in a group the elements are the group elements and the function is the group multiplication.

The **context of the physical** world [8] are the physical state variables (energy, momentum, angular momentum, entropy, temperature, pressure, space-time location, metric) , movement equations, material equations, equation-of-state, described by linear laws (e.g. elasticity law) or differential partial equations (e.g. Euler, Maxwell) in time t and location vector $\vec{x}$ order one or two, for scalars (density ρ) and vectors (force $\vec{F}$, velocity $\vec{u}$).

The physical world exists on three scales:

meso-scale (0.1mm-1000km)controlled by classical physics (mechanics, electrodynamics/optics, thermodynamics);this is our life environment.

-micro-scale (<100nm) =quantum scale controlled by quantum mechanics and Standard Model

-macro-scale (>10000km)= astrophysical scale controlled by gravity, astrophysics and cosmic Lambda-CDM model.

Concise description of the meso-scale physics

Meso-scale physics is described by linear laws (e.g. elasticity law) or differential partial equations (e.g. Euler, Maxwell) in time t and location vector $\vec{x}$ order one or two, for scalars (density ρ) and vectors (force $\vec{F}$, velocity $\vec{u}$)

chemical: law of mass action $K = \frac{[A']^{\alpha'} [B']^{\beta'} \dots}{[A]^{\alpha} [B]^{\beta} \dots}$

solids: elasticity law $\sigma = E\varepsilon$

fluids: Euler equations $\frac{\partial \vec{u}}{\partial t} + (\vec{u} \cdot \nabla) \vec{u} = -\frac{\nabla p}{\rho} \quad \nabla \cdot \vec{u} = 0$

gas: ideal gas $pV = RT$

force & movement: Newton $\vec{F} = m \frac{d^2 \vec{x}}{dt^2}$

electromagnetic: Maxwell

$$\nabla \cdot \vec{E} = \frac{\rho}{\epsilon_0} \quad \nabla \cdot \vec{B} = 0$$

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} \quad \nabla \times \vec{B} = \mu_0 \left(\vec{J} + \epsilon_0 \frac{\partial \vec{E}}{\partial t} \right)$$

The **context of the neural** world [52] [73] are the psychic-verbal entities , their types, their networks and their hierarchies.

-the evolution goal functions

survival probability, reproduction rate, energy supply and feeding rate,

-sensorial and learning functions

sensory input, motoric action, goal enforced learning, memory storage, goal-oriented valuation (emotion), purpose, goal-oriented planning,

-genetic functions

individual evolution, species evolution, species-specific genotype and structure and behavior.

The **context of the social** world is the behavioral network of human society, specifically by the contact group of an individual.

The corresponding models are statistical-behavioral Markov-models with goal-oriented behavior with statistical parameters, which deal with behavior and communication patterns in family environment, at workplace, in leisure activities.

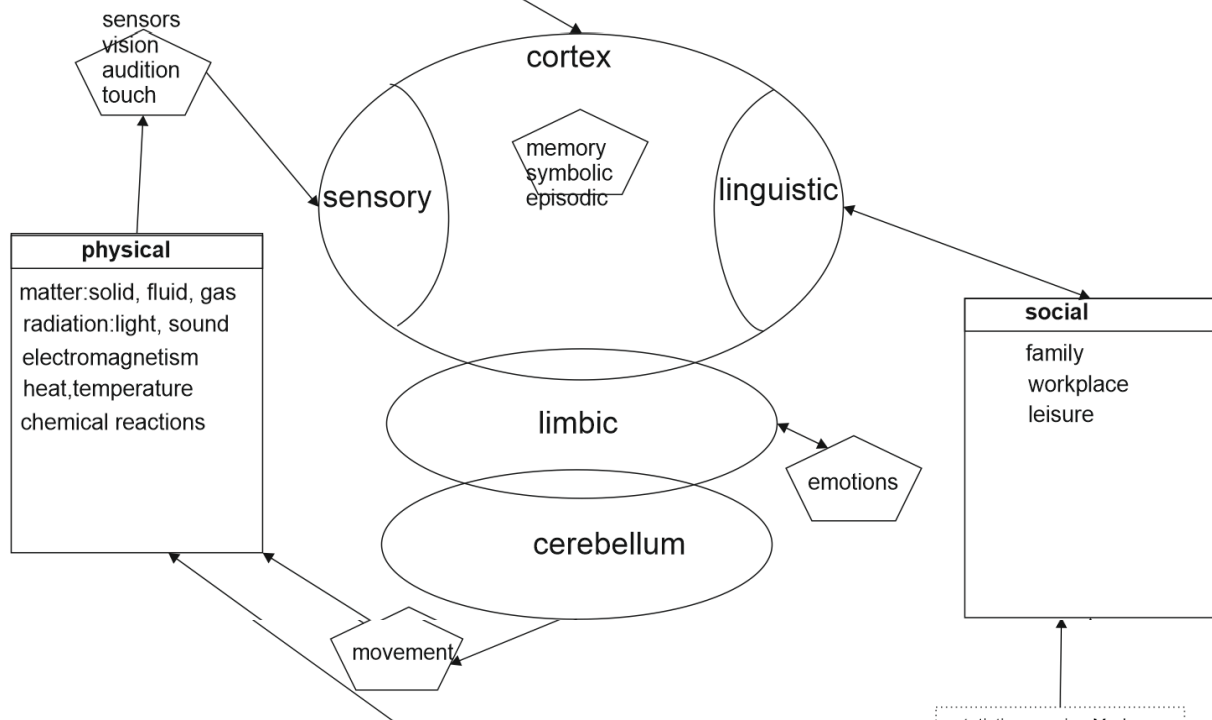
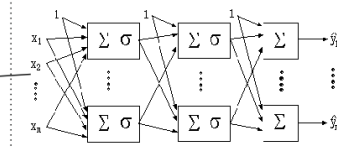
Interaction in social context runs by written or spoken communication in a natural language.

13.3 Schematics physical, social, neural world

neural entity	entity predicate
emotions	
symbols	sensorial(red), physical(stone), social(friendship), emotional(hatred), spatial-geometrical(triangle), arithmetic(three), temporal(year)
persons	face, behavior, personal relation
episodes	location, time, environment, involved persons
goals	status, power, security, wealth, work skills, social skills, erotic-emotional happiness

neural function	function predicate
verbal action SAO	subject, subject-predicate, action, action-predicate, object, object-predicate
verbal description SP	subject, predicate
intuitive pattern-oriented	recalling, searching, completing patterns
intuitive episode-oriented	recalling, comparing, imagining new episodes

neural: spike recursive GPT-nn



mass action

$$K = \frac{[A']^{\alpha'} [B']^{\beta'} \dots}{[A]^{\alpha} [B]^{\beta} \dots}$$

solid:elasticity

$$\sigma = E \varepsilon$$

fluid:Euler

$$\frac{\partial \vec{u}}{\partial t} + (\vec{u} \cdot \nabla) \vec{u} = -\frac{\nabla p}{\rho} \quad \nabla \cdot \vec{u} = 0$$

gas

$$pV = RT$$

movement: Newton

$$\vec{F} = m \frac{d^2 \vec{x}}{dt^2}$$

electromag. Maxwell

$$\nabla \cdot \vec{E} = \frac{\rho}{\varepsilon_0} \quad \nabla \cdot \vec{B} = 0 \quad \nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} \quad \nabla \times \vec{B} = \mu_0 \left(\vec{J} + \varepsilon_0 \frac{\partial \vec{E}}{\partial t} \right)$$

14. Quantum and classical reality

JH 10/2021, [75] [79]

14.1 Quantum and classical physics

Quantum and classical regimes differ basically in three respects.

-continuous and discrete

Classical variables are continuous-valued, quantum variables are in general discrete-valued

-deterministic and probabilistic

Classical variables are sharp-valued functions of space-time and parameters, e.g. temperature distribution has the form $T(\vec{x}, t)$. Classical objects move on sharp orbits $\vec{r}(t)$, which obey equation-of motion (eom), which is in general a partial differential equation in t of order 2.

Quantum objects are represented by a wave function, which yields a probability density

$$\psi(\vec{x}, t) = \sum_{i=1}^n \alpha_i \psi_i(\vec{x}, t) \quad \text{with eigenfunctions } \psi_i(\vec{x}, t) \text{ of a quantum variable } Q, \text{ where } |\psi|^2 = \int |\psi(\vec{x}, t)|^2 d^3x = 1,$$

and they possess an inherent uncertainty standard deviation $\sigma(\psi, t) = \sqrt{\int |\langle \psi \rangle - \psi(\vec{x}, t)|^2 d^3x}$.

Quantum variables are represented by expectation values for a given wave function

$$\langle \psi | Q | \psi \rangle = \int \psi^*(\vec{x}, t) (Q\psi(\vec{x}, t)) d^3x$$

-functions and operators

Classical variables (e.g. temperature $T(\vec{x}, t)$) are functions of space-time and parameters, quantum variables are operators, which map wave functions into wave functions (e.g. the non-relativistic energy operator is the

$$\text{Hamiltonian } -\frac{\hbar^2 \Delta}{2m} + V(\vec{x}).$$

The transition from quantum regime to the classical regime has the following properties.

1 Quantization with Planck constant

The starting point of quantum mechanics was the quantization of action $S = Et = n\hbar$ in units of the Planck

constant h , resp. its variant $\hbar = \frac{h}{2\pi}$, the reduced Planck constant (Planck 1905), later extended to the angular

momentum $\vec{L} = \vec{p} \times \vec{x} \quad |\vec{L}| = \sqrt{l(l+1)\hbar}$ (Bohr 1913, Bohr-Sommerfeld 1916).

Formally, the transition from the quantum to the classical regime is carried out by the transformation $\hbar \rightarrow 0$ in functions and commutator relations, respectively $\hbar \nabla \rightarrow i\vec{p}$ in differential equations and in Hamiltonian.

2 Hamiltonian and equation-of-motion in quantum and classical regime

Schrödinger equation and Hamiltonian in quantum regime

In quantum mechanics, the fundamental equation-of-motion is the time-dependent and the time-independent Schrödinger equation

$$i\hbar \frac{d}{dt} |\psi(t)\rangle = \hat{H} |\psi(t)\rangle \quad \hat{H} |\psi\rangle = E |\psi\rangle$$

$$\text{with the Hamiltonian } \hat{H} = -\frac{\hbar^2}{2m} \nabla^2 + V(\vec{x})$$

The Schrödinger Hamiltonian results from the classical Hamiltonian by the transformation $\vec{p} \rightarrow \frac{\hbar}{i} \nabla$

with valid general solution $\psi(\vec{x}, t) = \sum_k A_k \psi_k(\vec{x}) \exp(-iE_k t / \hbar)$ as a series in energy eigenfunctions.

Because of preservation of angular momentum Ψ is separable $\psi(r, \theta, \varphi) = R(r) Y_l^m(\theta, \varphi)$, where $Y_l^m(\theta, \varphi)$ are eigenfunctions of angular momentum L^2 and L_z with eigenvalues $L = \sqrt{l(l+1)\hbar} \quad l = 0, 1, 2, \dots$

$$L_z = m\hbar \quad m = -l, \dots, +l$$

Basic results:

Quantum harmonic oscillator $\hat{H} = \frac{\hat{p}^2}{2m} + \frac{m\omega^2 x^2}{2}$ $E_n = \hbar\omega\left(n + \frac{1}{2}\right)$

$\psi_n(x) = \frac{1}{2^n n!} \left(\frac{m\omega}{\pi\hbar}\right)^{1/4} \exp\left(-\frac{m\omega x^2}{2\hbar}\right) H_n\left(\sqrt{\frac{m\omega}{\hbar}}x\right)$, where H_n are Hermite polynomials

Hydrogen atom $\hat{H} = -\frac{\hbar^2}{2m}\Delta - \frac{Ze^2}{4\pi\epsilon_0 r}$ $E_n = -\frac{e^4 m}{2(4\pi\epsilon_0)^2 \hbar^2} \frac{Z^2}{n^2}$

$\psi_{nlm}(r, \theta, \varphi) = R_{nl}(r) Y_l^m(\theta, \varphi)$ $R_{nl}(r) = \sqrt{\left(\frac{2Z}{na_0}\right)^3 \frac{(n-l-1)!}{2n(n+l)!}} \exp\left(-\frac{\rho}{2}\right) \rho^l L_{n-l-1}^{2l+1}(\rho)$

$\rho = \frac{2Zr}{na_0}$ relative radius, a_0 Bohr-radius, $L_{n-l-1}^{2l+1}(\rho)$ Laguerre polynomials, $Y_l^m(\theta, \varphi)$ spherical functions

with the average orbit $\langle r(\theta) \rangle = \rho_0 m_\rho(n, l) (Y_l^0(\theta, 0))^2$ and its width $\sigma(\theta) = \rho_0 s_\rho(n, l) (Y_l^0(\theta, 0))^2$ and

$\rho_0 = \frac{na_0}{2Z}$ elementary radius

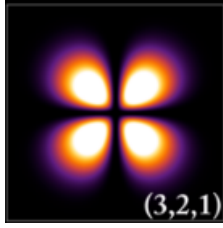
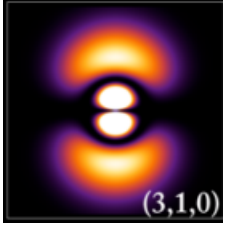
where e.g. $m_\rho(1, 0) = 1$ $m_\rho(2, 0) = 1$ $m_\rho(2, 1) = 3$ $m_\rho(3, 0) = 3$ $m_\rho(3, 1) = 5$

$s_\rho(1, 0) = 1$ $s_\rho(2, 0) = \sqrt{3}$ $s_\rho(2, 1) = \sqrt{3}$ $s_\rho(3, 1) = 3$ $s_\rho(3, 2) = \sqrt{5}$ [84]

Hydrogen wave function [81]

(n, l, m)=(3,1,0)

(n, l, m)=(3,2,1)



Particle in a box $V(x) = \begin{cases} 0 & x_c - \frac{L}{2} < x < x_c + \frac{L}{2} \\ \infty & \text{elsewhere} \end{cases}$ $\hat{H} = -\frac{\hbar^2}{2m} \frac{\partial^2}{\partial x^2} + V(x)$ $E_n = \frac{n^2 \pi^2 \hbar^2}{2mL^2}$

$\psi_n(x, t) = \begin{cases} A \sin\left(k_n\left(x - x_c + \frac{L}{2}\right)\right) \exp(-i\omega_n t) \\ 0 \end{cases}, \quad k_n = \frac{n\pi}{L}$

Hamilton equations in classical regime

From the Hamiltonian equations

$$\frac{dq}{dt} = \frac{\partial H}{\partial p} \quad \frac{dp}{dt} = -\frac{\partial H}{\partial q}$$

with $H = \frac{|\vec{p}|^2}{2m} + V(\vec{x})$

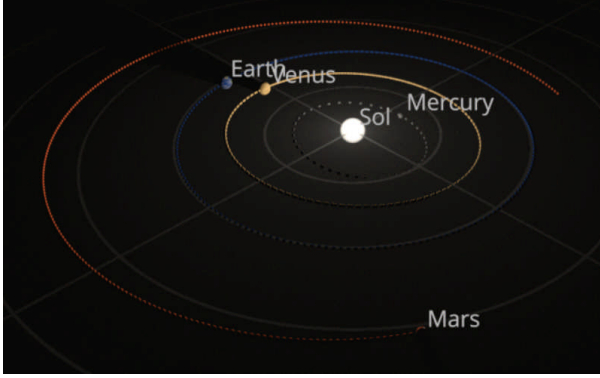
follow definition of momentum and **Newtonian equation-of-motion**

$$\frac{d\vec{x}}{dt} = \frac{\vec{p}}{m} \quad \frac{d^2\vec{x}}{dt^2} = -\nabla V(\vec{x}) \quad \text{which yields the orbit } \vec{x} = \vec{x}(t) \text{ as solution}$$

Basic results:

Harmonic oscillator $V(\vec{x}) = \frac{k}{2} x^2$ solution $x(t) = A \cos(\omega t + \varphi)$

Gravitational field $V(\vec{x}) = \frac{GMm}{\vec{x}}$ solution Kepler orbit $r = \frac{p}{1 + e \cos \theta}$, ellipse with (a,b) = major/minor semi-axis, p =semi-rectum $a = \frac{p}{1 - e^2}$, e eccentricity, $p = \frac{L^2}{\alpha}$ L ang. momentum, $\alpha = G(M + m)$



Planetary orbit in the inner solar system [82]

3 Commutation relations and uncertainty relations

In classical mechanics, with the Poisson bracket for functions $\{f, g\} \equiv \sum_i \left(\frac{\partial f}{\partial q_i} \frac{\partial g}{\partial p_i} - \frac{\partial f}{\partial p_i} \frac{\partial g}{\partial q_i} \right)$

from the Hamiltonian equations

$$\frac{dq_i}{dt} = \frac{\partial H}{\partial p_i} \quad \frac{dp_i}{dt} = -\frac{\partial H}{\partial q_i}$$

we obtain the following classical expressions

$$\frac{dq}{dt} = \frac{\partial H}{\partial p} = \{q, H\} \quad \frac{dp}{dt} = -\frac{\partial H}{\partial q} = \{p, H\}$$

We perform the transition to the quantum regime by the transformation $\{p, H\} \rightarrow \frac{1}{i\hbar} [P, H]$ from the classical

Poisson bracket to the quantum operator commutator and get

$$\frac{dQ}{dt} = \frac{1}{i\hbar} [Q, H] \quad \frac{dP}{dt} = \frac{1}{i\hbar} [P, H] \quad , \text{ it follows } [Q, P] = i\hbar I \text{ with } I = \text{identity for } Q = \text{location operator}$$

P =momentum operator, which is the quantum Heisenberg commutator relation.

From the commutator relation follows the Heisenberg uncertainty relation

$$\langle \Delta Q \rangle \langle \Delta P \rangle \geq \frac{\hbar}{2} \text{ for the expectation value of standard deviation } \langle \Delta Q \rangle \text{ and } \langle \Delta P \rangle .$$

The uncertainty relation can be generalized for every commutator relation in above form.

4 Quantum wave function and classical orbit

Static quantum systems usually have cylindrical symmetry and discrete energy values E_k , and are characterized by a wave function

$$\psi = \psi_k(r, \theta) \exp(-iE_k t / \hbar)$$

which defines a (3-dimensional) probability density $p(r, \theta) = |\psi_k(r, \theta)|^2$, $\int |p(r, \theta)|^2 \sin \theta d\theta dr = 1$.

$p(r, \theta)$ defines a mean radius $\langle r(\theta) \rangle = \int p(r, \theta) r dr$ which represents a “fuzzy” orbit $r_p(\theta) = \langle r(\theta) \rangle$ with a

$$\text{width } \Delta_p(\theta) = \sqrt{\langle (r(\theta) - \langle r(\theta) \rangle)^2 \rangle} .$$

In the analogous classical case the system is characterized by a (2-dimensional) orbit $r(\theta)$, which is sharp, i.e. has a width $\Delta_p(\theta) = 0$, and the orbit lies in a plane.

5 Transition region between the quantum and the classical regime

In the transition region the semi-classical Wentzel-Kramers-Brillouin (WKB) approximation is applied [79].

We set the wave function for one dimension in the form $\psi(x) = \exp\left(\frac{i}{\hbar}\phi(x)\right)$ and make an expansion of

$$\phi(x) = \sum_k \phi_k(x) \hbar^{k-1} \text{ in } \hbar\text{-powers, keeping only the first term.}$$

After insertion into the Schrödinger equation with potential $V(x)$, we get the approximate semi-classical WKB wave function

$$\psi(x, E) = \frac{C_+ \exp\left(\int k(x, E) dx\right) + C_- \exp\left(-\int k(x, E) dx\right)}{\sqrt{k(x, E)}} \text{ with the wave number } k(x, E) = \frac{\sqrt{2m(V(x) - E)}}{\hbar}$$

which depends *continuously* on energy E .

The validity criterion for the approximation is $\frac{d}{dx}\left(\frac{\hbar}{\phi'}\right) \ll 1$.

6 Particle-like and wave-like picture in quantum and classical mechanics

In the quantum regime, objects are represented by a wave function $\psi(\vec{x}, t) = \psi(\vec{x}) \exp\left(\frac{i}{\hbar}(\vec{p} \cdot \vec{x} - Et)\right)$, so they

can be viewed as wave-like with wave number vector $\vec{k} = \vec{p} / \hbar$ and angular frequency $\omega = E / \hbar$.

This explains purely quantum phenomena:

- an electron goes simultaneously through two slits and interferes with itself.
 - two objects can be entangled, i.e. they are represented by a common wave function.
 - two objects can form a superposition of their wavefunctions into one object (superposition principle)
- Quantum objects can be also viewed as particles with a definite energy and momentum.

The wave-like picture is applied in interference and superposition, the particle picture is applied in collision and transformation processes e.g. in Feynman diagrams.

In the classical regime, the waves are objects with the amplitude $A(\vec{x}) \exp i(\vec{k} \cdot \vec{x} - \omega t)$, particles have a sharp orbit $\vec{x}(t)$ in time.

7 Limit of quantum regime

As explained below, the Ashtekar-Kodama quantum gravitation demands a limit of quantum regime of

$$r_{gr} = \sqrt{l_p} \sqrt{\frac{1}{\Lambda}} = 3.1 \cdot 10^{-5} m = 31 \mu m. \text{ This is also supported by experiments.}$$

Of course, there is a transition range between the quantum and the classical regime, and the AK-limit marks only the center of this range. The real criterion is the decoherence time t_{dc} of a quantum state.

In [78] is shown that we can assess the decoherence time from the quantum gravitational noise and the

$$\text{characteristic length } l_0 \text{ in the form } t_{dc} = \frac{\hbar}{E_{gr}} = \frac{\hbar l_0}{G m^2} \sim \frac{l_0}{l_0^6} = \frac{1}{l_0^5}, \text{ and with } t_{dc}(l_0 = 3 \mu m) \approx 1 ms$$

we can assess the decoherence time for $l_0 = 1 mm$

$$t_{dc}(l_0 = 1 mm) = t_{dc}(l_0 = 3.42 \mu m) \left(\frac{1000 \mu m}{3.42 \mu m} \right)^{-5} = 4.67 \cdot 10^{-16} s$$

which is below the current limit of time-measurement.

$l_{q0} = 38.7 m$ **hard quantum limit** when $t_{dc}(l_{q0}) = t_p = 5.4 \times 10^{-44} s$ reaches the Planck time

For molecular beam interference experiments the interference criterion is $t_{dc}(l_0) > t_0$ where l_0 is the size of the

molecule, and $t_0 = \frac{L}{v_{th}} = \frac{L}{\sqrt{\frac{8k_B T}{m\pi}}}$ is its flight time with thermal velocity v_{th} in the apparatus of length L and at

temperature T .

Consider a quantum object with size=AK-limit $t_{dc}(l_0 = 31\mu m) \approx 2.5 \times 10^{-8} s$ with thermal speed of oxygen at room temperature $T=300K$ $v_{th} = 310 \frac{m}{s}$ in an apparatus of length $L = 1m$, then we get the flight time

$t_0 = \frac{L}{v_{th}} = 3.2 \times 10^{-3} s$, so here the interference criterion $t_{dc}(l_0) > t_0$ is violated and *there is no quantum behavior anymore.*

8. Planck-length quantization of space-time

It is generally accepted that the Planck length $l_p = 1.61 \times 10^{-35} m$ is a minimal length and defines a fundamental “granularity” of space-time. This is based on arguments from General Relativity and quantum mechanics. Furthermore, we have a maximal length in our universe derived from the cosmological constant Λ_0

$$R_\Lambda = \frac{1}{\sqrt{\Lambda_0}} = 0.95 \cdot 10^{26} m$$

and therefore we have a minimal energy $E_0 = \frac{\hbar c}{R_\Lambda} = 3.31 \times 10^{-52} J = 2.06 \times 10^{-34} eV$

From this point of view, there is a quantization of space-time at Planck-level

$x_k = n_k l_p$ $k = 1, 2, 3$ for spatial coordinates, and $t = n_0 \frac{l_p}{c}$ for the time coordinates

and a fundamental quantization of energy $E = n_E E_0$.

Therefore, in the Planckian regime, all physical variables are discrete, and the differential operator

$D_x f(x) = \frac{d}{dx} f(x)$ transforms into the difference operator $\Delta_x f(x) = \frac{f(x+l_p) - f(x)}{l_p}$, consequently all

differential equations transform into difference equations.

14.2 Quantum and classical measurement

There is a fundamental difference between a classical and a quantum measurement.

In the classical measurement, the measurement variables are continuous, have sharp values (no inherent uncertainty), can be measured simultaneously. The measurement is in principle deterministic and repeated results lie within the measurement error interval.

In the quantum measurement, the measurement variables are continuous or discrete, their values obey a probability distribution and have inherent uncertainty (standard deviation), and they obey uncertainty relations when measured simultaneously. The measurement is probabilistic and repeated results lie within the standard deviation plus measurement error interval.

1 classical measurement

Variables in classical physics are continuous, their values are sharp (in principle arbitrarily precisely measurable), and simultaneously measurable.

For instance, when measuring the equation-of-state of ideal gas $pV = n_{mol} RT$,

the measurement variables (p, V, T) are measured with an error $(\Delta p, \Delta V, \Delta T)$ simultaneously and reproducibly by a manometer, a geometric volume-meter (e.g. circumference scanner), a mercury thermometer.

2 quantum measurement

A quantum variable Q , e.g. energy, is in general a wave function in a superposition state of eigenfunctions

$\psi_k(\vec{x})$:

$\psi(\vec{x}) = \sum_{k=1}^n \alpha_k \psi_k(\vec{x})$, where α_k is the probability of state $\psi_k(\vec{x}, t)$ with variable value Q_k .

The value of the variable Q is in general indefinite, not only unknown.

As energy is always preserved, we can set $Q = H$ Hamiltonian=energy operator.

During a measurement, the wave function $\psi(\vec{x})$ “collapses” and transforms with probability α_k into an eigenstate $\psi'(\vec{x}) = P_{E,k} \psi(\vec{x}) = \psi_k(\vec{x})$ with energy value $E = E_k$, where $P_{E,k}$ is the k -projection operator, and $\psi(\vec{x})$ is normalized $|\psi|^2 = \int |\psi(\vec{x})|^2 d^3x = 1$. Before the measurement, the k -th component (projection of ψ onto the k -th energy eigenfunction space) had the norm $|\psi'| = |\alpha_k \psi_k| = \alpha_k$, so the collapse is not unitary: there is *violation of unitarity*.

Furthermore, in absence of interaction, the wave function *needs an observer* with a measurement in order to instantiate.

This wave function collapse is famous problem in quantum mechanics and there are several interpretations of it.

-Copenhagen interpretation

In Bohr’s Copenhagen interpretation, the problem of the wave function collapse is seen as an “intuitive” difficulty, which is not real, as the theory is mathematically consistent and experimentally verified.

The violation of unitarity is accepted as real, the observer dependence is ignored as an intuitive problem.

-Everett’s many-worlds interpretation

Everett’s hypothesis is that ψ is not indefinite, but multiple: it assumes the values $\alpha_i \psi_i(\vec{x})$ in different universes. This avoids the indefiniteness and the violation of unitarity, but can be rejected as untestable and by Ockham’s razor as unnecessary complicated (it creates a huge number of parallel universes).

-GRW interpretation of dynamic wave collapse

In the formulation of Ghirardi-Rimini-Weber (GRW) the wave function collapse is characterized by a spontaneous wave function collapse with width r_c and by the decay rate λ , and is caused by quantum-gravitational interaction, as gravitational interaction is always present. In Ashtekar-Kodama quantum gravity [78], there is a temperature-independent quantum noise, whose magnitude is calculated from the AK-equations

$P_p = \frac{r_\Lambda}{r_p} m_p c^2 \frac{c}{\lambda_0} \sim 10^{-27} \text{ eV} / \text{s}$, which is much smaller than the thermal Nyquist noise at room temperature

$$P_{th} = \frac{k_B T}{t_{th}} \sim 10^9 \text{ eV} / \text{s} .$$

In the recent test of collapse models carried out by Bassi et al. 2017 , possible values of these parameters are measured, and are found to be consistent with a limit of the quantum-gravitational regime at

$$r_{gr} = \sqrt{l_p} \sqrt{\frac{1}{\Lambda}} = 3.1 * 10^{-5} \text{ m} = 31 \mu\text{m} \text{ predicted by the Ashtekar-Kodama gravitation [78]. This is also}$$

supported by decoherence measurements by Kotler et al. 2021 [78].

In the GRW interpretation the wave function collapse spontaneously or by measurement is the result of a collision-absorption process of a field quantum (in a measurement usually by electromagnetic interaction with absorption of a photon, spontaneously by gravitational interaction with absorption of a graviton).

In this interpretation, the wave collapse takes place by *interaction and not by projection*, as we have here a normal Feynman interaction process with a regular state transition, so the transition operator needs only to be hermitian, not unitary : there is no violation of unitarity.

Also the *observer-dependence is eliminated*, as the wave collapse can proceed spontaneously.

14.3. Copenhagen interpretation of quantum mechanics

Primas & Omnes and Roland Omnès give the following summary of the Copenhagen interpretation

Basic rules:

- Quantum mechanics is intrinsically indeterministic.
- The correspondence principle: in the appropriate limit, quantum theory reproduces the classical predictions.
- The Born rule: the wave function $\Psi(\vec{x}, t)$ of a system yields probabilities for the outcomes of measurements

upon that system, $|\Psi(\vec{x}, t)|^2$ is the probability density of a quantum object.

- Complementarity: certain properties cannot be jointly defined for the same system at the same time.

Phase space variables position x and momentum p obey commutation relation $[x, p] = i\hbar$ and uncertainty relation $\Delta x \Delta p \geq \hbar / 2$

Advanced rules:

- Quantum physics applies to individual objects, not only to ensembles
- The results provided by measuring devices are essentially classical
- The device used to observe a system must be described in classical language, while the system under observation is treated in quantum terms.
- During an observation, the system must interact with a laboratory device. When that device makes a measurement, the wave function of the system collapses, irreversibly reducing to an eigenstate of the observable that is registered.
- Statements about measurements that are not actually made do not have meaning.

For example, there is no meaning to the statement that a photon traversed the upper path of a Mach–Zehnder interferometer unless the interferometer were actually built in such a way that the path taken is measured.

- Wave functions are objective, in that they do not depend upon personal opinions or other arbitrary influences.

There are some fundamental agreements and disagreements between the views of Bohr and Heisenberg.

- observer and object

Heisenberg : there is a sharp "cut" between the observer and the system being observed,

Bohr: measurement is independent of a subjective observer

- wave–particle duality

Bohr :the distinction between a wave view and a particle view is defined by experimental setups,

Heisenberg: viewing the mathematical formulas as referring to waves or particles.

15 Principles and evolution of life

[13:3]

15.1 Chemical base of life in general

Based on current experimental and theoretical evidence, we can conclude that the proto-biotic life chemistry in general (not only on Earth) develops in a liquid from one or several exothermic molecules (precursors) by selection-evolution via two parallel prebiotic random polymerization processes from basic compounds to catalyzers (enzymes) and synthesizers (polymer molecules which carry out template-based enzyme synthesis based on their sequence, i.e. genetic code) fed by an energy cycle. In terrestrial life chemistry, a vesicle-based chemistry is a precondition for a full life-cycle with bio-matter production and proliferation.

Therefore it is plausible to assume that in general there is a third class of polymers (layer-builders) produced by the life chemistry, which form a membrane and a self-dividing vesicle.

In extrapolation of these basics we can say that life in general has 5 principal features:

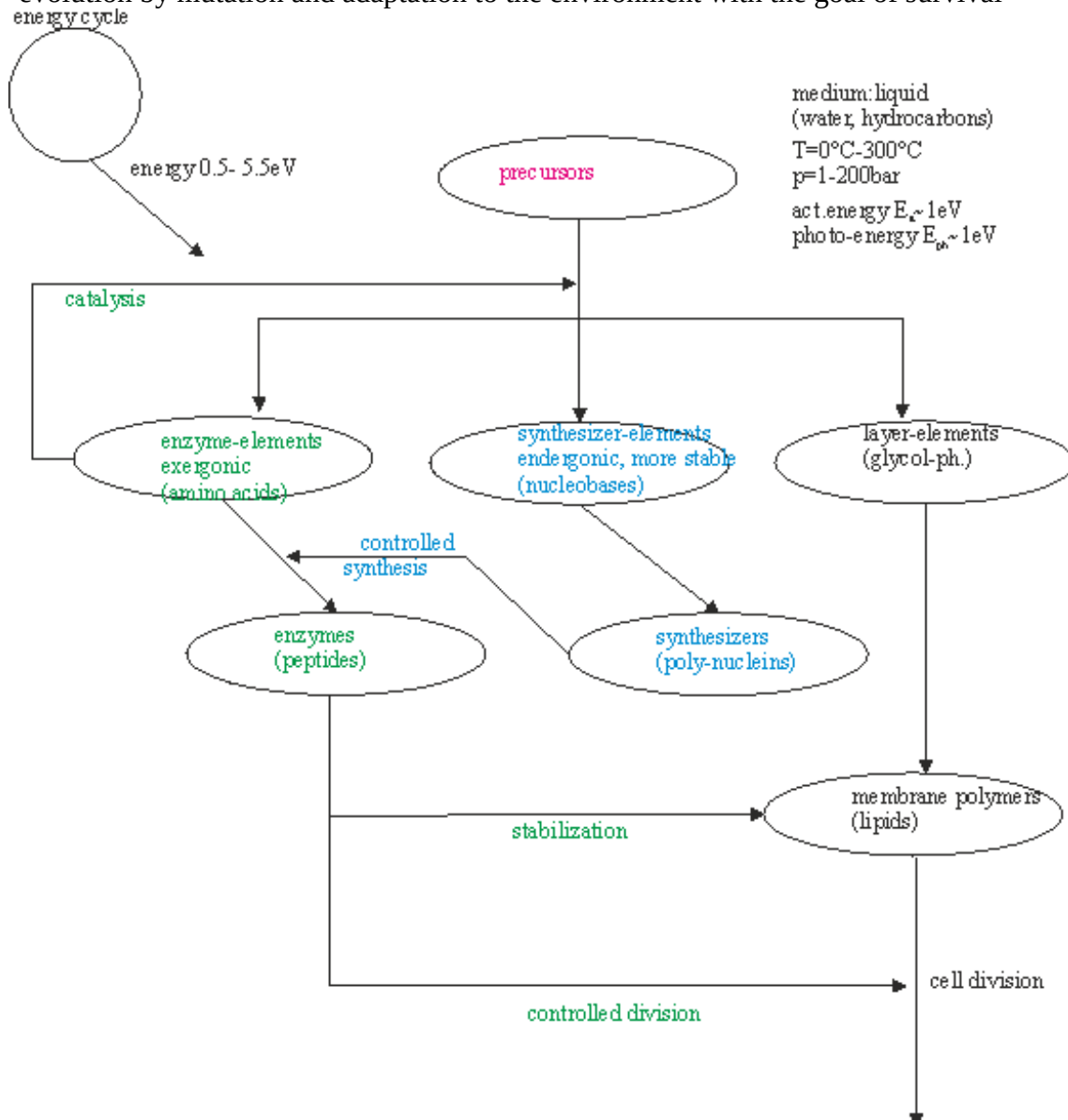
-synthesis of biological matter (including basic compounds) in a liquid (terrestrial: water) catalyzed by enzymes (terrestrial: proteins), where basic compounds (terrestrial: 20 amino acids, 4 nucleobases A,U,G,C) are synthesized from anorganic precursors (terrestrial primary: HCN, H₂, H₂S)

-use of an energy cycle with a continuous energy flow against entropic decay (terrestrial primary cycle: Wächtershäuser's iron-sulfur cycle)

-life chemistry based on enzymes and genes (terrestrial: poly-nucleobases) built from basic compounds, and running within a cell-membrane

-replication with copying of genes, and cell division within a fixed time interval (terrestrial: ca. 1000s)

-evolution by mutation and adaptation to the environment with the goal of survival



15.2 Alternative life-models**Carbon-nitrogen-hydrogen chemistry in water (terrestrial model)**

$T=0^{\circ}\text{C}\dots 150^{\circ}\text{C}$ ($P=1\text{-}100\text{bar}$)

basic materials: $\text{HCN} + \text{FeS} + \text{H}_2\text{S}$

polymers: peptides, poly-nucleins

solvent: water

energy cycle: $\text{FeS} + \text{H}_2\text{S}$, photosynthesis

location: water-carrying planets in habitable zone

Carbon-hydrogen-oxygen chemistry in water

$T=0^{\circ}\text{C}\dots 150^{\circ}\text{C}$ ($P=1\text{-}100\text{bar}$)

basic materials: $\text{CO}_2 + \text{CH}_4 + \text{NH}_3$

polymers: poly-alcohols, poly-ethylene-glycols, poly-ethylene-imines

solvent: water

energy cycle: photosynthesis, $\text{CO} + \text{H}_2\text{O}$

location: water-carrying planets in habitable zone

Carbon-hydrogen-nitrogen chemistry fluid hydrocarbons

$T=0^{\circ}\text{C}\dots 300^{\circ}\text{C}$ ($P=1\text{-}100\text{bar}$)

basic materials: $\text{CH}_4 + \text{H}_2\text{S} + \text{NH}_3$

enzymes: polyethylene derivatives, polyacryl derivatives

synthesizers: benzene-derivates

solvent: cycloalkanes C_nH_{2n} , aromatic hydrocarbons

energy cycle: photosynthesis

location: waterless planets in habitable zone with dense atmosphere

Silicon chemistry in molten rock

temperature range probably too high for high-complexity molecules and catalyzers

$T=1000^{\circ}\text{C}\dots 1500^{\circ}\text{C}$

basic materials: $\text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{MgO}$

polymers: polysilicates

solvent: molten silicates

energy cycle: ?

location: hot Earths

Carbon+salts compounds in liquid ammonia

reactions probably too slow for life evolution

$T = -78 \dots -33^{\circ}\text{C}$ ($P=1\text{bar}$)

$T = -77^{\circ}\text{C} \dots 98^{\circ}\text{C}$ ($P=60\text{bar}$)

solvent: liquid ammonia

basic materials: hydrocarbons, salts, organic metal complexes, organic carbon compounds $\text{C} - \text{H} - \text{N}$

polymers: complex hydrocarbons with oxyl-, amino- and metal-radicals

energy cycle: carbon-hydrogen chemistry ?

location: Titan-like planets

Carbon compounds in liquid ethane-methane

reactions probably too slow for life evolution

$T = -183 \dots -89^{\circ}\text{C}$ ($P=1\text{bar}$)

solvent: liquid ethane-methane

energy cycle: photosynthesis ?, tidal heating ?

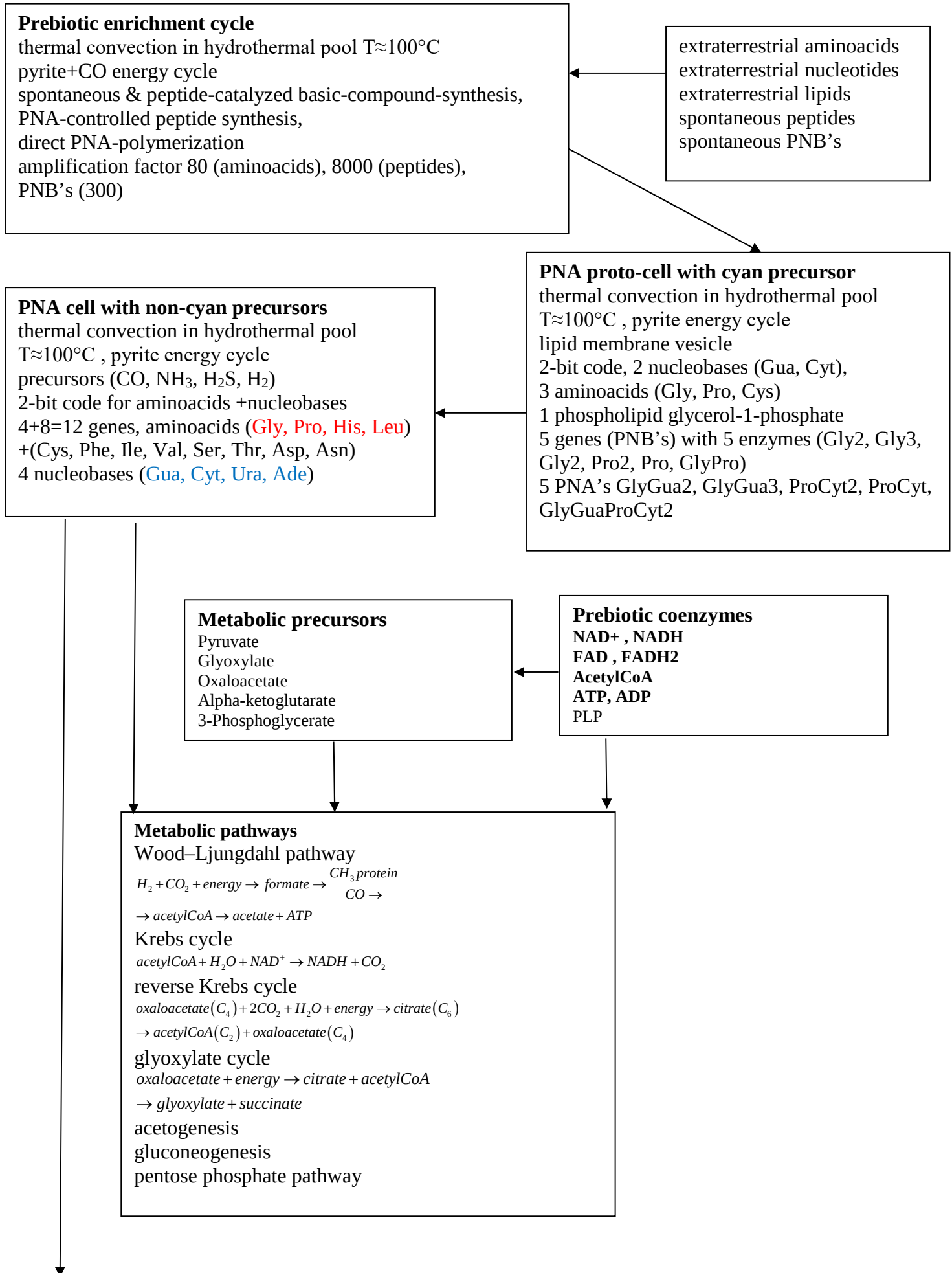
basic materials: organic carbon compounds $\text{C} - \text{H} - \text{N}$

polymers: complex hydrocarbons with oxyl-, amino-radicals

membrane (computer-modeled in February 2015): acrylonitrile similar to a phospholipid bilayer

location: Titan-like planets

15.3 Scheme of terrestrial life evolution [13:4]



PNA cell with non-cyan precursors +reverse Krebs cycle

thermal convection in hydrothermal pool $T \approx 100^\circ\text{C}$,
 energy cycle: acetogenesis+sulfate reduction
 precursors (CO , NH_3 , H_2S , H_2)
 2-bit code for aminoacids +nucleobases
 16 genes for 16 enzymes, 12 aminoacids (**Gly, Pro, His, Leu**)
 +(Cys, Phe, Ile, Val, Ser, Thr, Asp, Asn)
 4 nucleobases (**Gua, Cyt, Ura, Ade**)
 metabolic precursor genes
 reverse Krebs cycle

RNA proto-cell

hydrothermal pool $T \approx 80^\circ\text{C}$, $\text{pH}=9$, $P \sim 1-10$ bar
 precursors (CO_2 , NH_3 , H_2 , H_2S , H_3PO_4)
 ss-RNA 3-bit code, ≈ 150 genes
 energy cycle: acetogenesis+sulfate reduction
 virus-like protein capsid+lipid envelope
 RNA 4 nucleotides (C, U, A, G)
 tRNA/aaRNA protein synthesis:
 150 proteins with 20 amino acids
 RNA replication via RNA polymerase
 acetogenesis, gluconeogenesis, reverse Krebs
 cycle, pentose phosphate pathway

RNA viruses

LUCA

hydrothermal pool $T \approx 80^\circ\text{C}$, $\text{pH}=9$, $P \sim 1-10$ bar
 precursors (CO_2 , NH_3 , H_2 , H_2S , H_3PO_4)
 DNA 3-bit code, ≈ 400 genes, ribosome
 energy cycle: acetogenesis+sulfate reduction
 virus-like protein capsid+lipid envelope
 DNA 4 nucleotides (C, T, A, G)
 tRNA/aaRNA protein synthesis:
 2600 proteins with 20 amino acids
 DNA replication via DNA polymerase
 acetogenesis, gluconeogenesis, reverse Krebs
 cycle, pentose phosphate pathway

DNA world: eukaryotes

eukaryote=
 archaeon+ mitochondrion(bacterium)+nucleus

multicellulars

plants

fungi

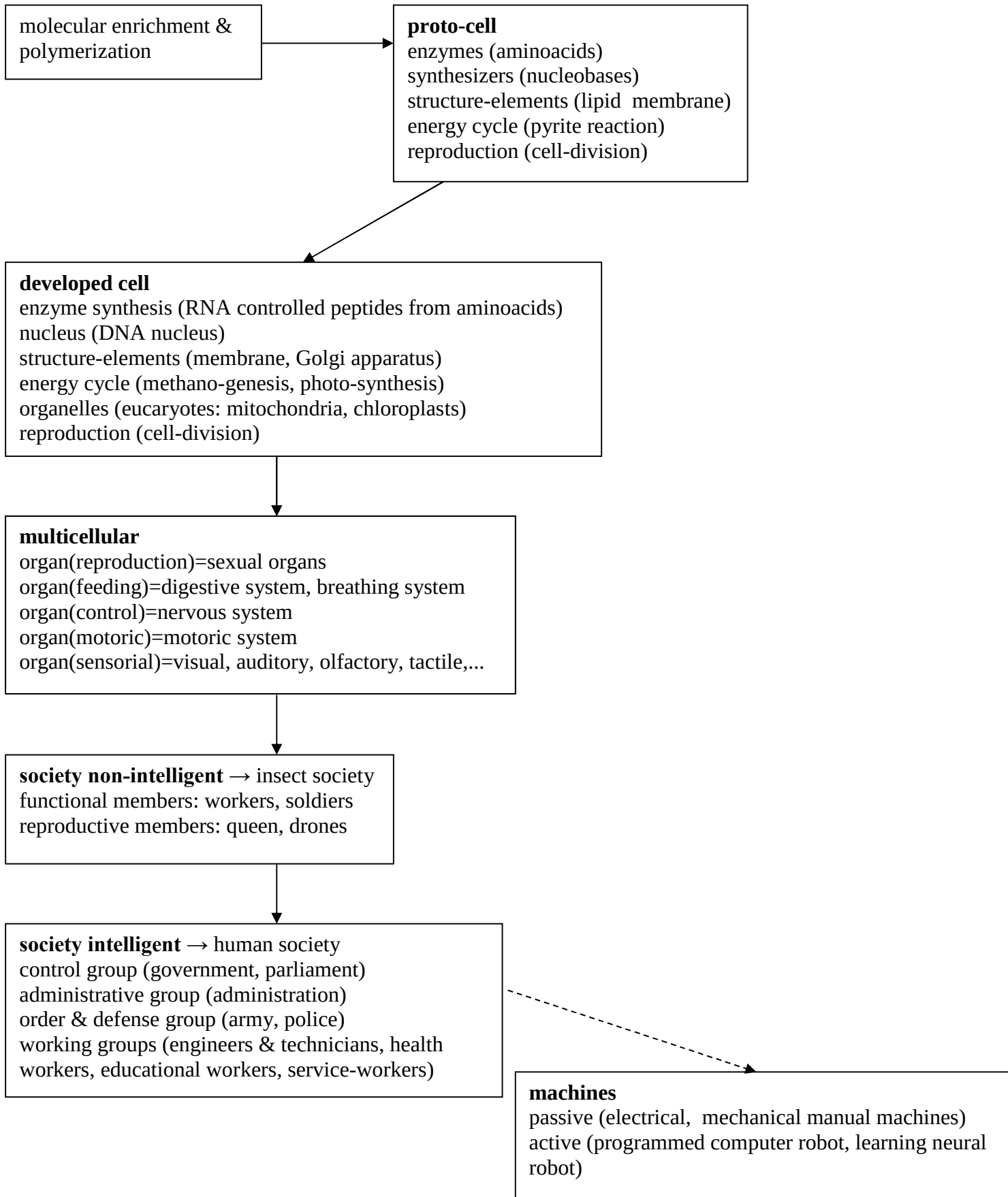
animals

DNA world: bacteria archaea

DNA genetic code 3-bit codon,
 20 aminoacids, 4 nucleotides C, T, A, G
 20 aaRNA protein synthesis
 lipid cell membrane
 energy cycle=
 - reverse acetogenesis sulfate red. (sulfur bacteria)
 - Wood-Ljungdahl aceto-genesis (archaea,bacteria)
 - methanogenesis (archaea)
 - photosynthesis (cyanobacteria)

DNA viruses

15.4 Scheme of evolution of life structures



15.5 Intelligent life

The genus Homo is the only life form on Earth, which reached a level of intelligence capable of transforming globally the environment and starting a secondary technical evolution of machines. Homo sapiens created an intelligent civilization and took control of the planet by introducing more and more sophisticated tools. Every living being with a control center (=brain) has an internal representation of reality (knowledge base), which it uses in its interaction with the environment with the goal to survive and to reproduce (survival of the species).

There are several features, which characterize an intelligent living being, independent of its physical-chemical basis:

- self-awareness: his mind's knowledge base contains himself as an active agent and an individual (he passes the mirror test)
- symbolic thinking: his mind works with symbols (not only sensorial images, events and emotions)
- consciousness: his mind is a working stage, where several task centers compete for focus control (decision taking, planning, motoric execution, sensorial input)
- planned behavior: he plans his behavior and constantly makes predictions, which he constantly checks against reality (and modifies his knowledge accordingly: a feedback-loop)
- use of tools: he manufactures and uses tools as an extension of his motoric capabilities
- symbolic language: there is a symbolic language as means of communication in the community, capable of mapping all aspects of the mind, including symbols and emotions and their relations

15.6 Technical evolution

It is very plausible that every intelligent society, independent of the physical-chemical basis of its individuals, will start a technical evolution.

The terrestrial technical evolution developed in 5 stages

- 1 Simple hand-tools: stone and wooden tools and projectiles, metal tools and weapons
- 2 External-power-driven machines: steam, gasoline, electric
- 3 Precision manufacture: semiconductor technology, laser machining
- 4 Computer technology: programmed von-Neumann-computer, learning neural-network in hardware, programmed computer robot, learning neural robot
- 5 Controlled peptide biochemistry: gene manipulation CRISPR, fast DNA analysis technique PCR

One can extrapolate from the terrestrial technical evolution and its current status to assess further technical developments [85].

F1 Analog problem solving

The goal here is to use designed physical many-object-systems for solving physical-mathematical problems. As an example, let us consider a minimization problem in many parameters, each in a certain interval:

$$f(p_1, \dots, p_n) = \min \quad p_i \in [x_{i1}, x_{i2}]$$

The designed physical many-object-systems in this case could be a reconfigurable (switched) array of analog nano-CPU's capable of analog addition-subtraction, multiplication-division, differentiation and integration (all this is realizable with analog electronic circuits). The array is on one IC (=FPAA), the connections are switchable (MOS-switches) and the nano-CPU's work in parallel, which makes the device very fast. Conceivable alternatives are programmable ensembles of molecules performing one of several reactions, guided by a minimization principle (e.g. energy).

F2 Micro-robot swarm

A connected micro-robot swarm can perform fast operations in parallel e.g. in the human body.

A possible realization are micro-robots (size~1µm) with micro-wave field as energy source, equipped with a neural-network learning CPU, mobile communication, piezo-propulsion and piezo-driven micro-tools. They can move in a fluid (e.g. blood vessels) driven by a piezo-spindle, or in air piezo-driven by micro-propellers.

F3 Programmed robotic chemistry

Programmed biochemistry: an array of micro-robots controls in parallel peptide reactions by release of programmed reactants, performs in parallel DNA-manipulations.

Programmed chemistry: an array of micro-robots performs in parallel parameterized molecule production.

F4 Mind-computer interface

The mind-computer interface can display and store sensorial brain images, symbol networks, linguistic and pattern-matching processes, it can read and store brain memories, can execute motoric control of external tools, and can insert sensorial information directly into the brain.

F5 Powerful energy supply

A candidate for a powerful, inexhaustible, clean, and climate-friendly energy supply is the laser-driven fusion.

F6 Sophisticated healthcare

In 2100 it will be probably possible to ensure extended longevity (potential immortality?) and health by constant action of biochemical agents, and to rejuvenate organs by stem-cell controlled rebuilding.

F7 Cyborg technology

The functionality of the human body will be extended implanted tissue-compatible electronics.

16 Comparison philosophical-physical thinking

Philosophical-physical duality

A comparison between philosophical and physical way of thinking reflects the fundamental duality of our brain functionality [52]:

-the right-cerebral intuitive-procedural information processing, which controls spatial orientation, perception, emotional response, and works with analogy reasoning, hierarchic-structural recognition, pattern recognition

-the left-cerebral analytic-declarative information processing, which controls speech, verbal information processing, calculation, language and works with logical deduction, calculation procedures.

This duality also appears in all aspects of philosophical and physical representation of reality.

-assertion

in philosophy: an assertion is plausible or implausible, and is argued by a gedankenexperiment;

a plausible assertion is non-unique (one of several possibilities)

in physics: an assertion is true or false, verified by experiment; a true assertion is in general unique (the simplest possible is valid by Occam's razor)

-reality check

in philosophy: checked by gedankenexperiment

in physics: checked by experiment

-language

in philosophy: the argument language is the natural language, where notions have a restricted scope of meaning

in physics: the mathematical language

-model of reality

in philosophy: hierarchic-structural model, biological (e.g. cell structure), brain-theoretical (e.g. emotions, dreams, memory), sociological (e.g. social groups, behavior models), physical (e.g. stellar-planetary systems)

in physics: mathematical model = interactions (e.g. Maxwell equations) + phenomenological structure (e.g. leptons and quarks in Standard Model)

-description

in philosophy: verbal-relational graph, structural image

in physics: partial differential equations, functions and operators, symmetry groups

-memorization of technology

in philosophy: technological recipe, e.g. cooking recipe, carpenter's description of how to make a specific chair

in physics: quantitative design, e.g. electric schematic, layout, functional simulation of a circuit board

Inner world and reality interaction

Humans, like all biological beings have a *representation of reality*, in order to act appropriately within this reality, i.e. live and survive. This representation is the model of reality in our *inner world*, which is the *functionality of the brain*: information processing working with symbols as representations of outer-real entities and of inner-real entities (emotions and images).

The interaction between inner-worlds (of different individuals) proceeds via natural language: we can communicate our knowledge (=representation of reality) and our inner-real entities to other individuals by language communication.

The interaction between inner-world and reality proceeds in two different ways: we can change the representation of reality (e.g. modify the mathematics of a physical model) or perform a motoric procedure (manufacturing a tool).

Comparison philosophical-physical thinking

aspect	philosophical-intuitive	physical-abstract
brain function	right-cerebral intuitive-procedural	left-cerebral analytic-declarative
assertion truth	plausible-implausible	true-false
assertion uniqueness	non-unique= multiple	unique
reality check	gedankenexperiment	experiment
language	natural language, restricted meaning	mathematical
reality model	hierarchic-structural	mathematical
description	verbal-relational graph, structural image	partial differential equations, functions and operators, symmetry groups
memorization of technology	technological recipe	quantitative design
reality interaction	motoric procedure	model modification
inner interaction	communication of emotions	communication of knowledge

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