How Determinism Governs All the Laws of Physics

Philosophy of Science

**“There are 4 determinisms opposites of chance:
1 causal and 3 causeless.”**

Daniel Martin

Philosophical Purpose of this Book

Philosophy of Science is interested in the doctrines, principles and rules which structure scientific laws and thought. The main common point of these precepts is causality, applied by determinism. This book presents 171 of them.

Many people believe that the adjective *deterministic* qualifies a causality that produces a unique result for a law of evolution of nature. Their error comes from an insufficient understanding of the notions of causality, determinism and chance.

This text shows that the causality of natural laws, for example in Quantum Physics, often leads the evolution of a given system to multiple results, that coexist as long as one of them has not been chosen. In general, this choice results from a brutal interference of the macroscopic world with the state of the system at atomic scale, at the end of an evolution, for example during a measurement.

There is a rigorous causal determinism of cases of multiplicity, and it generalizes the limited causal determinism of cases of single result. There are also three non-causal determinisms, which are not random either.

Understood correctly, chance never intervenes in a law of nature. Multiple results take the form of predetermined statistical distributions. Chance exists only in the choices of a result, made independently of the cause of the phenomenon whose variables are distributed. It is often put forward instead of admitting ignorance.

It is Man who writes the laws of physics, and he excludes two particular causes: chance and God.

This is what this book explains about determinism, by deepening its rules of application to the various kinds of laws of physics.

About this Book

Updated August 22, 2022

All philosophers are familiar with the traditional definition of determinism, taken from Laplace's *A Philosophical Essay on Probability*, published in 1814, which basically says: "Any evolution of a system which depends only on initial circumstances and obeys a law is deterministic". Laplace was a French astronomer, and when he wrote that definition he had in mind the movements of planets, which are perfectly regular and governed by Newton's laws.

By induction, Laplace extended this deterministic behavior to all physical systems of the Universe. He then inferred that an intelligence (Laplace's "demon"), knowing perfectly the state of a system at a given time, could predict its future evolution, and mentally reconstruct its past evolution, as far as it wanted to.

Unfortunately, this law can only be true at macroscopic scale, we have examples of that, but some traditional philosophers ignore this limitation. They believe that certain phenomena, for example in particle physics, are not deterministic because their evolutions have multiple probabilistic results.

This book takes the definition of determinism back to its philosophical basis, causality, to show how, using the empirical reality of physics, it can be extended to govern all of its laws, except those that dissipate energy such as friction, which are impossible to describe accurately.

The text completes the definition of determinism. It describes its limits and its opposite, chance, as well as extensions that govern Quantum Mechanics and natural phenomena of arbitrary complexity.

About the author

After studying engineering and astronomy, then teaching and doing research for five years, Daniel Martin pursued an international career as a database management specialist. For the last thirteen years, his area of interest has been Philosophy of Science.

This book was translated from French by the author.

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1 Historical Origin: Philosophical Determinism

In his monumental work *Treatise on Celestial Mechanics*, published in 5 volumes from 1798 to 1827, Laplace demonstrated the detailed laws of planetary motion based on Newton's laws. These celestial bodies moved with remarkable regularity: one could predict the position of each body many years in advance, and find the position they had at a distant date in the past. Laplace therefore naturally surmised that all the laws of nature had the same qualities:

- Universality: they apply to all bodies, in all circumstances and in all places;
- Stability: they have not changed since the dawn of time, and will remain valid indefinitely.

These qualities are at the origin of the doctrine of determinism, here is how.

In the *Philosophical Essay on Probabilities* (1814) of Laplace, one reads on page 3: "Present events have a connection with previous events, founded on the obvious principle that a thing cannot begin to be without a cause which produces it. This axiom, known as the *Principle of Sufficient Reason*, extends even to actions considered indifferent. Free will cannot create a thing without a determining reason; […] The opposite opinion is an illusion of the mind which […] convinces itself that it has made a decision without motives."

Interpretation of this quote

- The existence of an object or the occurrence of an event are due to a cause, they are not a product of chance.
- Even when this cause is the will of a being, this being had a reason to act. The existence of decisions made without emotion or constraint [as in a scientific calculation] does not justify the belief that a thought may exist independently of matter. [Being an atheist, Laplace militated against beliefs in God, in an immortal soul, etc.]
- Chaining of events by causality is a law of nature. No will can replace this natural causality, whatever its free will, without a sufficient natural cause; therefore, the will of a spirit cannot act physically.
- A physical action independent of natural laws is an illusion, such freedom exists only in the capabilities of thought.

Philosophical Determinism

In this 1814 text, the astronomer Laplace asserts determinism without using the word; his doctrine was called *determinism* because he puts forward a "determining reason". According to this doctrine, called *Philosophical Determinism*:

> **« Nothing can exist without a cause: a cause necessarily precedes any existence of an object; and it suffices, when it exists, for the thing to be or to appear. »**
> Laplace being an atheist, his doctrine is materialistic. For him, the existence of an object is never due to a transcendent will, its cause is always natural.

Laplace writes, following the previous quote:
"We must therefore consider the present state of the Universe as the effect of its previous state; and as the cause of that which will follow. Consider an intelligence

[Laplace's "demon"] which, for a given moment, would know all of the forces of nature, and the respective positions of the beings which make up the Universe. If, moreover, it were vast enough to analyze it, that intelligence would embrace in the same formula the movements of the greatest bodies of the Universe and those of the lightest atom: nothing would be uncertain for it, and it would see the future like the past. The human mind offers, in the perfection it has been able to give to astronomy, a weak sketch of this intelligence. Its discoveries in Mechanics and Geometry, together with that of Universal Gravity, have enabled it to understand, in the same analytical expressions, the past and future states of the world system."

According to Philosophical Determinism:

- The succession of causes produces the sequence of states of an evolving system, these successive states forming a causality chain.
- Human science must be able to explain the present state of a system by reconstructing mentally the complete history of the evolutions from which it results, in accordance with physical laws. This implies the possibility for Man to understand all of the phenomena of which he knows the successive causes, a *promise of intelligibility of phenomena* and of *the explanatory power of science*.
- The laws of science must also make it possible to foresee future developments, and to predict corresponding states, i.e. a *promise of a foreseeable nature*.

1.1 Philosophical Determinism Does Not Always Keep its Promises

Natural radioactivity is an example of a phenomenon that escapes Philosophical Determinism. When atoms of a sample of uranium 238 decay one by one spontaneously, producing atoms of thorium and helium:

- It is impossible to know which atom of the sample will be the first to decay, and at what time.
- In a sample of uranium containing thorium atoms resulting from such decays, it is not possible to find in what order these thorium atoms appeared.
- All decays occur without apparent cause, at unpredictable moments.

These *proven* impossibilities contradict Philosophical Determinism, which must therefore be abandoned because the laws and principles of physics may have no exceptions. So Daniel Martin developed a more encompassing definition of the determinism of physical evolution laws, that can govern them all; we will discover it step by step, starting with understanding natural radioactivity.

The problem with Philosophical Determinism is that it can neither predict all future states (for example which uranium atom will decay first, and at what time), nor reconstruct mentally the order of decay of the atoms. However, natural radioactive decay follows a law which Laplace could not know in his time. Here it is.

2 Natural Radioactivity

Radioactive Decay, Discovered by Henri Becquerel in 1896

A sample of radioactive uranium 238 (symbol: ^{238}U) decays spontaneously. From time to time one of its atoms breaks into two atoms, thorium 234 (^{234}Th) and helium 4 (^{4}He), an evolution we write: $^{238}U \rightarrow {}^{234}Th + {}^{4}He$.

Half-Life

The law which describes the decay of a sample of uranium only gives a half-life period, the duration at the end of which 50% of the atoms of its ^{238}U will have decayed; and this half-life is only a statistical average, accurate for a significant number of samples. The half-life of ^{238}U is 4.5 billion years: any sample therefore appears very stable.

However, ^{238}U decays spontaneously, atom by atom. If an atom in a given sample of ^{238}U is ^{234}Th, it was certainly formed during the decay of a ^{238}U atom, *but there can be no law as to when*. Let us insist: the problem is not that we do not know a "law for the date of the next natural decay of a ^{238}U atom", it is that *there cannot be such a law at atom level for this decay, because the law of decay at a given moment is at the level of a population of atoms*.

A Limit of Philosophical Determinism

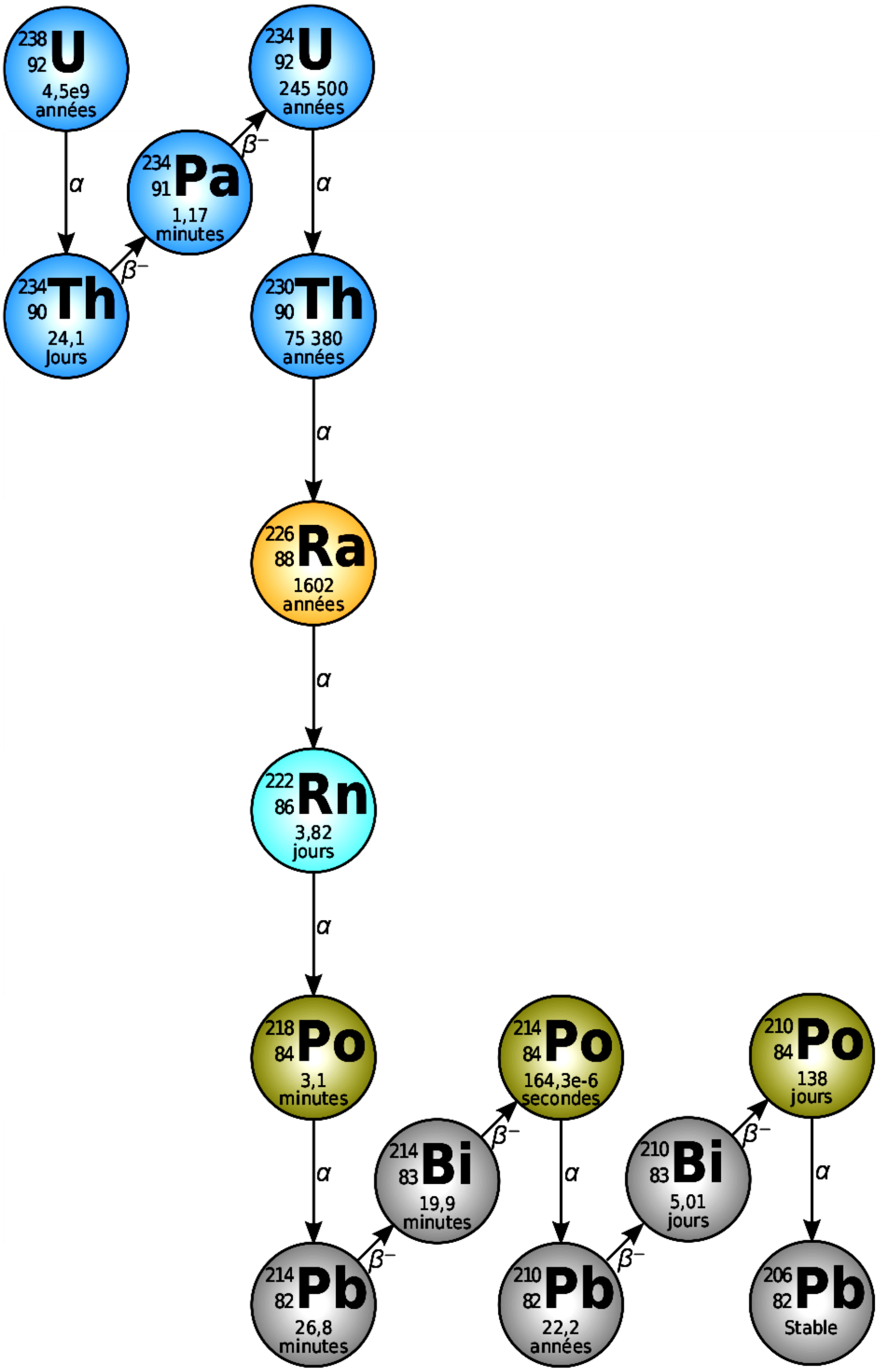
We have here an example of a limit of Philosophical Determinism: some natural phenomena are indeed governed by laws of evolution, but these laws do not predict a unique outcome such as identifying the time of a particular decay. The law of evolution at a given moment has statistical results, not a unique result.

Hence the following metaphysical conclusions:

> **« The results of a law of evolution may be multiple and statistically distributed, not unique. »**
>
> (A law of statistical evolution comes under the important case of *Causeless Determinism*.)
>
> **« Sometimes the human mind distinguishes a part of an object (here an individual atom), but the law of natural evolution does not act at the level of this part. »**
>
> **« A change of state of an object (e.g. a decay) may occur without any external exchange of energy. It is then due to internal causes, often coming under instability. »**

We will see below that there are other deterministic laws of evolution which have a global scope. We will also see other evolutions with no external cause. Finally, we will see which global law describes natural radioactivity.

In short: the phenomenon of radioactive decay of a given uranium atom has neither a sufficient cause, nor a predictable date. It is governed by a law that does not predict anything for that particular atom. Its predictions are only available for a statistical population of atoms. Knowing the current state of a ^{238}U sample containing ^{234}Th atoms does not make it possible to reconstruct mentally the succession of decays (which atom, when).



Radioactive decay of ^{238}U - © Microsoft Bing Creative Commons.
The circle of each isotope such as ^{238}U contains its atomic number (92)
and its half-life (4,5e9=4.5 **.**10^9 years). Arrows point to the type of decay (α, β^-).

2.1 Doctrinal Conclusions

Rejection of Philosophical Determinism

At atomic level, the doctrine of Philosophical Determinism does not keep its promises of predicting future states and reconstructing mentally the history of past states. It does not cover the absence of an external cause (i.e. instability) for this decay phenomenon.

As a counter-example, natural decay is enough to reject this kind of determinism as a principle, because a principle must be verified in all cases. Moreover, physics today has many examples of violations of this “principle”.

Construction of a Better Definition of the Adjective "Deterministic"

Since Philosophical Determinism, as Laplace defines it, can neither predict all future states, nor reconstitute all past states, let us see the conditions that the determinism of a law of evolution must verify:

- It must affirm causality, external or internal: a sufficient cause *C* (i.e. a system state or circumstances) produces an evolution *E*: $C \Rightarrow E$;
- It must postulate the existence of a law *L* which governs this evolution, i.e. the same cause always produces the same consequences: $C \overset{L}{\Rightarrow} E$;
- It must postulate that this law is a necessary and sufficient condition for evolution (necessary to eliminate chance or magical interventions, sufficient to surely trigger evolution as soon as the system state exists): $E \Leftrightarrow (C \overset{L}{\Rightarrow} E)$

The above conditions are satisfied by a definition of *deterministic* such as:

> **« The adjective deterministic qualifies an operation, an evolution or a rule the result of which depends only on initial data or circumstances, and which follows a law. »**

This definition reserves the qualifier *deterministic* for a change, and replaces the prediction of an end state of Philosophical Determinism by the promise of a change that respects the initial conditions and the law of evolution.

Note on the Evolution Results of Philosophical Determinism

Philosophical determinism also erroneously defines *the outcome* of an evolution, without specifying whether it is at a given time or after the end of evolution. This outcome is either a variable value, or the state of the system that evolved. This definition is unfortunate, because we will see that determinism does not always lead to the predictability of an outcome.

Deterministic Causes Produce Evolutions, Not Necessarily Unique Results

> **« The deterministic outcome of a cause (i.e. an initial state) is necessarily an evolution according to a law. »**
> (Not a unique final state)

Examples of deterministic operations: the execution of a computer program; Newton's law of gravitation; Ohm's law describing the potential difference across a resistor through which flows an electric current.

Natural Evolutions are Governed by Laws
Qualifying a system evolution as deterministic necessarily means that its is governed by a law, without any effect of chance or transcendence. Like Laplace, we will postulate that all natural evolutions are deterministic, and we will justify this doctrine in this text.

Need for a Statistical Determinism
The phenomenon of natural radioactive decay requires a particular kind of determinism we will call *statistical*. Radioactive decay is a deterministic evolution: the decay of a sample depends only on its initial state, and its decay rate is governed by the *Law of Half-Life*, which produces a statistical probability of the percentage of decayed matter as a function of time.

This decay law is indeed a matter of determinism, not of chance. Even if no date value can be predicted for the decay of a given uranium atom in a sample, this decay is not unpredictable, it is governed by a law at the sample's global proportion level. Nature replaces the level of atom-by-atom precision we would expect by a more global level. The half-life period of element ^{238}U results from a deterministic physical evolution law, described by a mathematical tool called *Quantum Mechanics*, the predictions of which have a statistical interpretation, although its evolution equation is deterministic in the traditional sense; we will return to that subject later.

We know today many evolutions governed by statistical prediction laws. These laws describe the resulting states of a system in which certain variables are stochastic: their values are distributed according to a precise statistical law; they are not random.

> Example: Quantum Mechanics calculations show that an ammonia molecule (NH_3) may form in one of two states, with its nitrogen atom located above or below the plane of the three hydrogen atoms. A given ammonia molecule may thus have a 50% chance of being above the hydrogen plane, and a 50% chance of being below it (see its structure): the result of the formation equation, "height above the plane", has two values, each with an occurrence probability of 50% if a molecule is selected by some random process. Before such a selection, we shall see below that a newly formed molecule is comprised of both states *existing together,* a combined state termed *quantum superposition*, with a combined molecular mass exactly equal to that of one extracted molecule.

We shall see below that *Statistical Determinism* is a part of the most general kind of determinism, *General Determinism,* which governs all the laws of physical evolution.

Need for a special kind of determinism, with a single evolution result
Radioactive decay occurs spontaneously, with no external cause and with multiple results. But some evolutions due to an external cause produce a unique outcome.

> Example: The second Newton's law relates a cause, the force, to a unique result, the acceleration of a mass.

As this "single result" feature is the case for all physical laws deriving from the laws of Newton, the equations of Maxwell or the Relativity laws of Einstein, we will call its kind of determinism *Special Determinism*, a subset of Statistical Determinism comprised in General Determinism.

The relationship we have here between Special Determinism and General Determinism is comparable to the relationship between Special Relativity and General Relativity; this is intentional.

2.2 Time Course of Radioactive Decay

Reading this technical paragraph is not essential to understanding the rest of the book, the objective of which is only the philosophy of determinism.

In the case of the radioactive decay of a uranium sample, the law of evolution applies, at each instant *t*, to the population of *N(t)* atoms of the ^{238}U sample that have not yet decayed: the number of decays per unit of time is proportional to *N(t)*.

Evolution Law of Radioactive Decay: Law of Half-Life

« In a given sample of a radioactive element, 50% of atoms decay after a constant time τ called the half-life of that element. »

The number *N(t)* of undecayed atoms of a sample which had N_0 atoms at time *t*=0 decreases according to the exponential law:

$N(t) = N_0 e^{-\lambda t}$, where:

- λ is a time interval termed *decay constant*;
- the date-time at which the number of undecayed atoms is 50% of N_0 is $\tau = \frac{ln2}{\lambda}$ where *ln2* is the natural logarithm of 2, *ln2* = 0.692.

This law is statistical: the proportion "50% in τ seconds" is the limit of the average of proportions observed when a number of samples tends towards infinity.

The ^{238}U isotope is not the only one that decays spontaneously. Here are a few more, with their corresponding half-lives:

Isotope	Element	Half-life (years)
^{3}H	Tritium	12.3
^{90}Sr	Strontium	28.9
^{232}U	Uranium	68.9
^{14}C	Carbon	5730
^{239}Pu	Plutonium	24110
^{230}Th	Thorium	75400
^{244}Pu	Plutonium	80.10^{6}
^{238}U	Uranium	$4.47.10^{9}$
^{50}V	Vanadium	$1.4.10^{17}$

Half-lives of various isotopes
Comparison: the age of the Universe is $4.6\ .10^{9}$ years

Finally, some isotopes decay quickly: einsteinium ^{253}Es in 20.5 days, mendelevium ^{256}Md in 78 minutes, and ununhexium ^{293}Uuh in 6 milliseconds.

Let us now redefine determinism in accordance with the previous conditions.

3 Postulates of Determinism

We will define determinism gradually, increasing its definition scope in stages. We will begin with a determinism close to Laplace's Philosophical Determinism, which does not promise the result of unique evolution criticized in the case of radioactivity: *Special Determinism*.

Special Determinism

Special Determinism is a doctrine based on the following postulate:

> **« The evolution over time of a physical system is governed by two postulates: the *causality postulate* and the *stability rule* ».**

An evolution that satisfies these two postulates is termed *deterministic*; conversely, every deterministic evolution satisfies these two postulates.

3.1 Causality Postulate – Principle of Reason

Causality Law

The natural sequence of causes and effects is governed by the causality postulate.

Definition of the Causality Postulate

The causality postulate is a necessary and sufficient condition.

Necessary condition: the Principle of Reason

> **« Any observed phenomenon (situation or evolution) necessarily has a reason, an effective cause in the Universe that created it or triggered it. This cause preceded it, and it results from, and only from, this cause. »**

Consequences

- Everything that exists, has existed or will exist in the Universe has a causality chain dating back to the Big Bang, the beginning of the Universe.

  Causality Chain
  This notion, now obsolete, was used extensively in the reasoning of philosophers such as Kant. Here it is.

  Any sufficient reason is based on a cause defined at a time t_1, itself based on another cause defined at a time t_2 preceding t_1, etc. The sequence of these causes defines a *causality chain* that goes back in time to a *first cause*, postulated for lack of knowing the cause, or so that the chain remains finite (which constitutes an exception to causality, by inventing a cause without cause such as God, logically absurd but necessary because nobody knew how to define a cause tending towards infinity).

  In our Universe, all physical causes go back in time to the era of Great Unification that followed the Big Bang, because our knowledge of physics does not allow us to deduce what preceded the Inflation era, other than speculatively.

- We know today that no transcendent intervention (from outside the Universe or preceding its existence) is possible: none created, will create or will modify anything in the Universe, because the Universe expanding faster than the speed of light this intervention would propagate even faster, which Relativity forbids.

Note: If we accept the Big Bang theory and remain consistent, we cannot admit the existence of a Creator God capable of acting physically today in the Universe.

- No cause from within the Universe can act outside – if such an outside exists (same reason: Relativity).

Sufficient condition

« The existence of an effective cause (a situation) immediately triggers its consequence, an evolution governed by a law .»
(This is certain.)

Example: I hold a stone in my hand;

- If it falls, I necessarily let it go; this is a necessary condition;
- If I drop it, it falls; this is a sufficient condition. The cause (dropping the stone) is then termed *effective cause*.

A sufficient condition of evolution is not enough for it to be deterministic: it must also be governed by a law of nature which respects the following *Stability Rule*:

« The same cause will produce the same effect, always and everywhere. »

We will come back to this rule later.

Important note: the definition of the causality postulate promises only an evolution governed by a stable law; it does not promise any result predictability.

Opposition between determinism and chance
This definition makes determinism the opposite of chance, defined as:

« A situation or an evolution is by chance if it has no cause and no law. »

3.2 Understanding and Predicting

The causality postulate satisfies two general requirements of rational thinking, explaining how a state came to be, and predicting the outcome of an evolution.

- The necessary condition explains at least part of an observation (evolution or state), by going back in time to its cause:
"If the stone falls, I *necessarily* dropped it".
- The sufficient condition lets us predict a consequence, by following time towards the future from its cause; the immediate evolution is *certainly* triggered:
"If I drop the stone, it falls (that is certain) following Newton's gravitation law".

Causality is a Principle of Understanding, not of Logic

Kant writes, page 647 of the *Critique of Pure Reason* [20]:
"If they are principles of understanding (for example, that of causality…)."

This postulate is used so spontaneously that we sometimes mistakenly consider causality a principle of Logic. However, physical causality and its resulting evolution imply an exchange of energy (the cause is then termed *effective* or *sufficient*). The *material*, *final* and *formal* causes described by Aristotle are not subject to a natural causality law.

3.3 The Two Kinds of Causal Deductions

There are two kinds of causal deduction:

- *Logical* causality, applicable to all deductions of logical propositions such as:
  - (a<b **.** b<c) ⇒(a<c), where "⇒" reads "IMPLIES" and the dot "**.**" reads "AND",
  - or the syllogism (a ⇒ b **.** c ⇒ a) ⇒ (c ⇒ b).
- *Natural* causality, applicable to all physical evolutions, such as Newton's 2nd law. This causality exists at two levels:
  - The laws of nature, governing all evolutions. Example: the conservation of the electric charge of an isolated system.
  - The value of a particular variable, subject to a certain calculation law. Example: value of the voltage V across a resistor R through which a current I flows: $V = RI$ (Ohm's law).

Separation of the Two Kinds of Causality

- Inferences by logical causation do not apply to natural phenomena, and inferences by natural causation do not apply to logical propositions. Kant showed in his Critique [20] that:
  - One cannot deduce a physical reality by logical reasoning: there cannot exist a logical proof of the existence of a God who could create the physical Universe, or act in it.
  - From a description of God as a creator of the Universe, one cannot logically deduce his physical existence or capabilities.

  Pure logic cannot demonstrate a physical causal effect: logic and physics are two areas of knowledge such that no deduction is possible from one to the other.

  Logic only imposes on Physics the non-contradiction of two assertions on the same subject.
- A purely abstract God (the Idea of God) cannot be an effective cause of the Universe, in spite of Plato's idealist doctrine which postulates that all reality is a copy of an Idea. As above, the reason for this is the absence of proof: no mental representation of a phenomenon, no concept of a physical object can cause a real object's existence. From the time of Plato until the age of Enlightenment [21], idealistic copying was admitted without proof, but today reality requires a proof.
- One can conceive of a physical God existing before the Universe that He created, but one cannot factually prove either the existence or the non-existence of such a God, nor can one prove the possibility or the impossibility of such a creation: Kant also demonstrated that in his Critique [20].

For centuries, in reasoning about natural phenomena, philosophers such as Descartes used *divine* causality. Some philosophers used *moral* causality (Good/Evil). Peoples such as the Greeks used *aesthetic* causality, such as the harmony of nature, where everything is bound to be good, and which requires the stars and planets of the "Upper Sphere" to have perfect (circular and uniform) movements.

Today we admit *psychological* causality in human relationships. But we have at last returned to the causality of the materialist Democritus, for whom a material phenomenon can only have a material explanation.

3.4 Details on the Notion of Evolution Used in this Text

An evolution concerns a system altered by an effective cause. When I say: "A dropped stone falls":

- The system that evolves is the stone.
- The evolution is the fall. It is governed by two laws discovered by Newton:
  - The law of universal gravitation, which exerts an attractive force;
  - Newton's second law, from which we can deduce the evolution of the height of the stone as a function of time.
- The effective cause is the force exerted by the gravitational field, gravity.

Energy Exchange

An effective cause of evolution implies an exchange of energy. While falling, a stone loses potential gravitational energy and adds kinetic energy by gaining speed.

- Although deterministic, the trajectory of a light ray reflected by a mirror is not an evolution, since there is no exchange of energy.
- In an insulated metal rod hotter at one end than at the other, heat propagates from the first end to the second. The energy of the system being constant, this deterministic propagation of heat, subject to Fourier's law of thermal diffusion, is computable, but it is not an evolution either.
- A planet following its elliptical trajectory in the empty space around the Sun does not exchange any energy, in the absence of the gravitational influence of other celestial bodies: its deterministic and perpetual movement is not an evolution.
- In a pot above a burner, boiling water undergoes a transformation: its deterministic phase change (transition from the liquid state to the gaseous state due to the addition of heat) is an evolution.

3.5 Evolution Laws Versus Descriptive Laws

Some physical laws are only descriptive. Examples: two of Newton's laws (the law of inertia and the law of action and reaction), which do not involve an exchange of energy, are descriptive laws involving no evolution. This kind of deterministic law allows calculations, the result of which is an *immediate* consequence of the formula associated with the law, whereas evolution laws (also deterministic) *require time and energy*.

So, there are two kinds of physical laws of nature: *evolution* laws and *descriptive* laws. The evolution laws of determinism draw the consequences of an exchange of energy. They describe variations of variables according to the values of the same or other variables; their mathematical expression uses *differential equations*.

However, in accordance with the definition of the adjective deterministic, we will include in the set of deterministic physical laws descriptive laws such as those of geometrical optics. The latter do not govern an evolution, but a path of light rays. They are deterministic because such a path is a function of the initial conditions (the optical system) and follows laws. A descriptive law applies to a phenomenon which does not change, or which does not exchange energy in the thermodynamic sense.

Other examples of descriptive laws also considered deterministic: two of Newton's three laws (the law of inertia and the law of action and reaction), which involve no exchange of energy or evolution.

A descriptive law allows calculations, the result of which is an *immediate* consequence of the formula associated with the law, with its data. Such a law is not, strictly speaking, a law of causality: there is no cause preceding an effect; it is a logical deduction.

3.6 An Evolution is Either Conservative or Dissipative

With energy exchange, an evolution is either *conservative* or *dissipative*.
Here are two definitions regarding Mechanics as a science.

- *Classical Mechanics* is the branch of Newton's physics that mathematically studies the motions of solid bodies.
- *Analytical Mechanics* is a very general and abstract branch of Classical Mechanics, useful in theoretical physics and Quantum Mechanics.

Definition of a Conservative System

In *Analytical Mechanics*, we consider *conservative* a material system which has a constant energy, because it does not exchange energy with its outside. This is the case, for example, for systems without friction (in practice those where friction only disturbs the evolution in a negligible way); example: a planet revolving around the Sun.

Time Symmetry
The mathematical evolution model of a conservative system has a *time symmetry*. It is a system of differential equations invariable when replacing the time variable *t* with -*t*; the evolution toward the future is then replaced with an evolution toward the past, described by the same equation(s): the evolution is reversed and time runs backwards.

Definition of a Dissipative System

A system which is not conservative (which exchanges energy with its exterior) is said to be *dissipative*. The differential equations which describe its evolution change when replacing *t* with -*t*. This happens with all evolutions subject to friction, or (in planetary astronomy) to *gravitational tides*.

Gravitational Tides
Together, the large planet Jupiter and its satellite Europa exert a variable attraction on the small satellite Io. This attraction is stronger whenever Io approaches their center of gravity, and weaker when it moves away from it. This results in forces that alternately compress or stretch Io's matter, which generates such heat that Io has volcanoes constantly spewing matter. The energy thus dispersed by Io decreases its potential energy relative to the couple Jupiter-Europa.

3.7 Determinism Promises Evolution, not Prediction

In response to an effective cause, Daniel Martin's definition of the causality postulate promises only an evolution. It promises no predictability of outcome, because such predictability is possible only at macroscopic scale; it is impossible at atomic scale (see *Natural Radioactivity*), and in chaotic phenomena (see *Chaos* in *Determinism of Iterative Processes*).

This definition is very different from the traditional definition of philosophers since Aristotle. For them, causality transforms an initial state into its consequence state, or goes up the causality chain by successive cause states or by dates of occurrence.

- The "sequence of moments" model of philosophers is discontinuous, whereas an evolution is necessarily uninterrupted as long as its cause persists, and even continuous in the mathematical sense when its law is described by a differential equation.
- The "traditional" determinism of philosophers considers a single result state as a consequence of a given initial state, which has two drawbacks.
  - The choice of the time of the result is arbitrary, whereas the evolution continues until the initial cause changes. The same cause can then produce different results depending on an arbitrary judgement criterion.
  - The prediction of a unique outcome is incompatible with Quantum Physics and chaotic phenomena, as we will see below.

  The determinism defined by Daniel Martin does not have these disadvantages.

3.8 Stability Rule (Universality, Reproducibility, Invariance)

« The same cause will produce the same effect, everywhere and always. »
(Postulate: every conservative evolution is governed by a law of nature.)

This rule postulates that for any state identical to a given state S_0 of a system, which evolves to a state S:

- The same natural evolution law L will apply, and produce a state identical to S after the same time interval;
- There being one and only one evolution law for a given state S_0, this state will undergo an identical evolution toward S at another time, or in another location;
- This law L does not vary, it applies everywhere and at all times for successive application locations and times, present, past or future.

Consequence: if two closed systems are identical, they will remain so by undergoing the same evolution, whatever their distance in space or time.

Stability Rather Than Universality - Fundamental Postulates of Physics

In the definition of Special Determinism, the name *Rule of Universality* would be vague, because it does not correspond to specific physical criteria. The name *Stability Rule* was preferred because it corresponds to the fundamental physical postulates that govern the changes of closed conservative systems:

- *The homogeneity of time*, origin of the law of energy conservation;
- *The homogeneity of space*, origin of the law of conservation of moment (vector product of a mass by a velocity vector);
- *The isotropy of space*, origin of the law of conservation of kinetic moment (vector distance to the origin by a moment vector);
- *The left-right symmetry of space*, origin of the law of invariance of the *CP* product of symmetries *C* (electric charge) and *P* (position with respect to a plane);

- *The symmetry with respect to the direction of time* (change from *t* to *-t*), origin of the law *T* of conservation of evolution laws during such a change;
- *Noether theorem about the correspondence between fundamental symmetries (invariances) and conservation laws*.

Knowledge Field of Physics

Metaphysics must also delimit the field of application of physics.

- To which domain of reality does physics apply, and what are its precise objectives? Does physics apply only to the field of experiments accessible to Man, or can we/should we include, for example, theological considerations on God, the Creator of the world, on His finality during this creation, on His possible intervention in the actual world, and on the harmony of nature?

  We have already seen that the notion of God should not intervene in any scientific discourse.
- How can one define the truth of a statement about physical reality, and how can one deduce it from experiments or pure logic?
- How can one establish the cause that explains a phenomenon? And the cause of this cause? Is a causality chain infinite towards the past, or how does it end?

This text offers answers to these questions about application conditions.

3.9 Usefulness of Determinism: to Understand, Foresee and Predict

Before acting, and out of curiosity, Man needs to *understand* a situation, to *foresee* its evolution and to *predict* its exact (numerical) consequences.

> Failing to understand a situation or foresee its evolution, Man is worried: for him, instinctively, what is misunderstood or unpredictable may be threatening, or may prevent him from taking advantage of an opportunity.

Understanding and foreseeing the natural evolution of a system are governed by a philosophical principle: determinism; believing this is adopting the doctrine of determinism.

Understanding the Situation of a System Means Describing:

- Its current state in its environment;
- Its past evolution, a prelude to a causal understanding of its evolution phenomenon and an answer to the question: was it inevitable?

Foreseeing the Evolution of a System Implies:

Qualitatively Describing This Evolution:

- Course of events, variables and field of definition;
- Is this evolution bounded, or does it diverge (go to infinity);
- Bifurcation diagram of the evolution (change of the evolution law, like changing from liquid to solid);
- Does it have a single result, or a set of results (and if so, what is the structure of this set - for example a statistical distribution of values)?
- Does it have symmetries, self-similarity, statistical properties?

- Does it have solutions that are sensitive to initial conditions?
- If it is bounded, does it go towards a limiting form, for example asymptotic to a curve, or does it oscillate indefinitely?
- Does it meet the conditions of universality?
- If it does not evolve towards an asymptotic curve, is it at least stable or is it chaotic?

Quantitatively Describing This Evolution by a Physical Law, Which Must Therefore be Known or Proposed.

Predicting the Consequences of the Future Evolution of a System Implies:

- Describing the future states of the system, with the expected precision of the values of their parameters. If this precision is only valid for a limited horizon - as is the case for the movement of an atomic particle, the wave packet of which spreads out progressively, or for a chaotic dynamical system – evaluate that horizon;
- Describing the interactions of this system with its environment.

Difference Between Foreseeing and Predicting

In this text, when the subject is the evolution law of a system's state:

- *Foreseeing* a state's evolution means presuming that it will occur by application of a known physical law, the state's law of evolution. This evolution is supposed to be possible, but not certain: it can be only a conjecture depending on the initial conditions.

  Example: I hold a stone in my hand. If (and only if) I let it go, I foresee that it will fall with a uniformly accelerated velocity.

  Foreseeing an evolution also means describing it qualitatively, as above.
- *Predicting* a system's state means announcing the result of its expected evolution, and describing its details.

  Example: I predict that the stone will fall to the precise altitude h ($\pm \Delta h$) at time t ($\pm \Delta t$).

  - In macroscopic physics, the prediction relates to precise values of variables;
  - In atomic physics (using Quantum Mechanics, its modeling tool), the prediction for each variable relates to a set of values, each associated with a probability or a probability density: Quantum Mechanics substitutes a probability for the certainty of Special Determinism, and a set of statistically *possible* evolutionary outcomes for a single *certain* outcome.

Deterministic Consequences

« Determinism implies foreseeability, but only sometimes predictability of a unique result. »
(Unpredictability affects Quantum Physics and chaotic phenomena.)

- The evolutionary behavior of a deterministic system is foreseeable by definition, but it can:
  - Be unpredictable, for example if it is chaotic: we will see this when we discuss dynamical systems;

- Be predictable only as an arbitrary element of a predictable set, at atomic scale where the interpretation of the laws of evolution is statistical due to Quantum Mechanics.

- A state's evolution law is independent of the chosen reference system.

  One can foresee the same evolution, according to this law, in any reference system. But predicting the numerical results of this law depends on the position and relative movement of the observer-predictor with respect to the reference system where the evolution takes place. This topic is discussed in [0] in the chapter about Special Relativity.

3.10 Deterministic Behaviors Should Not Be Judged Using System States

A Law of Physics Has No Exceptions

We want the postulate of determinism to govern all the laws of nature. Philosophers often judge the deterministic nature of such a law according to experimental results of its application (supposedly unique), for example by verifying that they have predicted values.

But a result is a human notion defined by arbitrary conditions: "at time *t*", "at the end of…", "at point *P*", etc. Judging the deterministic behavior of an evolution law according to an arbitrary set of results guarantees a validity limited to that set of criteria, *and only to those criteria*. To be objective, the result of an evolution law must not be certain only for a limited number of arbitrary states. This is why, in the criterion "…is deterministic because this set of results agrees with predictions…" the criterion "set of results" must be replaced by "evolution": the agreement between results and predictions must be verified *throughout the evolution*, not only under arbitrary circumstances.

A Law of Physics Applies As Long As Its Cause Exists, and Only While it Exists

An uninterrupted cause of evolution must result in an uninterrupted application of its evolution law. This application should not be judged at some separate times, and the law must apply continuously as long as its initial assumptions remain valid.

Critique of Reasoning Based on a Causality Chain

We must criticize the model of causal evolution of philosophers such as Kant, who only reason with causality chains comprised of successive states at distinct points in time.

- Their reasoning suffers from problems of beginning and end of time (at certain dates? at infinity?).
- They also suffer from problems of causality, due to the formal incompatibility between the intrinsic continuity of an evolution and the discontinuity of arbitrary moments of judgment.
- With a causality chain of distinct states, an infinitely distant state in the past or the future does not exist (just as infinity is not a number), and mathematical notions such as limit and convergence do not apply.

Issues such as "Does the world have a beginning, does it have an end? and "Is there a first cause, is there an ultimate end?" must therefore be approached as a continuous function of time when it tends towards infinity in the past or in the future, taking into account the possibilities of convergence and divergence of the law of evolution, at finite or infinite distances. The studies of continuous phenomena by philosophical reasoning with purely logical steps run into problems such as the paradox of *Achilles and the tortoise*.

3.11 Physics' Two Basic Kinds of Objects

Physical objects come in only two basic kinds, mass-energy and electric charge. Therefore, there are only two fundamental groups of laws of evolution: the group of Newton's laws (for mass-energy), and the group of Maxwell's equations (for electric charge). All other laws of macroscopic physics are governed by Special Determinism, and are deduced from them; the laws of thermodynamics are also governed by Special Determinism.

And since there is a *Correspondence Principle*, the laws of Quantum Physics also derive from the laws of macroscopic physics.

> **« Macroscopic state evolutions have only two fundamental law groups, Newton's and Maxwell's. »**
> (However, there is a difference between evolution laws and state transition laws.)

Consequence: the deterministic features of physics' laws of evolution will be those of these fundamental laws and equations of mass-energy and electric charge.

3.12 Laws of Evolution Governed by Special Determinism

Special Determinism therefore governs all the conservative macroscopic laws of evolution belonging to at least one of the two preceding basic kinds. It also governs the laws of thermodynamics, which are only statistics on macroscopic considerations of energy and information. Finally, it governs the laws of Special Relativity and General Relativity, based on Newton's laws and Maxwell's equations.

3.13 Scope of Determinism: Local or Global

Local determinism governs the evolution from an initial state under the effect of a law of local evolution, which applies to the starting state regardless of the states that preceded it. Its application is non-stop, continuous in the mathematical sense, each state of the evolving system being the cause of all future states.

But local determinism is not its only kind, determinism can also, acting more globally:

- Choose a law of evolution from several possible laws, as in the case of bifurcations and in Maupertuis' *Principle of Least Action*, *Fermat's Principle* and the *Quasicrystals* described in detail in [0].

  But the *Correspondence Principle* enforces a consistency rule: no law of a given scope can cause an object's state to evolve in a way different than a law of a different scope: nature is consistent, and Man postulates consistent laws.

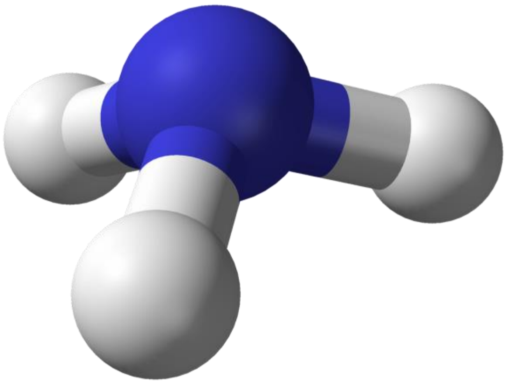
- Group together some of the variables, by specifying a global law of evolution which prohibits knowing the evolution of one of the variables taken in isolation. This is the case with Statistical Determinism, the complementary observables (i.e. measurable variables) of Quantum Mechanics, and its entangled particles.

4 Statistical Determinism

We have seen that natural radioactive decay requires a kind of determinism other than Philosophical Determinism. We will see a precise definition of that other determinism below. Let's first see a phenomenon that justifies its existence: the formation of an ammonia molecule NH_3.

4.1 Formation of the Ammonia Molecule as a Superposition of States

In a molecule of ammonia NH_3 the 4 atoms are linked by chemical bonds resulting from electrical forces. These forces impose a structure where the nitrogen atom N is at a certain distance from the plane of the 3 hydrogen atoms H, and at an equal distance from each. Quantum Mechanics calculations show that, during the synthesis of the molecule, there are two possible positions of the nitrogen atom, on either side of the plane of the three hydrogen atoms.



Ammonia molecule NH_3 – Blue: nitrogen atom N – Grey: hydrogen atom H
(only one of the two possible states is shown: N *above* the plane of hydrogen atoms)
The chemical bonds between the nitrogen atom and each hydrogen atom share one electron

Evolution Towards a Set of Superimposed States

These calculations give two solutions, corresponding to a molecule that exists in two possible kinds. The state of the NH_3 molecule at the end of its formation is a particular state of matter termed *quantum superposition of states,* or simply *superposition of states*. In this state, *the NH_3 molecule exists in its two kinds at the same time*. Such a state exists only at atomic scale, and as long as no physical interaction with the macroscopic scale occurs; its life usually is very short, and we can never see it.

Determinism should therefore take into account this state superposition phenomenon to also govern the laws of the atomic scale.

> **« At atomic scale, evolution laws can have *a set of* simultaneous solutions, contrary to the macroscopic scale. »**
> (At atomic scale, the evolutions of a system in space and time are described by the Schrödinger equation, which is one of the mathematical tools of Quantum Mechanics.)

The particular kind of determinism governing the laws of the atomic scale will be termed *Statistical Determinism*, a subset of *General Determinism* discussed below.

4.2 A State Superposition is a Particular State of Matter

A state superposition of a particle, or of a system of particles, is its state (like the solid, liquid, gas and plasma states) at the end of an evolution, or at the end of a formation predicted by the Schrödinger Equation of Quantum Mechanics. The various simultaneous quantum states resulting from this evolution share the same mass-energy and some other properties, most of which also exist at macroscopic scale. Because of this sharing of physical and mathematical properties, the quantum superposition of states is said to be *coherent*. But we will see that this state of matter is not structured.

Fragility of a State Superposition - Decoherence

This state is very fragile because it has no binding energy. It does not have, like an oxygen molecule O_2 does, a negative potential energy binding the oxygen atoms, an energy which one would have to provide to separate the molecule into its two atoms.

No such amount of energy was released during the formation of the superposition, for example as an emission of photons: it would have been part of the evolution which ended as a superposition, and we did not suppose or observe its existence in evolutions at atomic scale.

Therefore, the state superposition at the end of an evolution is unstable. Any macroscopic state energy given to the system by an interaction will immediately separate its elements, the unique resulting state receiving all of that energy as heat. Which unique state is chosen is unpredictable, because the interaction is not governed by the law of the preceding evolution; it is a separate transformation that cannot be described by any repeatable physical law.

> Example: an ammonia molecule formed in (invisible) state superposition will decompose, after a collision with another molecule. The (visible) molecule *M* resulting from the decomposition has a 50% probability of having the nitrogen atom "above" the hydrogen plane, and the same probability of having it "below". Its kinetic energy in superimposed form will change upon impact with the other molecule, and end up in molecule *M*'s only state.

Therefore, a state superposition generally has a short lifespan: a slight friction with its surrounding macroscopic scale is enough to destroy it, reducing it to one of its constituent states which is impossible to predict; there was a state transition governed by an *interrupt law* (concept described below). This transition is termed *decoherence*.

> **« Mass-energy can also exist as a superposition of quantum states, an unstructured and fragile state of matter. »**
>
> **« The result of an evolution at atomic scale can be a superposition of quantum states that share mass-energy, electric charge, etc. »**

What We Can "See" of a State Superposition

A superposition of quantum states is evidenced in some atomic physics experiments as a result of evolution [200], but we can never actually see one physically, such states being virtual. Any human attempt to see (on a macroscopic scale, for example during a measurement) a superposition of quantum states implies an exchange of energy, which disturbs the superposition enough to decompose it, retaining only one of its coherent states, which alone becomes visible: a *decoherence* occurred.

« The lifespan of a system's state superposition decreases when the system's interaction with its environment (for example through shocks between molecules) increases, thus making it unstable. »

This disturbance is not described by the law of evolution which produced the superposition, since it happens after the evolution completed. Its result cannot therefore be predicted by it. It can never be described quantitatively, because it is due to a macroscopic energy distinct from the evolution energy of the atomic scale. The choice of the visible state that it selects among the formerly superimposed states is therefore not predictable, because this final disturbance cannot be described precisely.

A Frequent Error

This unpredictability has been wrongly attributed by some people to the laws of evolution of quantum states, which they termed non-deterministic since some can produce multiple probabilistic evolutions and results. This opinion is erroneous in the theory of determinism described in this text, since being deterministic only requires that an evolution depend only on its initial state, and can be described faithfully by a law. As defined in this text, determinism does not exclude laws with multiple probabilistic results, it was defined to govern them.

Quantum State Evolution Laws Have Sets of Results With Predetermined Elements

The evolution law that applies to a given state creates the set of resulting superimposed states: all the element-states of this set are known as soon as the evolution is defined, and this set will persist throughout this evolution. Thus, an NH_3 molecule which has just formed is a set of coherent states with two molecule-elements: the molecule with the nitrogen atom *above* the plane of the hydrogens, and the molecule with the nitrogen atom *below* the plane of the hydrogens. A measurement or disturbance of energy will unpredictably choose one of these states, which will be visible and persist at a macroscopic scale.

Particles Can Travel in Superimposed States

A neutrino is another natural example of a particle's state superposition: see [318], from which we quote the following:

« The study showed the particles can be in a superimposed state, without individual entities, when traveling hundreds of kilometers […] Neutrino particles can oscillate, or change between several distinct "flavors" while traveling through space close to the speed of light […] The neutrinos leave their original location as one flavor, but they can oscillate during the journey, reaching their destination as another flavor […]

What's fascinating is, many of us tend to think of Quantum Mechanics applying on small scales. But it turns out that we can't escape Quantum Mechanics, even when we describe processes that happen over large distances. We can't stop our quantum mechanical description even when these things leave one state and enter another, traveling hundreds of miles. I think that's breathtaking," said David Kaiser, the Germeshausen professor of the History of Science and professor of physics at MIT. »

In short:

« Particles can travel in superimposed states. »
(Which proves that a superposition can last for quite some time.)

« Particles existing in several kinds likely to coexist in a superposition, can spontaneously change kind or oscillate from one kind to another. »
(Such a change or oscillation exchanges no energy.)

4.3 Conclusions for Physics

It has been demonstrated that nature does not have, and cannot have, a law for knowing *when* a particular atom will decay, or *which* atom in a sample will decay first: its law of decay can only apply to a *population* of atoms.

In the case of radioactive decay, one can *foresee* an evolution qualitatively (the chemical elements produced by the decay), but one cannot *predict* some of its quantitative results (such as the time when a particular atom will decay, or the first time an atom decays). Hence the important metaphysical conclusion:

« We can always foresee an evolution's result, but we can't always predict it. »

There are many natural phenomena, the evolution of which can thus be foreseen (qualitatively), but not predicted (quantitatively). Since the examples that can be cited are at atomic scale, it is necessary to name the mathematical tool of atomic physics, *Quantum Mechanics,* which covers, for example, radioactive decay.

4.4 Philosophical Conclusions – Instability

Natural determinism can therefore produce *instability*, a circumstance where the system's present state will evolve without external cause towards a more stable state, after statistically distributed times. This phenomenon is explained and quantified in Quantum Mechanics by the *Heisenberg uncertainty principle*.

« The instability of some atoms or molecules produces irreversible state transitions governed by Statistical Determinism. »

More Features of Determinism

- Determinism is continuous (uninterrupted: its evolution law applies as long as its cause exists).

  « Any natural system is constantly evolving, and will evolve until the end of time, its thermodynamic equilibrium is never completely stable. »
  (Any void location in the Universe receives radiation, therefore also energy, and is subject to quantum fluctuations).

  « All bodies keep radiating, absorbing and reflecting electromagnetic energy. ».
- Determinism can have several stages (when there is a succession of distinct evolution laws or state change laws, like the series of decays of ^{238}U).
- Determinism can be more or less rapid with regard to the duration of an evolution's consequence (and the duration itself is relative, since Relativity makes it vary with the speed of the observer: a moving clock runs more slowly than a clock at rest);
- Determinism can be unpredictable, in the sense that no one can predict the order in which the nuclei of a radioactive body will decay, or predict when a given nucleus will decay; the statistical law of decay applies to a population, not to one of its elements.

Remarks on the Decay of Atomic Nuclei and Their Instability

The causality that produces the decay of nuclei is not fully understood today. However, its effect involves binding mechanisms between nucleons (i.e. protons or neutrons) similar to the surface tension of a drop of liquid, electrostatic repulsion (Coulomb force), the nuclear (i.e. strong) force, and the weak force.

We know, however, that some heavy nuclei, originally synthesized in supernovae (i.e. very powerful stellar explosions), have a low binding energy per nucleon. If such a nucleus is deformed - for example by a shock, or by an intense thermal agitation of its nucleons - the repulsion between its protons amplifies the deformation, and the heavy nucleus tends to break. Since a nucleus decays with a loss of mass, and also with a release of energy and an increase in entropy, there can be spontaneous fission.

Energy instability is not an active cause, it is a property; and its consequence - which only appears after some time - does not affect a nucleus or an isolated particle, it affects a statistical number of nuclei or particles. We are here at the limits of the postulates of causality and determinism, some properties of the evolution resulting from instability being unpredictable at the atomic level. The philosophical solution is the existence of a feature of *General Determinism*, interrupt laws. For the time being, let us remember that:

> **« Some deterministic effects can only be described by statistical laws affecting a population and durations. »**

4.5 Quantum Decoherence

This section is completed in the appendix by the chapter Quantum Physics - Quantum mechanics and the following chapters.

Definition

A decoherence is an irreversible transformation, fundamentally different than the reversible evolution governed by the Schrödinger equation that preceded it. It is a transition bringing the system’s state from the unstable superposition to one of its component quantum states, which survives it. Unpredictability intervenes, by Statistical Determinism, in the choice of one of the elements of the former superposition’s set.

> Another example of unpredictability: *quantum fluctuations* are spontaneous phenomena (i.e. without prior cause) that are not evolutions. They result from *intrinsic indeterminations* (instability due to the *Heisenberg uncertainty principle*) that evade the very concept of causality.

Instability

A superposition of states decomposes fairly quickly by interacting with its environment, for example in the form of heat exchange. See the article *From the quantum world to the macroscopic world: decoherence caught in the act* (in French) [200]. The larger and heavier the system, the more unstable it is; this is why a macroscopic superimposed state is never observed.

> **« State superposition can only be stable at atomic scale. »**

Wave Function Reduction

The transition from a superposition of states to one of its states reduces this superposition to a single stable state visible at macroscopic scale. It reduces the coherent wave function of the complete system (i.e. the object in superimposed states + the measuring device) to that of a particular eigenvalue of an observable (i.e. measurable variable) of the device, hence the name *decoherence*: it chooses one of the eigenvalues, corresponding to one of the superimposed objects, attributes to it the global parameters of the initial object such as mass-energy and electric charge, and lets it subsist stably on the macroscopic scale. It is impossible to predict which of the superimposed objects will be chosen, because one cannot describe accurately the parameters of the macroscopic disturbance inflicted on the superposition in the atomic state by the decoherence, disturbance which creates the unique state observed from the superposition.

> **« A macroscopic object is in a unique and stable quantum state. »**
> (Except when it is unstable, like radioactive matter.)

From the point of view of wave-particle duality, the reduction of the wave function removes the wave behavior which made variable values uncertain or unstable, leaving only the macroscopic state without uncertainty or instability.

4.6 Multiplicity of Evolution Results

A system's state superposition resulting from an evolution also exists as probabilistic values of variables such as position or impulse (mass x speed). A particle which has moved finds itself *simultaneously*, at time *t*, not at one but at an infinity of neighboring positions; and its speed can have an infinity of neighboring values.

Probability of Presence of a Particle at Point *Q* – Probability Density

Each of a particle's positions, for example at point *Q*, is assigned a probability density of position *p(Q)* that describes the probability of presence in a volume *dV* around *Q* by the product *p(Q)dV*.

The Multiplicity of a Particle's Positions at the End of an Evolution can Be:

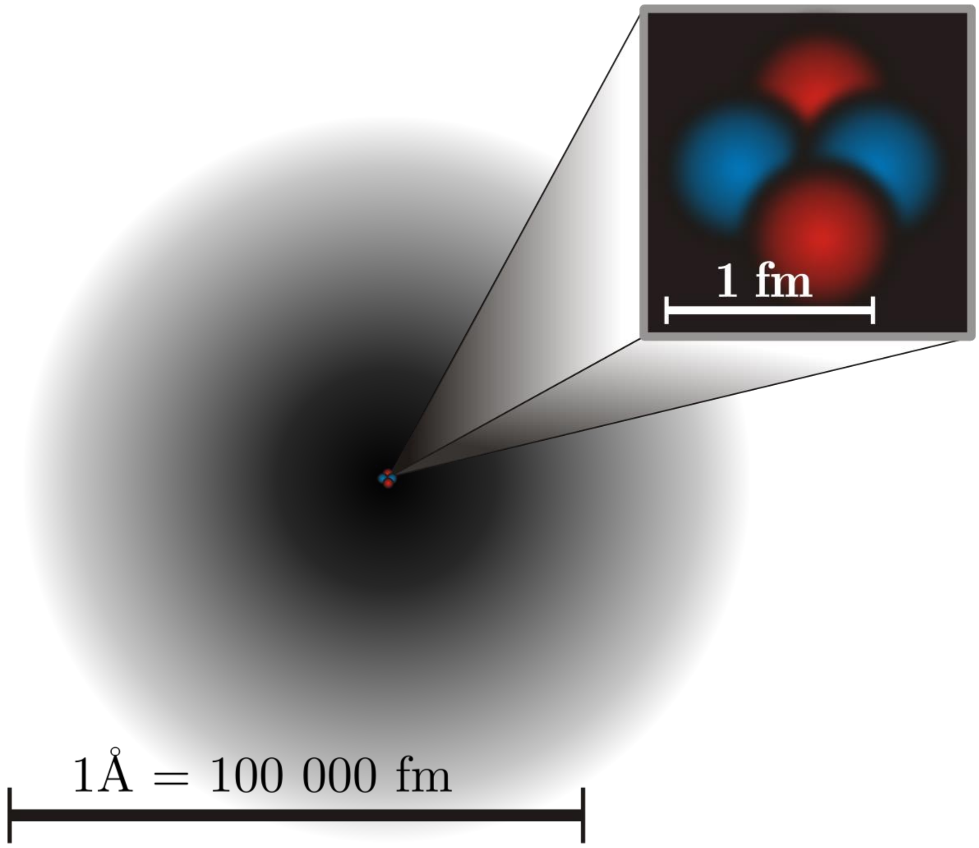
1. Either its most likely location, where the probability density is highest;
2. Or its multiple simultaneous presence throughout space, giving a blurred but sharper image where the probability density is highest;
3. Or its various possible locations if the experiment is repeated a large number of times, some being more likely than others. This is a probabilistic position prediction for which there is an equivalent law for velocities. Hence the law:

> **« At atomic scale, positions and velocities are always probable. »**

Example

In the figure below, the probability density of position of the two electrons of the electron cloud of a helium ^{2}He atom in a small zone increases as this zone grows darker (it includes more points). The nucleus (2 protons + 2 neutrons) is in the center.

The square at the top right represents the probability density of presence of the two protons in the nucleus. A helium atom has a size of about 1 angstrom (1Å = 10^{-10} m), while its nucleus is 100,000 times smaller, with a size of about 1 fermi (1fm = 10^{-15} m).



Atome d'hélium: densité de probabilité de présence des 2 électrons autour du noyau
© Wikimédia Commons

See also: Reminders on Gauss's Law (reading not required).

4.7 The Indeterminacies of Quantum Mechanics

At a given time, not only is the position of a particle inaccurate, but so is its speed.

> **« At a given moment a particle's position and speed are both probabilistic, therefore inaccurate and uncertain. »**

Worse still, it is impossible to choose arbitrarily, or to know with precision, simultaneously, the position *x* and the momentum (impulse) *p=mv* relative to a given reference axis of a particle of mass *m* and speed *v*: the product of their inaccuracies *Δx* and *Δp* has a lower bound given by the *Heisenberg uncertainty principle*, demonstrated in Quantum Mechanics. This law is written:

$$\Delta x \,.\, \Delta p \geq \tfrac{1}{2}\hbar$$

where $\hbar=\frac{h}{2\pi}$, h being the Planck constant, h=6.626.10^{-34} joule**.**second.

Mass is always constant in Quantum Mechanics, because it is non-relativistic; but the greater the position precision, the lower the speed precision, and vice versa.

> **« This limitation is not due to an inaccuracy of the measurement methods adopted, but is instead a basic principle of nature. »**
> (This principle imposes au upper limit of precision, both on simultaneous arbitrary choices of position and speed, and on the reproducibility of the results of successive simultaneous measurements.)

> **« This principle also describes an instability of nature. »**

See also:

- There are other pairs of variables subject to the same limitation
- Heisenberg uncertainty principle.

4.8 A Result is Created by its Measurement. Before, it Did Not Exist

It is important to understand that the evolution of a system at atomic scale creates *a set of results*, not a particular result. Just as in mathematics one does not confuse a set with one of its elements, in Quantum Physics an evolution creates a set of potential, virtual, superimposed results; *before the end of this evolution the measured result does not yet exist*:

> **« It is the measurement that creates the result, choosing it from the elements of the superimposed set of virtual results created by evolution. »**
>
> **« Unlike in macroscopic physics, no observable (i.e. measurable variable) in Quantum Physics has value independently of its measurement. »**

It is important to understand that measurement creates the result, it does not reveal a pre-existing result. What preexists is the set of *possible* results of the evolution, the elements of which are the eigenvalues of an observable which has the initial mass of the system before its evolution.

This evolution, governed by the Schrödinger equation, creates this set in superimposed state, all of its elements existing together and sharing the same energy and other properties (a feature termed *coherence*). What Quantum Mechanics affirms, and Schrödinger's equation produces, is this superimposed state, a reality of mass-energy that can be seen using ad hoc experimental devices [200]. This result is therefore a *virtual* state of matter, impossible to see because:

- It was not materialized by an interference with the system's environment;
- Such an interference can only create, by decoherence, an existing state of matter corresponding to one of the possible eigenvalues.

4.9 Orthogonal Eigenvalues and Interferences

Source: [301].

The superposition of states produced by the evolution's Schrödinger equation is not visible: the chosen state is only visible after an interaction with the environment, for example during a measurement. Then:

- Either the superimposed quantum states are independent (physicists say "orthogonal"), and the interaction produced a state associated with one of its possible eigenvalues, in a physical state visible at macroscopic scale (in the ammonia molecule the atom of nitrogen will be above or below the plane of three hydrogen atoms);
- Or these quantum states interfere with each other because they are not independent, which changes the distribution of their probabilities of occurrence. The interaction again produced one of the possible eigenvalues; the effect of the interferences simply changed the probabilities of these eigenvalues. This different probability distribution is the only visible feature of the interferences, the possible end states being the same as in its absence.

4.10 How the Superposition's Decomposed State is Chosen

The physical sequence of events of the choice of the element of the set of the evolution's virtual results depends on the measuring device, there is no general rule. But in all cases it involves energy, it is not neutral; and this energy is sufficient to select a result visible at macroscopic scale.

> Example: a photon is destroyed by its impact on a photoelectric cell, that produces an electrical signal with a visible result. Destroying it is the only way to "see" it.

In all cases, a measurement amplifies the energy it exchanges with the experimental device of which it is part: without this amplification, we could not see anything, our senses not being sensitive enough. However, this amplification uses an energy much greater than those of the atomic scale, an energy which is not part of the experiment, which has not intervened in its evolution, and the law of evolution of which does not exist. And since this disturbing energy does not obey any law, the element that it chooses in the superimposed set of states is unpredictable: that is why some people who do not know the previous explanation, erroneously consider the choice a random outcome of the evolution.

> **« The Schrödinger equation is deterministic, but in the statistical sense. It produces a set of virtual results, from which one must subsequently be chosen by a non-deterministic interference with the macroscopic environment. »**

<u>At Atomic Scale, any Measurement Disturbs the Measured System</u>

To provide a visible result, a measurement uses a macroscopic device. However, this device cannot fail to exchange energy (for example a photon) with the object it measures, energy which is therefore necessarily part of the experiment, that must therefore be designed to take it into account.

> **« At atomic scale, any measurement disturbs the measured system. »**

> **« The only way to "see" a photon is to absorb it in a macroscopic device. »**

4.11 The Two Kinds of Physical Changes: Transitions and Evolutions

The need to exchange energy to measure something is a consequence of the fact that there are only two kinds of physical changes:

- *Transitions* (changes of state) such as water freezing, decoherence or radioactive decay. They are only visible through energy-carrying photons, the capture of which would disturb the experiment at atomic scale.
- *Actual evolutions*, always continuous and accompanied by an exchange of energy.

> **« There are only two kinds of physical changes: state transitions and evolutions. »**

4.12 A Transfer of Information Implies a Transfer of Energy

At atomic scale, a minimum light ray (a single photon carrying the minimum information, 1 bit) reflected by a mirror transfers an impulse to this mirror, therefore an energy which counts at this scale; and conversely, any transfer of information implies a transfer of energy. This is why physicists claim that:

> **« A transfer of information supposes a transfer of energy, and vice versa. »**

Therefore:

> **« An evolution that conserves a system's energy also retains its descriptive information, and vice versa. »**

See also [302].

Some science fiction films feature a machine that "reads all the information of an object, in particular a person", then transfers it instantaneously light-years away, where a receiver can reconstruct the physical object or the person. Such films describe a physical impossibility: one cannot transfer information without transferring energy, and Relativity has shown that energy cannot travel faster than light.

4.13 Definition of Statistical Determinism

Since the Special Determinism of the laws of Newton and Maxwell cannot govern all physical evolutions, particularly those of the atomic scale and those of dynamic (chaotic) systems, we have defined an extension termed *Statistical Determinism*. It is a doctrine according to which the natural time evolution of a state is governed by the Causality Postulate and the Stability Rule (just as Special Determinism does), but the application of these laws produces results that are distributed statistically. The predictability of a final state is statistical, the choice occurring after the decoherence of the states superposition.

The simplest kind of determinism, which produces the understanding, the forecasting and the prediction of an evolution, is Special determinism. Statistical Determinism only exists for evolutions with multiple results belonging to a set defined when they start.

Evolution Laws Governed by Statistical Determinism

Statistical Determinism is a superset of Special Determinism. It governs evolution laws, the outcome of which is a set of states, the elements of which:

- Are predictable:
  - Each element has a *probability of occurrence*, in the case of discrete sets; example, in the case of ammonia: 2 states, each with a 50% probability;
  - Each element has a *probability density of occurrence*, in the case of continuous sets (see *Probability of Presence of a Particle at Point Q – Probability Density*).
- Are either end states of a periodic iterative evolution, tending to attractors or statistically predictable;
- Or exist simultaneously as a coherent superposition, before undergoing a decoherence that chooses one of the elements in a necessarily unpredictable way (as in the case of ammonia);
- Or have already undergone, by decoherence, a stochastic choice producing a unique element (as in the case of a die roll).

In addition to the conservative macroscopic laws of evolution governed by Special Determinism, Statistical Determinism governs the laws of the atomic scale. For this purpose, it governs the calculation tools of Quantum Mechanics, the fundamental equation of which is Schrödinger's. Il also governs Quantum Electrodynamics and Quantum Chromodynamics, which are mathematical tools for subatomic scales. Finally, it governs dynamic systems following the laws of Chaos theory.

Definitions of the Adjectives Continuous and Uninterruptible

In this text, continuity is a feature of evolution functions.

A numerical function *f(x)* defined on an interval *I* is continuous at point x_0 of *I* if $f(x) \rightarrow f(x_0)$ when $x \rightarrow x_0$. (The symbol $\rightarrow$ means « tends to »).

Such a function exists only when the evolution is governed by a law, but when it exists its application is uninterruptible as long as its cause exists, and only when it exists.

Being uninterruptible is a consequence of a sufficient cause: while such a cause exists its consequence is certain, it cannot be interrupted.

Affirming that a cause is uninterruptible affirms the existence of a consequence, but not necessarily that this consequence follows a law *of evolution*; for example, the consequence could be *a state change* that will continue as long as its cause exists.

> Example: as long as the water temperature is 212°F the water boils, and will not stop boiling as long as its temperature is 212°F.

Postulate of Continuity (Of Being Uninterruptible)

The continuity of a cause entails that of its law of evolution. If a sufficient cause results in the application of a law of evolution, this law must remain active as long as its cause, neither more nor less, whence the continuity postulate:

> **« An evolution law applies as long as its sufficient cause exists;**
> **no interrupt is possible. »**

4.14 Statistical Determinism Also Governs State Transitions

Radioactivity, mentioned above, causes decays that are both foreseeable and unpredictable. The list of elements produced by the decay of a nucleus, or of one of its particles (a neutron in this case), is perfectly foreseeable, as well as its emissions of radiation:

> **« A particle decay is not an evolution, it is a transformation into a known set of other particles. »**

Metaphysical Conclusion

> **« A system's state can produce a change of state (decay, atomic fusion, liquefaction, etc.), not only a continuous evolution. »**

4.15 Hierarchical Structure of the Laws of Determinism

Phase Changes of Water

Consider a pot of water heated by a burner. The supply of heat from this burner causes the temperature of the water to rise at a rate which depends on the mass of the water and its heat capacity, a rate we will call the *Vliquid* law.

When on the same burner the temperature reaches 212°F, it remains constant, but the water is transformed into steam at a rate given by a law we will call *Vboiling*, where the heat capacity of the previous law is replaced by the latent vaporization heat.

If, while pressure remains constant and the burner supplies the same quantity of heat per unit of time, the water vapor is heated above 212°F, its temperature rises following a third rate law, *Vsteam*.

In this thought experiment, the water in the pot went through 3 successive causes of heating, each with its rate law. Hence the conclusions:

> **« An object's evolution can go through successive phases, each with its own law. »**

> **« Natural circumstances provide conditions of change of an evolution law, or of alternation between an evolution and a state transition. »**

Need for Conditional Laws

A condition governing the beginning or termination of application of a law of evolution or state transition, is of a hierarchical level higher than that law. Such a condition is of a fundamentally different nature from the law of evolution or transition it governs;
it performs a test of the form:

< If this condition is met >
(Example: if the water temperature reached 212°F.)

and draws *a consequence* which depends on the test's result, of the form:

< If the result is YES, perform or prevent action *A* >
(Example: stop applying the *Vliquid* law, and start applying the *Vboiling* law.)

< If the result is NO, perform or prevent action *B* >.

Laws of Transformation: Evolutions and Changes of State

A system can undergo evolutions and transitions (changes) of state. To term one or the other indifferently, we will henceforth use the word *transformation*; there will then be l*aws of transformation*. And for these laws to be deterministic, we will postulate that all system transformations respect the Stability Rule.

Interrupt Laws

The deterministic laws triggering or stopping the application of a transformation law will be termed *interrupt laws*.

Depending on a system's circumstances (state, environment) an interrupt law allows or prevents, starts or interrupts the application to this system of a transformation law. And each launch of a transformation law provides it with an initial system state: the interrupt law « passes it the values of parameters and execution variables it needs ».

> **« An interrupt law is the effective cause of the transformation it initiates or terminates. »**

Monitoring Function of Interrupt Laws

The application of a causal relation is obviously immediate: as soon as the cause of a transformation exists, its law applies; and as soon as the cause no longer exists, its law no longer applies: this is a *monitoring* rule. Nature thus has a multitude of monitoring functions, for inanimate objects as well as for living beings.

We will therefore add to the postulate of determinism this monitoring function, just as we added the conditionality function, of which it is the essential complement.

New Definition of Determinism

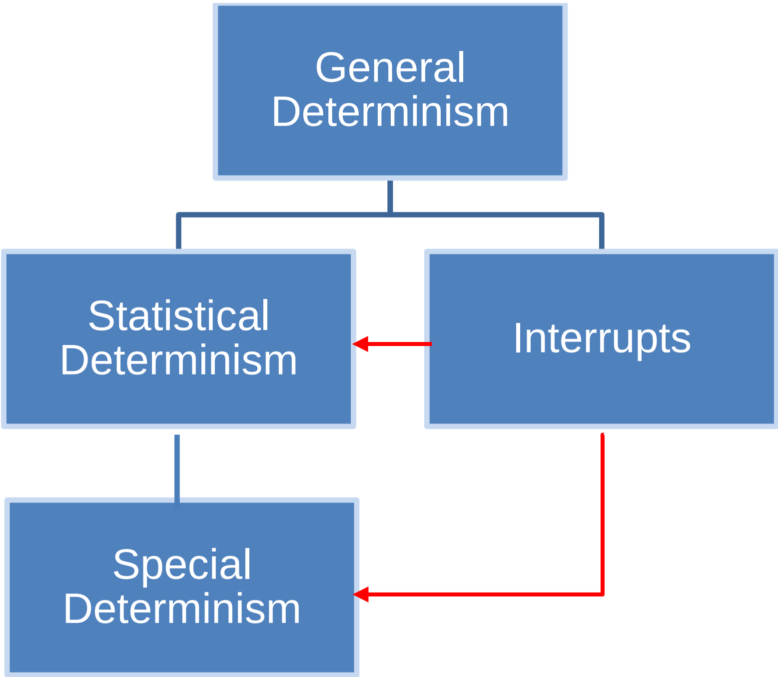
At this point in the presentation, our definition of determinism has become:

« Determinism is a doctrine according to which the causal transformation of any conservative system is governed by three postulates;

- **The causality postulate;**
- **The stability rule;**
- **The interrupt function based on the monitoring function. »**

Determinism Hierarchy

As a set of postulates, the determinism of nature comprises two interrelated subsets of postulates: the Statistical Determinism of the laws of evolution and state change, and the laws of interrupt. Statistical Determinism itself includes a subset, Special Determinism. This logical structure is a hierarchy. Its summit will be termed *General Determinism*.



Temporary Hierarchical Structure of Determinism

4.16 Necessary Conditions for Unique Predictable Results

For a natural law of evolution to produce a single predictable result, its deterministic character is not enough: knowing that a result depends only on the initial conditions and on a law does not guarantee its uniqueness, its computability and its precision.

A - We First Need an Algorithm for Predicting the Evolution From the Initial State

Definition of an Algorithm

An algorithm is a rigorous reasoning. It is a sequence of numerical or logical calculation steps, with condition tests allowing jumps to a step other than the next, if necessary. It is the description of a reasoning in a programming language. A computer program runs algorithms; reciprocally, any algorithm is programmable for execution in a computer.

Postulate 1: All Transformation Laws are Algorithmic
The existence of a deterministic transformation law implies the existence of an algorithm for foreseeing evolutions resulting from the initial state of a system, a rigorous method that guarantees its computability. This evolution expectation does not guarantee the prediction of numerical results. Algorithm examples are:

1. Newton's second law connecting the force ***F*** (vector), the mass on which it acts *M*, and the acceleration $\boldsymbol{\gamma}$ (vector) imparted to this mass is: $\boldsymbol{F}=M\boldsymbol{\gamma}$.
   The acceleration being the second derivative of position with respect to time, the law of position uses a differential equation.

   All evolution laws of Special Determinism, Statistical Determinism and General Relativity are based on a differential equation (or a system of equations). However, some *iterative laws* (of which we will see examples below) are deterministic but not based on a differential equation.

2. An iterative function such as $f(x) = r\,x(1-x)$, that calculates the successive terms of a sequence $x_{n+1} = r\,x_n(1-x_n)$ knowing the coefficient r and the initial value x_0. Such a sequence is found in dynamical systems. See Example n°2: Logistics function.

3. A system of differential equations such as the Lotka-Volterra dynamical system model ([0]).

Hence the postulate:

> **« Any transformation law is algorithmic. »**

Postulate 2: All Logical Reasonings are Algorithmic
The algorithmic character of the laws of evolution is a particular case of this second postulate. The power of logical reasoning is the power of its judgments, itself based on the possibility of formulating criteria and verifying whether a proposition satisfies them. Any criterion based on data that can be represented in a computer can be subject, in an algorithm, to a judgment of the form:

<If> condition <Then> proposition1 (or calculation1) <Else> proposition2 (or calculation 2)

An algorithm is written in a computer language. It is a reasoning sequence of computation or judgment steps, including the decision to continue execution with the next step or with another step, or to terminate it.

> Examples of algorithms: an inventory management calculation, a Quantum Mechanics calculation, a chess game strategy, a theorem proof, and artificial intelligence software.

B – It is Then Necessary that the Evolution Following the Initial State be Unique

- Example 1 above predicts a single evolution result for each initial state. But at atomic scale, where a system's evolution is described by the Schrödinger equation, the results are stochastic variables: the position or the speed of a moving particle are not unique, they depend on a law of probability. Although Schrödinger's equation is deterministic, the probabilistic interpretation of its results prevents their uniqueness, while making them members of a predefined set, a condition which prevents them from being "random"; the transition from a transient set of superimposed results to a single result is a non-deterministic choice that happens during decoherence.

Quantum Mechanics, a mathematical tool for computing evolutions at atomic scale, defines a model of determinism richer than the Special Determinism of classical physics: Statistical Determinism.

- Examples 2 and 3 above sometimes give multiple results such as a periodic oscillation between several successive states, or an evolution towards a limit “attractor” cycle (see Chaos), etc.

  A deterministic evolution may therefore produce multiple numerical results, possibly predictable with limit values. Those results are then subject to Statistical Determinism.

Remark on the Uniqueness of the Evolution of the Universe
The uniqueness requirement is postulated for the evolution model of the entire Universe by Laplace’s Philosophical Determinism, and the spacetime of Einstein's Relativity. Laplace (an astronomer) and Einstein (a physicist) had in mind the deterministic universe (in the Special sense) of astronomical phenomena. Uniqueness implies the existence of a single causality chain linking past, present and future states.

This single causality chain of the sequence of past states is a subset of the causality chains of the hierarchical structure of possible states, that includes state superpositions, position and speed uncertainties, and unpredictable state transitions. Multiple possibilities have arisen whenever an evolution (or state transition) outcome has been an element of a set of solutions among which nature has made an unpredictable choice, for example by interacting with the environment.

No prediction of result is possible beyond a hierarchical tree node: the choice of the branch followed may be a function of non-deterministic processes, such as the date of an atom’s radioactive decay or the reasoning of the human subconscious. And Man acts on nature, sometimes with the brutality of an atomic explosion. Conclusion:

> **« The global evolution of the Universe is not deterministic. »**

C – Finally, the Result Predicted by Calculation Must be Precise

From a logical point of view, a predicted evolution result representing a physical quantity must be correct, its value must not be marred by inaccuracy, indeterminacy or ambiguity.

This requirement is incompatible with Quantum Mechanics, the results of which are marred by probabilistic uncertainty. Moreover, even at macroscopic scale, we will see that some evolution laws have a *sensitivity to initial conditions* which limits the precision of their results and their prediction horizon, even when the calculations and the initial data are precise. Hence the conclusion:

> **« The determinism of an evolution law does not guarantee the precision of its predicted states, although these depend on a law. »**

Additional information: see in the *Chance* chapter the paragraph *Determinism Does Not Guarantee Predictability*.

4.17 Determinism of Iterative Processes

Dynamic Systems

Iterative processes describe the evolutions of systems termed *dynamic*.

They are an alternative to the continuous (uninterrupted) processes of the macroscopic evolution laws of nature. This alternative was designed to model intrinsically discontinuous evolutions, such as the evolution of a population known only by annual statistics. To describe the evolution of a dynamic system, we talk about its *dynamics*.

Definition of an Iterative Process

An iterative process is a series of successive steps, the progress and results of which are such that:

- Its course is governed by a computable law defined by Man. This law defines, for any given rank *n*, the term of rank *n+1*, which only depends on the term of rank *n* and on the initial term (*n*=0 or *n*=1); the law of evolution is therefore deterministic.
- The result of each step is defined at the end of this step (and not during its progress).
- The initial step proceeds from the initial conditions, then the results of each step become the initial conditions for the next step.

Example 1

Consider the series of numbers whose first term is 1 and the term of rank *n+1* is defined from its predecessor *n* by the formula $\boldsymbol{x_{n+1}} = \frac{1}{2}(\boldsymbol{x_n} + \frac{2}{x^n})$.

The first terms are: 1; ½(1+2/1)=1.5; ½(1.5+2/1.5)=1.4166, etc.

When *n* tends to infinity ($n \to \infty$) $x_n \to 1.4142135\ldots$ which is the value of $\sqrt{\mathbf{2}}$.

Such a process is deterministic, because its course is governed by a law and depends only on the initial condition $n_1=1$.

Example 2

A population has a natural growth of 1.5% per year, measured by annual statistics. This growth leads to an increasing consumption of a limited natural resource, such as water. The consumption is measured each year at the same time as the population. Knowing the limit of the resource and the initial population (of year zero), calculate its evolution in the short term (years 1, 2, 3…) and in the long term.

A Bounded Iterative Evolution Can Produce 4 Kinds of Results, and Only 4

We will see in the *Chaos Theory* below, that the evolution of such an iterative deterministic process can produce, after a large number of iterations:

- Either a unique finite result;
- Or an infinite result;
- Or an asymptotic oscillation between a finite number of results;
- Or an infinite series of unique results.

4.18 Chaos: Sensitivity to Initial Conditions and Amplification

In this section we will study the important particular case where the iterative character of an evolution is due to its non-linearity.

Linear and Non-linear Functions

By definition, a function *F(x)* of the variable *x* is linear if and only if, when *x* is multiplied by *k*, so is *F(x)*. This is written:

$$F(kx) = kF(x)$$

Of course, if x is divided by k, so is $F(x)$: $F(\frac{x}{k}) = \frac{F(x)}{k}$.

A non-linear function involves, for example, a power of the variable, a product of variables such as xy, or functions such as $cos(x)$.
Examples of nonlinear functions: x^2, $cos(x)$, xy, e^x (where e = 2.71828…).

Chaos

The word chaos evokes disorganization, unpredictability. In physical or artificial systems which evolve, the chaotic character comes from the fact that their descriptive evolution equations are deterministic, but have unpredictable solutions. This phenomenon is discussed in the Chance chapter, in section *Determinism Does not Guarantee Predictability*. One of the reasons for the unpredictability of chaotic systems is their *sensitivity to initial conditions*, described below.

We shall also see that this unpredictability is not total: predictions are possible with statistical models, the prediction functions being stochastic. The evolutions of dynamic systems are therefore governed by Statistical Determinism; there is an analogy here with the evolutions in Quantum Mechanics, also governed by Statistical Determinism.

An Initial Definition of Chaos

By definition, chaos characterizes a deterministic phenomenon in a negative way:

- It prevents the prediction of distant future states;
- It amplifies experimental inaccuracies.

The Three-Body Problem, an Example of Sensitivity to Initial Conditions

A Disrupted Planetary Orbit

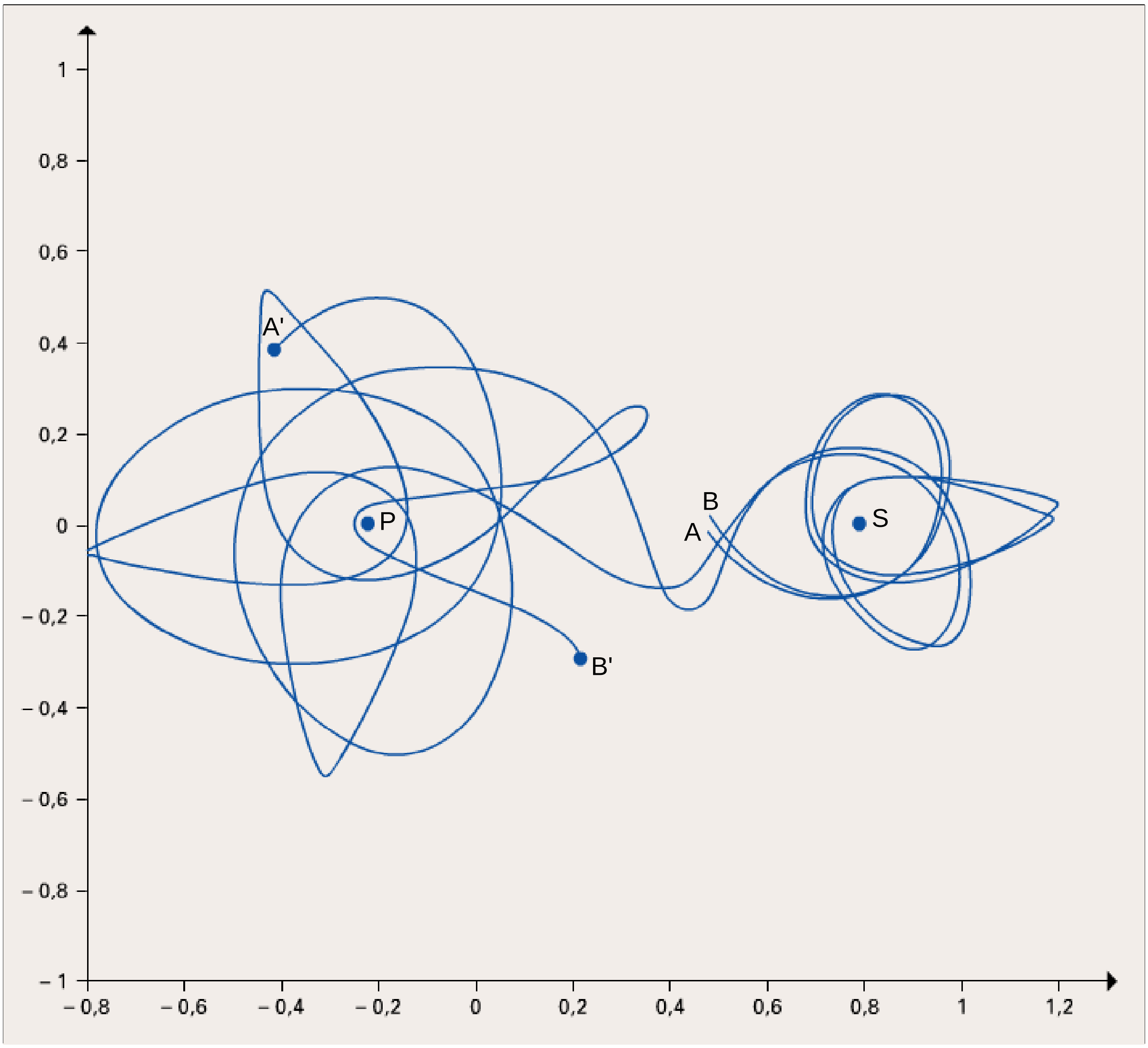
The problem proposed in 1885 by king Oscar II of Sweden and Norway, with a prize for the first scientist who would solve it, concerns a conservative phenomenon with a chaotic evolution. The question was whether the solar system is stable in the long term, for example over millions of years, or whether a body (planet or asteroid) can change orbit by attraction of another body, or collide with it, or fall on the Sun, or be ejected from the system, in short change orbit significantly.

The winner of the prize, the French mathematician Henri Poincaré, studied the general properties of possible solutions to this problem. He showed its complexity, and went thoroughly into the simple case where there are only 3 bodies - for example two large ones such as the Sun and a planet, and a very small one such as a satellite; - this case was termed since *Problem of the Three Bodies*. He showed that even in this simple case *the orbits are too complex to be described by an explicit formula*.

To solve this problem, Poincaré had to go deeper into a branch of mathematics, *Algebraic Topology*, which studies the continuous transformations of geometric objects using algebraic structures. He summarized the general solutions of the astronomical problem proposed in a new discipline, for which he laid the foundations: the *Theory of Dynamic Systems*.

In the 20th century, other mathematicians completed Poincaré's work, showing that *in some cases the evolution of an orbit can be unpredictable*, a discovery which called into question the definition of determinism accepted at the time.

Example of chaotic evolution from [177]: trajectory of the "small" celestial body of the 3-body problem. The graph below represents, in a reference system where the horizontal axis passes through the centers of the Sun *S* and of a planet *P*, and the vertical axis is any perpendicular to the first, two trajectories *A→A′* and *B→B′* of the small body, when it started from points *A* and *B* which are very close. These two trajectories diverge, the final distance *A′B′* being much greater than the initial distance *AB*: it underwent amplification.



Divergence of the trajectories of a small body attracted by the Sun *S* and a planet *P*

Today we know chaotic developments in many fields: fluid dynamics, meteorology, the chemistry of dissipative reactions, and even Quantum Mechanics. A chaotic evolution can concern a conservative system as well as a dissipative system.

Iterative Evolution

Non-linearity requires a numerical search for the limit to infinity, using successive iterations. The non-linear character of the evolution of a chaotic function prohibits, in general, expressing it as a time formula of the form *F(t)*.

Calculating the evolution of such a system was illustrated in the previous example $x_{n+1} = \frac{1}{2}(x_n + \frac{2}{x^n})$. One calculates *numerically*, by successive iterations at times t_0, t_{0+h}, t_{0+2h}…, the values of its variables *x(t)*, *y(t), z(t)…* and their variations during a short time interval *h*, using their derivatives. The evolution of dynamic systems is therefore described by a series of calculation steps, each of which has as its initial value the result of the previous step. This calculation principle is deterministic, being a series of deterministic steps.

Complete Definition of a Dynamic System with Chaotic Evolution

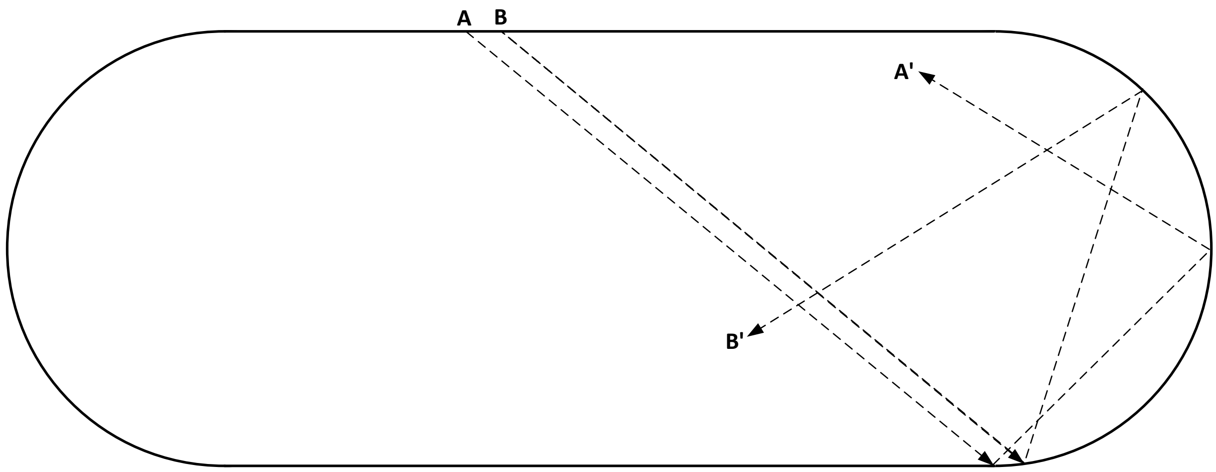
A dynamic system has a chaotic evolution if and only if, considering an iterative sequence of states *i* of its variable x_i:

1. This sequence is such that the evolution function is of the form $x_{n+1} = f(x_n)$ where the state *n+1* only depends on the previous state *n*:
   The evolution function (the sequence of states) is therefore deterministic;
2. The sequence of states is aperiodic:
   No state of the sequence exists more than once;
3. The sequence is bounded below and above:
   The values of the evolution function lie between a minimum and a maximum;
4. The dynamic system is sensitive to initial conditions:
   A variation - even small - of the initial state of the system's evolution law produces, in the more or less long term, significant and unpredictable variations of the function: the dynamic system is therefore a non-linear amplifier.

Examples

1 - Sensitivity to Initial Conditions

Consider a billiard table that has two rounded sides, as shown below. Suppose that two balls are launched in parallel directions from two neighboring points *A* and *B*. When it encounters a wall, a ball bounces, making an angle exactly opposite to that which it made with the normal to the wall at the point of contact. Suppose the ball that started in *A* touches the opposite wall in a rectilinear part, and the ball that started in *B* touches it at the beginning of a round part. The tangents to the wall of these two arrival points not being parallel, the final trajectories *AA'* and *BB'* are very different.

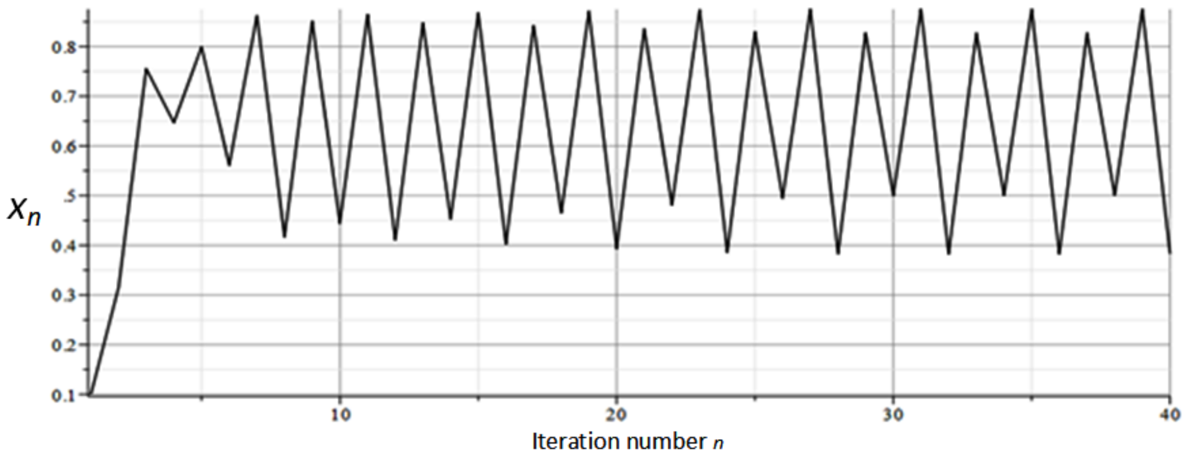


In this example of sensitivity to initial conditions there was no iteration, only non-linearity.

2 - Logistic Function $f(x) = rx(1-x)$ $where\ 0 \leq x \leq 1\ and\ \ r \leq 4$

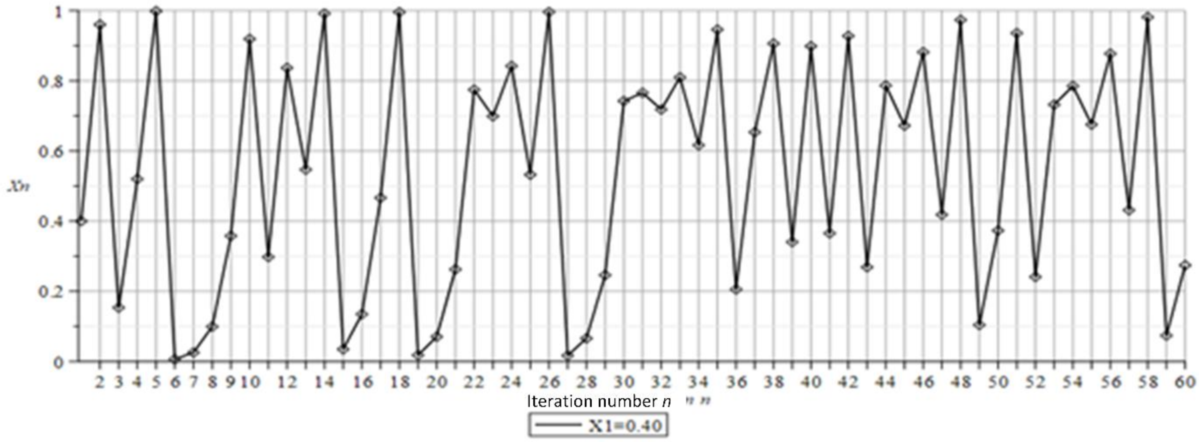
- Variable *x*, defined between 0 and 1, represents the ratio between a counted population, a given year, and an arbitrary maximum;
- The Logistic function *f(x)* calculates its value (the population) after a period of time defined as 1 unit; this calculation is done by successive iterations (see next paragraph).
- Parameter *r* represents the growth rate of the population. Its maximum value is 4, to prevent the function from growing indefinitely when the number of iterations increases.

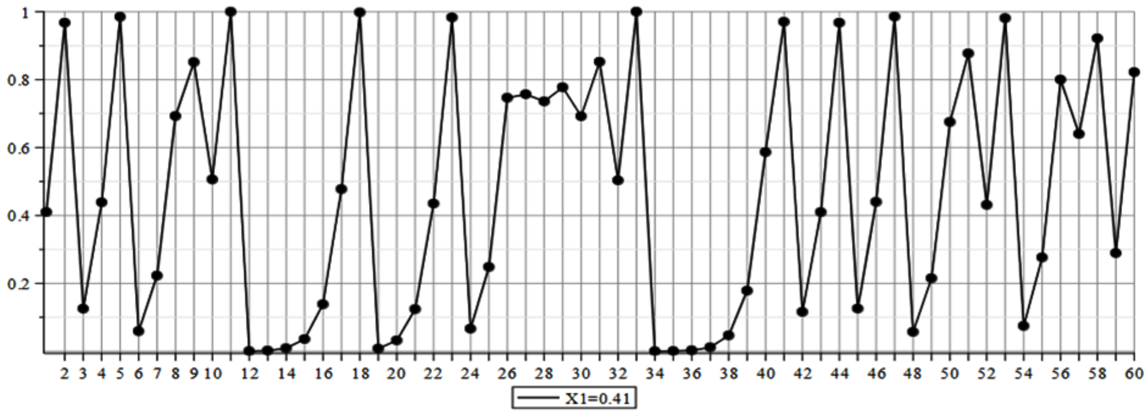
a) Evolution of the Logistic function with *r*=3.5



We see that from iteration 30 there is an oscillation of period 4: successive values of x_n in the graph seem to recur every 4 iterations.

b) Evolution of the Logistic function with *r*=4.0 for two close initial values:
x_1=0.40 and x_1=0.41. We see that after iteration 5 there is a large difference.



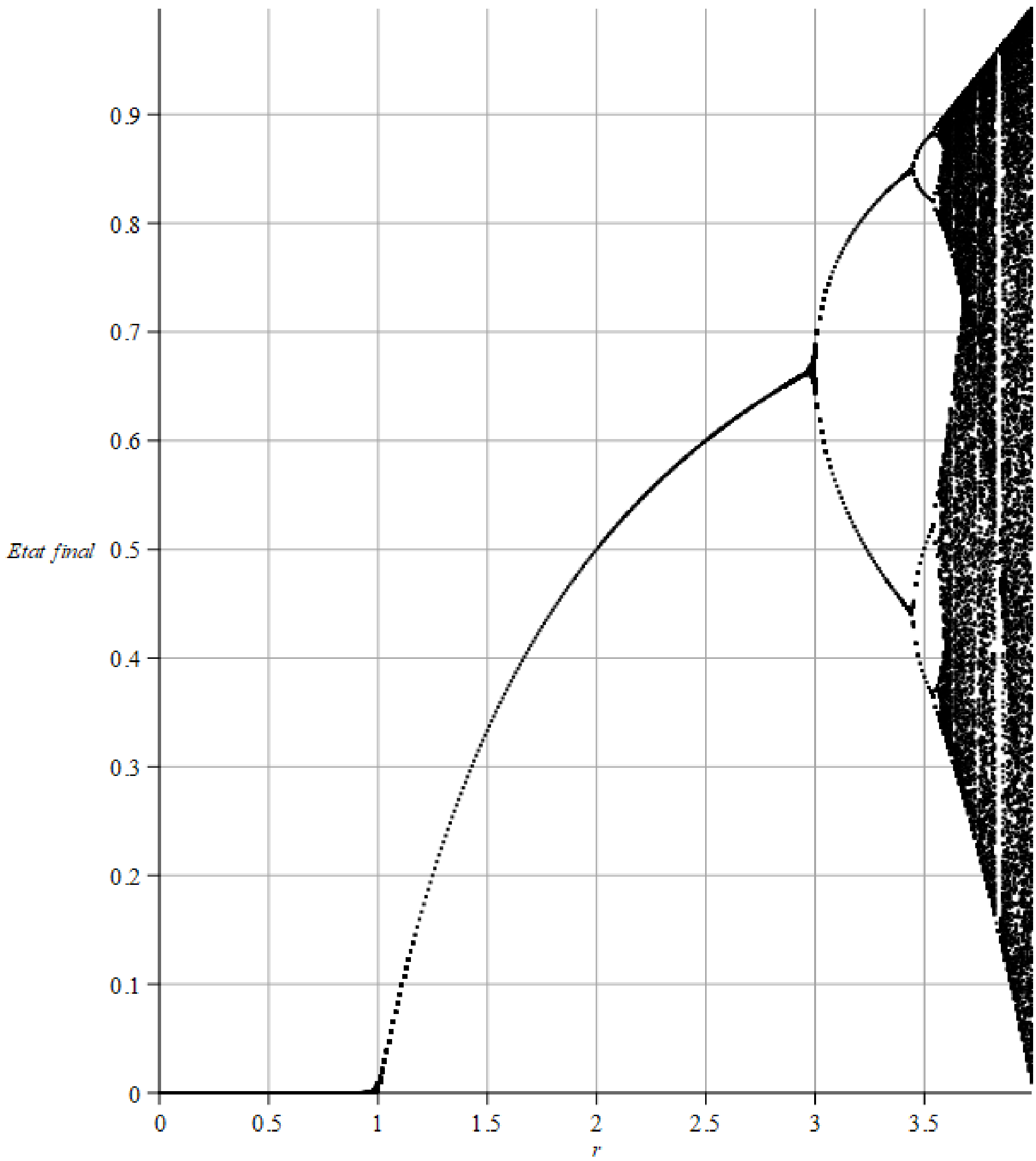


Conclusion for the Logistic Function on the Sensitivity to Initial Conditions
With r=4, the Logistic function is sensitive to initial conditions: after a few iterations *it amplifies a small initial difference*. One can therefore predict its final state only if the precision of its initial state is infinite, or for an infinitely small difference of initial values; and the state can only be predicted accurately for a small number of iterations, i.e. for *a near future*.

This aperiodic evolution occurs for all initial values of x when r=4. And the successive, aperiodic, chaotic values are all distinct: a value already obtained will never be reproduced. This uniqueness is obvious: from a given state (i of a given x_i) there is only one possible evolution (a single value of the Logistic function), in accordance with the deterministic postulate.

Logistic Function: Bifurcation Diagram

The period of the Logistic function (number of values forming a repeating group after a large number of iterations) depends on the value of the parameter r. A simple MAPLE program [145] can graphically represent the set of final values ($n \to \infty$) of the Logistic function for various values of r.



Bifurcation diagram: final state of the Logistics function when *r* varies

Remarks

- For 0≤*r*≤1, the final value is zero.
- For 1<*r*<3, there is a single final value.
- For 3≤*r*<3.46 approximately, there is a period of 2 final values.
- For 3.46≤*r*<3.544 approximately, there is a period of 4 final values.
- Pour 3.544≤*r*<3.5644 approximately, there is a period of 8 final values.
- For *r*>3.5644 there is a short period of 16 final values up to about 3.5687, where a period of 32 values begins.

4.19 Causeless Determinisms

We have seen that the notion of chance (defined as the demonstrable absence of cause or law) is a convenient abstraction, used by people who don't know something to reject responsibility for their ignorance, or for certain acts.

Logically, one cannot prove that an observed phenomenon, of which one does not know the cause or the law, does not have a cause or a law. Never attribute a physical phenomenon to chance!

> **« In physics there is no such thing as chance. »**

In terms of evolution, the notion of chance is opposed to causal determinism, that intervenes in the determinisms we already discussed. But it is also opposed to the *causeless determinisms* of the following phenomena.

Determinism Due to Instability

We have seen that the spontaneous radioactive decay of certain atomic nuclei is due to their instability. This decay is governed by the statistical law of Half-Life, it is not random. Instability is not a cause with a unique outcome, like that of Special Determinism: it produces a statistical distribution of effects; its law of evolution is an example of Statistical Determinism.

Determinism Due to Imprecision

The *Heisenberg uncertainty principle* limits the precision of simultaneous measurements of certain pairs of variables, such as position and speed, or energy and time. It describes *a limitation law of nature*, whose determinism is of another kind than that, causal, of Special Determinism: it is a determinism of imprecision, a relationship imposed between the uncertainties on simultaneous measurements of variables of certain couples. It frequently intervenes in Statistical Determinism.

Determinism Due to Mathematical Particularities

Some evolutions have surprising behaviors of their mathematical model. Thus, chaotic evolutions, although deterministic because they can be calculated with arbitrary precision, turn out to be unpredictable in the long term due to excessive sensitivity to the initial physical conditions, which can never be perfectly known. After a certain evolution time, this sensitivity can considerably amplify minimal differences between two initial values.

Example of a Deterministic Process with a Non-Computable Result
Source: [B67] page 243.

The differential equations of wave propagation are deterministic in the traditional sense: their solutions are such that the initial data completely determine the wave at any subsequent instant.

However, there are cases where a solution has computable initial data and non-computable later values. In such a solution to a deterministic physical problem, certain functions have sometimes computable and sometimes non-computable values.

[B123] cites an example of a wave defined by its propagation function whose amplitude at time t=0 is computable, and the amplitude at time t=1 is continuous but not computable.

> **« The result of a formula or of a deterministic physical process can be non-computable, or sometimes computable and sometimes non-computable. »**
> (Non-computability does not prevent evolution, it only prevents predicting its outcome.)

But nature does not hesitate: from any initial state, it immediately triggers an evolution in accordance with its interrupt law.

Non-computable real numbers
There are non-computable real numbers. An example of a procedure for proving the existence of such a number (without calculating it) is cited in [B67] page 108; this number has an infinity of decimals, such that its decimal of rank *n* is defined as taking the value 1 or the value 0 depending on whether the Turing machine of rank *n* calculating on the number *n* stops or not, which is impossible to know in advance by means of an algorithm (impossibility demonstrated by Turing). [B268]

> You may get dizzy thinking of a real number (well named, because it really exists) that you can't write because you can't calculate it!

Conclusion

> **« There are 4 determinisms opposites of chance:**
> **1 causal and 3 causeless. »**

5 General Determinism

In this chapter we will construct a kind of determinism which can govern all conservative transformation laws of Physics, *General Determinism*. Postulating such a determinism has a prerequisite: adherence to the realism of modern science, of which here is a summary.

5.1 Modern Realist Doctrine

Today a realist states two postulates:

1. There is a reality independent of Man's knowledge;
2. This reality is intelligible: Man can therefore discover it, and describe its laws.
   The knowledge that Man acquires of reality (by perception, intuition, understanding and reasoning) is trustworthy until proven otherwise. This position is opposed to that of idealism, prisoner of the allegory of the cave (Plato), which considers reality forever unknowable.

Fundamental Opposition Between Realism and Idealism

Realists trust a priori their own ability to know reality, whereas idealists negate a priori this possibility.

Realism is Hard to Define and Sustain at Atomic Scale
At atomic scale we can see nothing, or almost nothing even with powerful microscopes. We then replace this vision by the representation of objects (particles and waves) and their evolution, provided by Quantum Mechanics: we "see" using equations whose results we interpret. And then a problem appears: their probabilistic nature.

> Many people, Einstein for example, considered this probabilistic character as incompatible with realism. Einstein even went so far as to reject Quantum Mechanics, which he considered a temporary solution, to be replaced by a realistic solution as soon as it was found.

Doctrinal Controversy Opposing Realism and Antirealism
This doctrinal controversy begun at the time of Plato and Aristotle, between the idealism of the first (for whom reality is an Idea of which a physical object is a mere copy) and the realism of his disciple Aristotle (for whom reality is what one sees, and the intelligible Idea is a useless abstraction). It continued between the antirealist doctrine of Niels Bohr and Heisenberg, and the realist doctrine of Einstein and De Broglie. Einstein's realism can itself be considered a variant of Kant's Transcendental Idealism, a variant which abandons the notion of *real* Idea just as Aristotle did. The doctrinal controversy between realism and antirealism continues to this day.

According to [313] pages 9 and following, there are two ways to be realistic, depending on the answer to the following question: "Does the natural world consist only of the kinds of objects that we discern when we look around us, and of their constituents? In other words: "Does what we can see constitute all of the Universe?"

- Those who answer *yes* to this question – let's call them "naive realists" (i.e. uncomplicated) do not need sophisticated justifications to describe the world and the evolutions of its objects.

  Example of theory falling under naive realism: a theory of atoms described in [313]; it is distinct from Quantum Mechanics and more complete. See also [183].

- Those who answer *no* believe in a hidden reality existing in addition to the one everyone agrees on; the author of [313] calls their doctrine "magical realism".

  Example of hidden reality: the multiverses (multiple parallel Universes) described in [0] et [203].

It is obvious that the scientific descriptions of the whole Universe, and of the transformations of its objects, must be able to depict them as much as possible without hidden realities, the existence of which can never be justified, and the non-existence of which is also not-provable. Thus, there is today a theory which describes the detailed course of the Big Bang, taking it out of its category of “hidden phenomenon”: *Loop Quantum Gravity*, which constitutes a bridge between physics of the macroscopic scale (which includes General Relativity), and Quantum Mechanics of the atomic scale.

5.2 Procedural Synthesis of Several Evolution Laws

The movement of a cork floating on the surface of a torrent’s water depends simultaneously on the laws of fluid mechanics and on Newton's laws. Nature constantly and instantaneously synthesizes all the laws that apply to a given system, whatever it is, whatever its complexity and whatever the circumstances. It is as if nature executed a transformation algorithm taking into account all possible circumstances.

> **« Nature constantly and instantaneously synthesizes the transformation laws that apply to a given system. »**

In fact, it is Man who invents reductive laws governing only a part of a phenomenon. Even if (by virtue of realism) he thinks *he* has discovered natural laws existing independently of him, he is the one who imagines them, then checks them and perfects them until they have no remaining counter-example.

We can also postulate that nature has only *one Global Synthetic Law* governing all possible conservative systems, regardless of the number of human partial laws that apply simultaneously to a given system. It is too complicated a law for us, but given the unlimited power of synthesis of nature (think about the cellular mechanism based on DNA) its existence can be postulated.

> **« Postulate: nature has a general law of synthesis governing the evolution or state transition of any system, and it obeys the Rule of Stability. »**

This synthesis capability will necessarily be part of the definition of the General Determinism we are completing step by step.

Nature is Complete

One must also postulate that nature is *complete*: it never lacks a transformation law. One never observes non-transformation when the circumstances are an effective cause of transformation, or an “erroneous transformation” contradicting known laws.

> **« Postulate: in nature any transformation is governed by a law,
> as required by the Rule of stability. »**

This completeness feature will also be part of General Determinism.

Method for a Conditional Application of Transformation Laws

The only way to take into account all possible circumstances in a decision to launch or stop an evolution law, is to use an algorithm comprising the number of necessary reasoning steps, with conditions of the form:

« If <condition *C* is met> Then <apply law *L* with parameters [*P*], or interrupt *L*> ».

Example: Phase Changes of Water

Whatever the complexity of a transformation with successive steps, detecting the conditions of change of law is how nature does it.

5.3 Declarative and Procedural Transformations

A multi-step process for transformation or decision-making can take two forms:

- Either the list of steps is independent of the initial data, and they are all executed from start to finish, in the predefined order; the process is then one-way, it is termed *declarative*.
- Or the order of the steps and their possible omission depends on the initial data, and/or of the data calculated up to each step where a decision of execution or omission is taken; the process is then termed *procedural*.
  Example of procedural reasoning: the algorithm of Phase Changes of Water.

  It is important to know that simply reading the list of steps of an algorithm will not provide its results or conclusions, which depend on the answers to the <If> <Then> <Else> tests computed during the process.

  « To get the results of an algorithm, you have to run it from start to finish. »

5.4 Rules That Start or Stop Transformation Laws

We defined a natural transformation as either an evolution or a state transition. We must therefore now postulate that:

« All the laws of transformation that Man can define are subject to start or stop conditions describable by algorithms. »
(An algorithm is the description of a reasoning in a programming language.)

« For any given state, a state transition is always followed by an evolution. »

« An evolution can be followed by a bifurcation that chooses a new evolution law among several possible laws. »

« Nature automatically and instantly manages all transformation cases of all systems, in all circumstances, however complex they may be, with the appropriate synthesis laws. »

« All conservative systems are governed by a unique *Global Evolution Law*. Human transformation laws are consistent parts of that global law, reduced to particular circumstances. »

5.5 Complementarity of Laws of Evolution and Laws of Interrupt

According to the above, all possible physical laws belong to one (and only one) of the following two categories:

1. Evolution laws in the broad sense, including descriptive laws, transformation laws (evolution, decay, fusion, state transition), and in general all conservative physical laws with energy exchange;
2. Conditional laws, such as the water heating laws of the example above, or the radioactive decay law of uranium 238. These laws will be termed *interrupt laws:*
   - Either they trigger or interrupt the application of an evolution law;
   - Or they cause a state transition.

   Interrupt laws apply simply by testing conditions, without energy exchange. In nature, these tests are carried out continuously, to detect a cause change as soon as it occurs, or to prevent an undesirable change from taking place, or an undesirable situation from occurring (as the *Heisenberg uncertainty principle* does).

These two categories of laws are complementary: a law of evolution cannot be conceived without an interrupt law that triggers or interrupts its application; and an interrupt law exists only to govern laws of evolution.

Beginning and End of the Action of an Evolution Law

> **« Any change of sufficient cause is governed by a law of interrupt. »**
>
> **« A transformation continues, with the same law, as long as an interrupt law does not intervene to trigger the application of an evolution law. »**

- Interrupting a state transition always triggers an evolution;
- Interrupting an evolution triggers either another evolution, or a state transition;
- An interrupt can be interrupted by another that has priority, but it never triggers another interrupt.

Example 1
When liquid water is heated, its temperature increases until it boils; continued heating causes boiling at a constant temperature as long as there is liquid left; it then causes a rise in the steam's temperature. In this thought experiment there are 3 different laws of evolution separated by 2 laws of interrupt; and there are 3 heat capacities (in joules/kg and per degree): that of liquid water, that of vaporization and that of steam.

Example 2
At atomic scale, when an evolution governed by the Schrödinger equation has produced a superposition of states, this superposition persists until an external intervention (having the violence of a phenomenon on the macroscopic scale, like a measurement) disturbs it; the superposition is then destroyed (decoherence occurs) and the evolution of the disturbed system continues with only one of the previously superimposed states. Decoherence is not an evolution, it is a state transition like the freezing of a liquid, but without energy exchange.

5.6 Global Laws of Interrupt, Transformation and Determinism

Every transformation (i.e. evolution or state change) law applies and ceases to apply because of interrupt laws, and only because of these laws. We can therefore postulate that all interrupt laws, already known by Man or not, constitute in nature a *Global Law of Interrupt* which performs coherent syntheses, applicable to all states. Everything changes as if all natural transformations were governed by a *Global Law of Determinism,* comprising a *Global Law of Transformation* and (thanks to the *Global Law of Interrupt*) all necessary application conditions.

The Global Transformation Law includes all the laws of General Determinism, hence the laws of Statistical Determinism, and also those of Special Determinism.

Algorithmic Interrupt Capability

This Global Law of Determinism includes an *algorithmic interrupt* for supervising circumstances, i.e. for detecting sufficient causes for starting and stopping transformations. It launches the application of each transformation law with the appropriate initial conditions. It also performs the syntheses required when multiple causes require multiple transformation laws.

In accordance with the realism doctrine, Man only discovers and enunciates, progressively, the various laws of transformation applicable to circumstances sufficiently reductive for him. All these laws suppose conservative systems, a necessary condition of determinism itself imposed by the Stability Rule.

> Note: determinism only considers conservative systems.
> There is no evolution law that applies to a dissipative system, for which it is impossible to faithfully describe the exchanges or losses of energy and matter: we always initially consider systems conservative, then we apply corrections.

Classification of Newton's Laws as Evolution Laws or Interrupt Laws

- The 2nd law and the gravitation law are evolution laws, because they apply to forces that can cause accelerations and exchange energy.
- The 1st law and the 3rd law are interrupt laws, because they describe conditions that imply constraints.

5.7 Man Defines the Laws of Nature with No Exceptions

(Quote from Kant's *Critique of Pure Reason* [20], page 194)
"Order and regularity [conformity to the laws of nature], are therefore defined by Man for the phenomena which we call nature, and we could not find them there if we, or the nature of our minds, had not put them there first. For this unity of nature must be a necessity, that is to say certain a priori, for the connection [by causality] of phenomena. Now, how could we establish a priori a synthetic unity, if, in the original sources of knowledge of our mind, we could not find a priori subjective principles of such a unity [such as the postulate of determinism and the rule of stability], and if these subjective conditions did not at the same time possess an objective validity, insofar as they are the principles of the possibility of knowing any object in experience?"
(End of quote)

Obviously, Man defines the laws of nature according to what he guesses that they are in reality, following his observations. He then verifies that the observed effect of each law is consistent with his expectations and predictions.

Principle of the Primacy of Knowledge over Objects and Phenomena (Doctrine)

This idea consists in considering real the physical objects and phenomena observed and present in the mind by their representations, that is to say in postulating that reality follows the model that Man conceives of it. It is a revolutionary idea, in the sense that it gives up asserting like Plato that reality is inaccessible because Man only sees representations of it in his mind. Therefore, every man trusts *a priori* what he perceives because it is the only accessible reality. But this trust is temporary, it can be called into question as soon as a difference or a contradiction appears with another expected, observed or predicted reality, and something must then be changed in the model.

The initial step in constructing this knowledge of the world is to accept assumptions of the human mind such as space, time, Kant's judgment categories (concepts of quantity, quality, relation and modality), and causality. The next step is to develop our knowledge of the real world (objects and physical evolution laws) in relation to them, with the necessary predicates and relationship links. This is how Man constructed geometry, starting from the a priori concepts of point, line and circle, to define figures, angles, etc. Each new knowledge will be built from knowledge items already acquired, by linking to them [0].

5.8 Consequences of the Global Law of Determinism due to Causality

The metaphysical consequences of causality, which governs the transformation of a system as long as no cause of interrupt or limitation occurs, are:

> **« The application of a new causality is an instantaneous consequence. »**
> (Interrupt conditions are taken into account without delay.)

> **« The application of a causality is an uninterrupted consequence. »**
> See: Definitions of the Adjectives Continuous and Uninterruptible.

> **« The application of a causality is deterministic. »**
> See: There is no such thing as chance.

> **« Applying a causality preserves the information of a closed system. »**

Time Symmetry of Evolution Laws

All the equations of the physical evolution laws of macroscopic physics (whether they derive from the laws of Newton, electromagnetism or relativistic gravitation), as well as those of Quantum Mechanics, are *symmetrical with respect to time*. They would remain unchanged if time ran backwards, from present to past.

Absences of symmetry are due to laws of interrupt, such as: solid ➔ liquid phase changes, radioactive decays, quantum fluctuations, black holes, etc.

> **« Conservative laws of evolution are symmetrical with respect to time. »**
> (State transition laws, even conservative laws, are often irreversible.)

All the equations with time symmetry allow, in theory, an inverted course of time (from present to past), and such a course toward the past necessarily has the corresponding information. The normal course of an evolution law has, therefore, not destroyed it.

> **« The laws of evolution symmetrical with respect to time retain the information of the past. »**

We can also infer this conservation of information by deterministic evolutions by remembering that any transfer of information implies a transfer of energy, and vice versa. However, by definition, a closed system does not exchange energy with the outside.

« There are causeless transformations due to the Heisenberg uncertainty principle. »
See: *Quantum fluctuations due to the Heisenberg uncertainty principle*.

« There are various constraints on the application of causality. »
(Pauli exclusion principle, CP and CPT invariances, principles of conservation and symmetry, etc. - See *Levels of determinism (diagram)*.)

« Determinism does not guarantee the predictability of evolution results. »
We saw that *Determinism Does Not Guarantee Predictability*.

What Features of General Determinism Remain to be Defined?

We need a postulate of determinism adapted to all conservative evolutions of nature. Such a postulate must also be a superset of Statistical Determinism, itself a superset of Special Determinism, levels of determinism whose necessity we have shown. We will construct General Determinism by induction from properties of the Universe. These properties follow, beginning with the metaphysical principles of the laws of nature that General Determinism must implement.

5.9 Metaphysics of the Laws of Nature

This section defines the metaphysical principles of the laws of transformation that General Determinism must implement.

Cosmological Principle

« Space is Homogeneous and Isotropic. »
(Astronomic space has the same properties everywhere, and in all directions.)

This Cosmological Principle is postulated to simplify some General Relativity calculations. The homogeneity and isotropy of the Universe after the Big Bang, are confirmed with great precision by the discovery in 1965 of the *Cosmic Microwave Background*: the energy density of the early Universe was the same in all of its points, but there were (and still are) quantum fluctuations from which galaxies were born. The *Inflation Theory* explains the extreme homogeneity observed today on large scales (~100 million light-years and more). (Details: [0])

Uniformity of Physical Laws Throughout Space-Time

« Nature Described by Physical Laws is Uniform. ».
(Physical laws are the same everywhere; they always have been, and always will be. Hence, transformation laws are also the same everywhere.)

This uniformity of the Universe has fundamental consequences, such as the conservation of momentum, of angular momentum, of energy, of electric charge, etc.

Stability of Physical Laws

« Physical Laws are Stable (Invariant) Throughout Time and Space. »

In astronomy, to look 1 billion light-years away is to see there what happened about 1 billion years ago. We see, then, that the physical laws were the same as on Earth today. This stability is the origin of the Rule of stability associated with the Postulate of causality in Special Determinism. Even when a law varies with time, there is always a stable law above it in the hierarchy of determinism that describes or even explains this variation.

Example: the radius of the Universe increases; we realized this in 1927, when we discovered its expansion: the speed of distant galaxies relative to Earth increases in proportion to their distance, while remaining the same in all directions.

Then we noticed that the law of growth of this radius varied: the expansion of the Universe is faster and faster.

Finally, calculations proved that, at the beginning of the Universe, a tiny fraction of a second after the Big Bang and for a very short time, its expansion speed was extraordinarily fast, billions of billions of times faster than the speed of light: this time interval was termed the *inflation* phase.

> **« At its periphery, the expansion of the Universe is, and always has been, faster than the speed of light. »**
> (The expansion speed of space is in no way limited by that of light, because it does not move matter or energy.)

Consistency of Physical Laws

> **« Physical Laws are Consistent. »**

The laws of nature complement each other without ever contradicting each other. They respect three fundamental principles of logic: the *Principle of non-contradiction*, the *Principle of excluded middle* and the *Principle of identity*.

They also respect Aristotle's Principle of homogeneity: "One may not conclude from one kind to another." He meant that a logical relation can only exist between two objects of the same kind, for which a rule of association can be stated. Here are two examples.

Physical Relationship
A relationship can only exist between quantities of the same kind. Thus, the relations $A = B$; $A > B$ and $A \neq B$ are only possible if A and B are both masses (or lengths, or durations, etc.) The same is true for the addition $A + B$.

Another example of the requirement of homogeneity: there is no way to measure a mass in units of electric charge, or length.

Consistency of Physical Laws in the Action of Mind on Matter
This action, considered possible by some idealists, is contrary to the principle of homogeneity. Moreover, it contradicts physics: a physical action is only possible with an exchange of energy, and we do not see how a thought could provide or absorb the energy brought into play, except for an animal's muscles.

This consistency is inevitable: it is Man who creates the laws of nature, and he verifies for each new law that it does not contradict an existing law.

Moreover, some laws of nature apply at a certain level of detail without ever contradicting a law of another level. Examples:

- The statistical laws of thermodynamics apply without contradicting the laws of the motions and shocks of molecules.
- Maupertuis' *Principle of Least Action* is a global law of motion which does not contradict Newton's step by step laws [0].

Completeness of Natural Laws

« The laws of transformation of nature make up a complete set. »

Consider the realist doctrine, according to which nature exists and has laws independently of Man.

- Nature has all the laws it needs to react to all situations and explain all phenomena: it is said to be *complete*.
  (It is Man who writes the laws he discovers; asserting the completeness of nature is consistent with the realist doctrine.)
- There is no state without evolution law, a necessarily universal and immutable law, so that the same cause produces the same effect, everywhere and always.

The Universe is Empty Nowhere

« Space-Time Has no Point Stable or Immune to External Influences. »

There is no single point in space or instant in time in the Universe that is isolated from outside influences. Any point, at any time, is subject to the influences of gravitational and electromagnetic fields. In some places there are high energy radiations that can trigger a transformation. And there are also, everywhere and all the time, quantum fluctuations of energy.

Man Can Trust His Experience

« Postulate of Reproducibility of Human Experience. »

We postulate that the same causes produce the same effects, everywhere and always; but these reproducible effects are those which *we* observe.

For Plato and Kant, the true causes and the true effects (those of nature) are inaccessible to us, and there is no certainty concerning the existence of natural laws producing these effects from these causes. According to this doctrine, *we* must imagine deterministic laws making it possible to describe, foresee and predict the effects that *we* observe, produced by causes that *we* imagine.

We will follow Kant, and therefore adopt the essential part of his doctrine of *Transcendental Idealism*: it is Man who defines the laws of nature; *he* must then verify their consistency with his observations, expectations and predictions. However, we will define space and time not as sensitive forms of our intuition, but as the space-time continuum of Relativity, a medium which has energy density.

This difference is considerable. While for Kant and his Transcendental Idealism space and time are indispensable abstractions for the human representation of phenomena, the space-time of Relativity is a medium that contains mass-energy that deforms it.

« The space-time of the Universe is not empty. It is a medium containing mass-energy that distorts space and time. »

Nothing Prevents Us From Understanding Everything About Nature

« We postulate intelligibility. »

For Man to be able to imagine laws of evolution in accordance with all the phenomena of each law's definition domain, it is essential that the "inaccessible" reality of nature be intelligible to us. We will therefore postulate that:

> **« Nothing prevents Man from finding laws that perfectly describe all instantaneous or evolving phenomena that he observes. Nothing is incomprehensible to him a priori; nothing restricts his freedom to know. »**

This understanding will often require effort, time, multiple iterations, collaboration between researchers, honesty, etc. But a priori no phenomenon is incomprehensible to us forever, and we are free to try to understand it.

This position conforms to that of the *Enlightenment* [21]. It opposes the attitude of resigned ignorance of religions that teach to accept that “The ways of the Lord are inscrutable” [201]. It also transgresses the curse of Original Sin. It is therefore opposed to religions which want Man to believe their revelations without doubting them, by assuring him that he can have confidence in his faculty of knowledge.

Nature Instantly Makes All Syntheses, No Matter How Complex

> **« All necessary natural syntheses takes place. »**

Man often imagines his laws from experiences of which he forges simplified abstract representations. This reductive approach is necessary for practical reasons, such as to facilitate reasoning. But real phenomena most often evolve according to several human laws, as nature spontaneously synthesizes them.

In general, Man also reasons on closed systems, whereas nature ignores this notion. A closed system naturally conserves energy and electric charge, whereas in nature nothing stands in the way of exchanges. Man makes hypotheses of absent or negligible friction, because he does not know how to describe it with enough precision to submit it to deterministic laws; nature, on the other hand...

Nature makes a spontaneous synthesis of all the laws of transformation that apply to a state, a synthesis governed by General Determinism.

The 3 Dimensions of the Completeness of the Set of Natural Evolutions

> **« Natural completeness is analytical, synthetic and procedural. »**

To fully understand a phenomenon is to be able to describe all of its aspects: its analysis (breakdown into elements), as well as the relationships and interactions between these elements, and between the phenomenon and the outside world.

Need for Procedural Descriptions
Such a description, that is both analytical and synthetic, *is often incomplete if it is not also procedural*.

> Procedural
> The adjective *procedural* is used by computer scientists to describe the logic of reasoning that includes value tests and instruction sequence breaks, i.e. instructions such as:
>
> > « If < condition> then < action to be performed or continuation with a designated instruction> »
> >
> > *Example:* Method for a Conditional Application of Transformation Laws.

The procedural character is essential to take into account complex interactions between phenomena, such as those where several laws of nature apply simultaneously and/or successively, due to natural syntheses. A complete description therefore requires an *algorithm*, that Man implements in software.

Sometimes it will be necessary to foresee a long-term behavior, using a reasoning of tending to a limit or of convergence of a series, operations that are impossible from analyzes and syntheses as envisaged by such philosophers as Descartes and Kant.

Sometimes it will be necessary to conclude that it is impossible to predict too far ahead, as happened to Poincaré faced with the problem of the trajectories of planetary bodies known as the *Three Bodies Problem*.

A description of a natural transformation must therefore be procedural. Kant, for example, did not suspect it; and Descartes, in his *Discourse on Method*, limited it to an analysis followed by a synthesis. Their concept of natural phenomena understanding was static, while ours is dynamic. This error limited their representation of the consequence of a cause to a state, instead of a transformation.

The Procedural Process of Transformations Requires Interrupts and Monitoring

> **« Triggered by the monitoring function, an interrupt initiates or stops a transformation. »**

We have defined a transformation as an evolution or a change of state affecting a conservative system; such a transformation is governed by a law.

We also know that the action of transformation laws is controlled by interrupt laws that watch, trigger and stop evolutions or changes of state.

Monitoring Function: Supervision of Systems Transformations
Nature triggers and stops each evolution instantaneously when circumstances demand it. Therefore, nature has a monitoring function that detects the conditions for launching or interrupting the application of a transformation law. Any transformation is triggered according to such a law, with the initial values of parameters conforming to the circumstances.

> *Operating system of a computer*
> An operating system such as Windows, Unix or Android is a computer program that supervises and stops application programs. It starts them with the required initial parameters, and provides all data input, output and storage services.
>
> The response of the operating system to an electronically detected event (such as typing a character on a keyboard or the arrival of an Internet message) is called an interrupt. It is an analysis of that event, followed by a decision to "wake up" (launch with parameter passing) or stop one or more application or input-output programs. Such analysis and decision processes are algorithms written in a programming language.

Nature therefore has a monitoring function which submits the laws of evolution to rules. Besides stop and start rules, there are also limitation rules such as: conservation of the energy of a closed system, of its momentum, of its angular momentum and of its electric charge; the Heisenberg uncertainty principle, etc.

Nature is therefore the set of laws of the Universe, in particular its laws of transformation, at all its points and at all times. We will therefore postulate the existence of a synthetic set of these laws, the *Global Law of Interrupt*. We may need to distinguish from it a subset applicable to a particular system, terming it law of interrupt: the Global Law of Interrupt will therefore be the synthetic set of laws of interrupt which ensures coherent syntheses whenever required by a simultaneous application of several laws.

> In summary, nature has two kinds of laws: the laws of transformation and the laws of interrupt. These laws are complementary, no law of one kind may exist without a law of the other kind. Their synthetic global applicability and unity of action allows their grouping into a (postulated) *Global Law of the Determinism of Nature*.

Conclusions on Causation and Consequences for Determinism

A given natural sufficient cause always produces an effect instantly, and as long as it exists (without interruption). This effect is always the same, everywhere: this is why we can postulate that it is governed by a law, therefore also postulating determinism.

Since we want determinism:

- To be able to govern any system transformation;
- To provide a complete description of a system's history, in order to make its existence understandable;
- To foresee a system's evolution, and to predict its result whenever possible (at the level of detail where it is possible),

we have enriched Statistical Determinism to also govern descriptive laws and interrupt laws, in the definition of General Determinism, that also includes:

- A theory of quantum fluctuations (example: Casimir-Lifshitz force);
- Indeterminations due to the *Heisenberg uncertainty principle*;
- Exclusion rules such as Pauli's;
- Conservation and symmetry (invariances) laws;
- Stability and decay laws, at molecular, atomic or nuclear levels;
- Fusion and synthesis laws;
- Hysteresis laws;
- State transition laws;
- Rules for representing, managing and storing information;
  (stretched horizon of black holes, holographic principle, etc.);
- A law of information conservation for closed systems, etc.

We can therefore represent the levels of determinism with the following diagram.

5.10 Levels of Determinism (diagram)

Human Cognitive Determinism

* *Genetic Heritage*
* *Cultural Heritage and Acquired Knowledge*
* *Context of the Moment*

General Determinism

* *Interrupt Laws*
  - Heisenberg Uncertainty Principle, Pauli Exclusion Principle, CPT Invariance, etc.
  - Principles of Conservation and Symmetry
  - Laws of Stability, Laws of Decay
  - Laws of Fusion, Laws of Synthesis
  - Laws of State transition
  - Laws of hysteresis
  - etc.
* *Laws of evolution*
* *Information Laws (representation, handling and storage)*

Statistical Determinism

* *Quantum Mechanics, Quantum Electrodynamics, and Quantum Chromodynamics*
* *Dynamic Systems (chaos)*

Special Determinism of Traditional Physics

* *Laws of Newton*
* *Equations of Maxwell*
* *Special Relativity and General Relativity*
* *Thermodynamics*

Levels of determinism governing scientific knowledge

5.11 Conclusion About General Determinism

General determinism, as postulated by our doctrine, can govern all conservative laws of evolution, and all laws of state transition in nature. The reason is based on the observation that nature synthesizes instantaneously the laws of evolution and state transition necessary, in all circumstances: in General Determinism, this synthesis is carried out by the Global Law of Interrupt, with its algorithmic power capable of all the logical reasonings of human thought, and its monitoring function that detects all changes instantly.

6 Chance and Randomness

Among my friends, I found no one who denies the existence and influence of chance: “chance exists, admitting its effect is common sense”. We will see why they are all wrong.

6.1 "At Random" vs "Deterministic"

We defined chance above: “A system state (or an evolution) exists (or happens) by chance if it has no cause or no law of transformation”. Let's expand on this description.

What Everyone Knows About Chance

The notion of chance is opposed to that of determinism by denying or restricting the possibilities of understanding, foreseeing and predicting. According to a Merriam-Webster Dictionary, a state or an evolution is said to be:

- "At random" when it is without definite aim, direction, rule or method (such as subjects chosen at random);
- "Random" (adjective) when it lacks a definite plan, purpose, or pattern;
  or when it relates to, or has, or is without definite probability of occurrence;
- "Random" (adjective) when it is an element of a set, or relates to a set each of whose elements has equal probability of occurrence;
- "Random" (adjective) when it characterizes a procedure designed to obtain such sets or elements, for example for sampling.

What is Mistakenly Believed

The adjective *random* is often used to describe something that has no known cause, and whose evolution we are unable to predict. So, for example:

- A random natural phenomenon would occur without applying any *causal* law of nature, which would then "have done it without reason".

  Example: the radioactive decay above seems random to people who do not know its physical explanation; this phenomenon is described by Quantum Mechanics, and comes under Statistical determinism.

  The course of a decay due to an instability of atomic nuclei is not causal at the level of an atom, but collective at the level of a population; it obeys the law of half-life, hence it is not random.
- Most physical measurements are marred by errors that limit their accuracy; a measurement result then appears random, defined by a probability law such as the Gauss law, encountered so often that it is also termed “Normal law”.

  Example: height distribution (in inches) of adult males in a country (probability that a given adult male has a certain height). In this case there is no randomness either, let's see why.

  Like any scientific assertion, a possible lack of rule or explanation must be demonstrable. Not knowing them does not justify attributing the creation of a phenomenon or its distribution of values to chance. Hence:

  « Since it is impossible to demonstrate the fortuitous character of an unexplained phenomenon, by showing that the existence of an explanation

> **would contradict an established certainty, one must assume ignorance, not put forward chance. »**

More on this subject below.

Random Value of a Variable - Definitions

A variable is random when its value does not depend on any other values or statistical law. This variable is then only known, in addition to its type (numerical, binary, etc.), by an existence domain such as an interval or a set of discrete values.

Stochastic (adjective)
Stochastic means "involving probability", such as the result of a dice roll. A variable is stochastic when its values are distributed according to a law of probability, such as the Normal Law, the Poisson Law, the Binomial Law, the Uniform Law (whose values all have the same probability, like those of a dice roll), etc.

Difference Between Stochastic and Deterministic
In the same initial circumstances:

- A stochastic process produces values distributed according to its probability law;
- A deterministic process reproduces the same value, at macroscopic scale, or the same set of values distributed according to its probability law, at atomic scale (reason: Stability Rule).

Chance or Unpredictability?
Chance has 3 scientific definitions we will specify later, but which can be summarized as follows: *at chance* qualifies any structure, any behavior for which it is possible to demonstrate the impossibility of a complete description knowing one of its parts and/or the context, because there are no applicable laws of deduction or calculation.

If it existed, a random natural evolution would be an objective characteristic (independent of Man), whose absence of descriptive law is demonstrated.

> Remark: at chance or not, nature cannot violate general laws such as the conservation of energy, or of electric charge, or of angular momentum, or of quantity of information in Quantum Mechanics, etc. These laws are defined by Man for the purpose of governing all the cases of their definition domain, without exception.

For people who believe in chance, a random evolution is impossible to foresee, and its outcome is unpredictable. For people who know that there is no chance in physics (see the following paragraph), the impossibility of foreseeing, and a fortiori of predicting, stems from an absence of knowledge.

6.2 The Notion of Chance Does Not Exist in Physics

Celebrity Quotes

Kant writes in [20] page 286
« Everything that happens is hypothetically necessary [i.e. necessary by hypothesis]: this is a fundamental principle which subjects change in the world to a law, that is to say to a rule applying to any necessary existence, a rule without which nature would not even exist. Therefore, the principle: nothing happens by blind chance (Latin: *in mundo non datur casus*) is an a priori law of nature. »

« Nothing happens by blind chance is an a priori law of nature. »
(It is Man who defines the laws of nature, and he defines them with no exceptions.)

René Thom, mathematician, Fields Medal 1958, writes in [63]:
« Judging that chance exists is an ontological position which affirms that there are natural phenomena that we can never describe, and therefore never understand. »
(And it is contrary to the Principle of Intelligibility.)

Henri Poincaré, famous 19th century French mathematician, wrote in [65]:
« Chance is only a measurement of our ignorance. »

Einstein said, at the 1927 Solvay Congress:
« Gott würfelt nicht » (God does not play dice, i.e. nature does not act without reason). Einstein said this to oppose the Copenhagen probabilistic interpretation of Quantum Mechanics.

Let's explain these opinions.

6.3 The Need For Rigor in The Invocation of Chance

When do People Attribute Something to Chance?

When a man affirms that something is due to chance, it may be because he does not know the cause, therefore does not know to what circumstances and what law of nature this thing is due; it may also be because he thinks that nobody knows. This is ignorance attributed to chance, a confusion between unpredictability and chance.

> Special case of ignorance: sometimes, the unpredictability or the lack of precision are due to the complexity, to the number of variables of the problem. This is the case, for example, in the diagnosis of a psychiatrist, in the expectation of a stock market price by an investor, or in the prediction of the evolution of unemployment by a head of state.

Attributing a Cause to Chance Requires a Demonstration

Affirming that the state of a system, or an evolution, are due to chance requires as much rigor as affirming that they are governed by a law of physics.

> To whoever says to me: “it's due to chance”, I reply: “prove it!”.

The statement "It is due to chance" must be proven by the person who formulates it, with the same rigor as the proposition "It is due to law X". However, apart from the laws resulting from a purely logical deduction (which bring us nothing new, because their content results entirely from their premises), a law of nature cannot be demonstrated, it is postulated by induction from observed phenomena and their evolution, and it is admitted on a provisional basis until a counterexample causes it to be declared false: *a law affirmed after contradictory examination by competent people is therefore always assumed to be true until proven otherwise* (see Karl Popper's Critical Rationalism).

No Observation of a Set of Phenomena Proves That They are Due to Chance

One cannot demonstrate that *there is no law of evolution* of a given state, i.e. that from one time to another it may not evolve, or evolve differently. One cannot prove that a law *cannot be found,* or that *there will exist states where any law will necessarily be unstable*, therefore will not be a law of evolution .

> In mathematics, one can prove that a value of a variable does not exist, but not prove that two variables of the same type are independent. When John Bell demonstrated that in a Quantum Mechanics problem "there are no hidden variables" he used correlations, not logic.

Whatever the observations made on a phenomenon and their number, whatever the astonishment they suggest to us, it is impossible to deduce from them a proof of the absence of a natural law which governs the phenomenon; and the fact of not having discovered a law does not prove that there is none.

When one does not know the law of evolution of a given state, one can always affirm this ignorance, one can never affirm the necessary character of chance, with its absence of law.

> **« Chance is always put forward instead of ignorance. »**

6.4 Determinism Does Not Guarantee Predictability

When we dropped Philosophical Determinism in favor of Special Determinism, then of Statistical Determinism, and finally of General Determinism, we abandoned the promise of predictability of evolution results; we simply retained the necessary consequence of a sufficient cause: the immediate and inevitable triggering of a transformation.

It is surprising that the promises of determinism (understanding, foreseeing and predicting) have distinguished a difference between foreseeing and predicting: doesn't being able to foresee guarantee being able to predict?

Well; no. There are natural phenomena whose laws of evolution are known, but the application of those laws does not make it possible to obtain all desirable predictions. Let's see some details.

Cases in Which an Evolution has an Unpredictable Outcome

The unpredictability of a state or of a transformation result can have various causes, but it is not a proof of chance. Here are cases of unpredictability of an evolution result.

The Stochastic Nature of the Object's Law of Evolution – Statistical predictability

- Example 1
  A physical law of deterministic evolution at atomic level, the Schrödinger equation, asserts that, at a given moment, the position and speed of a particle moving in an electromagnetic field each have several possible measurable values governed by a statistical law; these values are deterministic and their sets are known before the measurement; see Evolution towards a set of superimposed states.

  But, at the end of evolution, an actually measured value is chosen among the elements of its set by a brutal decoherence action, which is not governed by the Schrödinger equation, and is not even deterministic, because it is impossible to describe and execute in a reproducible way.

- Example 2
  A *dynamic system* (i.e. a system whose evolution is described by a succession of iterations of a deterministic evolution function), frequently tends to a chaotic state: it is computable at each iteration, but unpredictable in the long term,

knowing only its initial state. It can only be described in advance, under certain conditions, by statistics such as a histogram of final states.

These two examples come under Special Determinism. We now need the following definition.

Statistical Predictability of an Evolution

By definition, an evolution has *statistical predictability* if its results are stochastic; an experiment repeated several times can then yield different results. Its natural law of evolution is governed by a statistical kind of determinism, where *it is the set of possible results which is predetermined by the conditions of the experiment and the law of evolution, not a particular result*.

At the time of such an evolution, nature refuses the unique result that Man wants; it is the set to which this result belongs that is unique and predetermined, each experiment has a result belonging to this set.

In addition, during repeated experiments, or when the initial value before iteration has changed, the results are distributed according to a predetermined stochastic law of probability. We should not speak, then, of a random result, because it cannot be random, i.e. totally unpredictable; we should speak of Statistical Determinism because *only the choice* of a result in the predetermined set is unpredictable; and it is so because this choice is not governed by any law: decoherence is brutal, the choice of a position in the vicinity of a point is arbitrary, and so on.

Complexity: Evolution of a State Governed by One or More Deterministic Laws

The overall effect of a large number of deterministic phenomena, simultaneous or not, can be unpredictable, even if each phenomenon is simple and has a predictable outcome.

Example: Brownian Motion

Consider a small closed enclosure which contains an immense number of identical molecules of liquid or gas. The mere fact that these molecules have a temperature above absolute zero (-273.15°C) causes them to move constantly, the kinetic energy associated with their speed characterizing the temperature.

This agitation, the *Brownian motion*, causes them to bounce on each other and on the enclosure walls, in accordance with perfectly known and deterministic laws of elastic shocks, therefore without the intervention of chance. But it is impossible to know the position and velocity at time *t* of a particular molecule, because:

- It has undergone too many rebounds against other moving molecules, and against the walls of the enclosure, for the calculations to run in a reasonable time, even on a powerful computer;
- At atomic scale, each molecule bounce is affected by its irregular shape, the local roughness of the wall, and the inaccuracy on the position, direction and velocity of a shock due to the width of the packet of probability waves accompanying each molecule. The law of elastic shocks is therefore difficult to apply with precision, the initial conditions of each shock being marred by non-negligible errors.

This impossibility of knowing the precise trajectory of a particular molecule is a very general issue: the combination of a significant number of deterministic phenomena, each one with a predictable individual evolution, produces an unpredictable resulting evolution, whether or not these phenomena are of the same type. Here, the word combination applies to:

- Either a succession of phenomena of the same type, such as the elastic shocks of a particular molecule;
- Or the simultaneity of different deterministic phenomena, acting or interacting independently to produce an overall effect;
- Or the instability of a phenomenon which changes evolution law according to a critical parameter depending on another changing phenomenon, for example during a bifurcation.

In summary, the complexity of a phenomenon with deterministic components generally produces an unpredictable evolution, and even more unpredictable if we take into account the inaccuracies and indeterminations due to Quantum Mechanics.

> However, we must beware of attributing to chance an evolution which is unpredictable only because the complexity of the original phenomenon makes its result too difficult to predict by calculation or reasoning. The random character of an evolution at atomic scale characterizes the choice of an element of the (deterministic) set of possible results that are the eigenvalues of an equation, while chance characterizes the non-existence of an algorithm that yields results.

Unpredictability by excess of complexity, which does not exist in theory in nature (its deterministic transformations being stopped or triggered by laws of interrupt), unfortunately prevails in practice. It does not affect nature, which never hesitates or foresees the future (it is not a thinking being), but it prevents Man from predicting what it is going to do. And the unpredictability increases when the number of successive or simultaneous phenomena grows; or when their diversity increases; or when the number of their interactions increases; or when quantum imprecision intervenes.

The interactions between phenomena impact the behavior of their determinism. An evolution whose result impacts the initial conditions of another evolution affects the reproducibility of the latter, which further mars the prediction of its result.

This is why the most complex phenomena (the phenomena of living beings, the psyche of Man and his behavior, etc.) being only deterministic physical transformations at the molecular biology level, their results are in general so unpredictable that Man has the impression that nature acts without reason.

Too Complex Calculations
A system subject to known deterministic laws may have a precise evolution requiring calculations that are too complex or too prolonged to be feasible.

Examples

- Predicting which ball will "come out" of a lotto drawing machine knowing the initial parameters;
- Forecasting the weather in London 30 days ahead.

Solution: an Approximate Description
The complexity of natural phenomena often encourages Man to describe them using general theories, allowing knowledge in broad outlines with rules of possibility and impossibility, but not allowing the prediction of evolutions.

Example: Darwin's theory of the evolution of species by natural selection predicts the survival of those whose individuals are best adapted to their environment, and most prolific. But it does not make it possible to predict the evolution of a given species; for example, we don't know the features of the species that will succeed *Homo Sapiens*.

Ignorance
In addition to all we don't know about physics, there are many systems in human society whose evolution is difficult to predict, or predict with adequate accuracy, because some of the necessary parameter values cannot be known. Examples:

- Stock market prices subject to investor expectations, optimistic or not, influenced by the media or not;
- What happens in the subconscious, that cannot be described with enough accuracy for affects and reasoning to be predictable.

Some people tend to attribute to chance what they cannot explain or foresee. Others attribute it to God. This is the case, for example, of the American law which admits as the cause of a natural disaster outside of human control "An act of God". Muslims have an equivalent expression: “Maktub”, which means “It was written”, and comes from the Islamic notions that Allah writes one's destiny, and that whatever we experience occurs because it had to occur.

In addition to the ignorance of parameter values, there is their experimental inaccuracy: a result may seem "marred by chance" while it suffers from material or operational inaccuracy.

Affect (definition)
Conscious subjective aspect of an emotion that cannot be described using other concepts, because it is a basic concept.

Imprecision
Sometimes the precision of the result (calculated or measured) of the application of an evolution law can be considered insufficient.

- Imprecision of the parameters and simplifying hypotheses of an evolution law. The mathematical formulation of an evolution law has parameters. If these are known with insufficient precision, the calculated result will itself be marred by imprecision. This is particularly the case when a law of evolution makes simplifying assumptions.

  Example: The motion of a simple pendulum is described by a nonlinear differential equation. To simplify its resolution, one resorts to the “small oscillations approximation”, which equates a sine to its angle in radians. This simplification leads to motion prediction errors that increase with the amplitude of the oscillations.

- Inaccuracy or non-termination of calculations within an acceptable time.
  - If the calculation of a formula or an equation solution is insufficiently precise, the result may itself be inaccurate.
  - Sometimes the algorithm of the phenomenon's mathematical model cannot provide its result, for example because it converges too slowly.

- Finally, the mathematical model of a deterministic process may have a case where the calculation of certain evolutions is impossible, for example in wave propagation [B67].

- Change of evolution law following a phase transition
  An evolution can be subject to successive laws, for example during a phase change. General Determinism handles this problem with its interrupt laws.
- See also Sensitivity to Initial Conditions.

Instability
Quantum energy fluctuations are due to an intrinsic instability, an impossibility to define an energy at a given moment in a given place, because it varies constantly and without cause; this natural impossibility is quantified by the *Heisenberg uncertainty principle*, theorem demonstrated in Quantum Mechanics.

Sensitivity to Initial Conditions
There are laws of chaotic deterministic evolution, where an accurate prediction of change requires an impossible knowledge of its parameters with infinite precision. Example: trajectory of an asteroid in the solar system, subject to gravitational disturbances from the enormous Jupiter and other planets; Henri Poincaré demonstrated the impossibility of accurate prediction by studying the Three-Body Problem. We covered this subject in section Determinism of Iterative Processes.

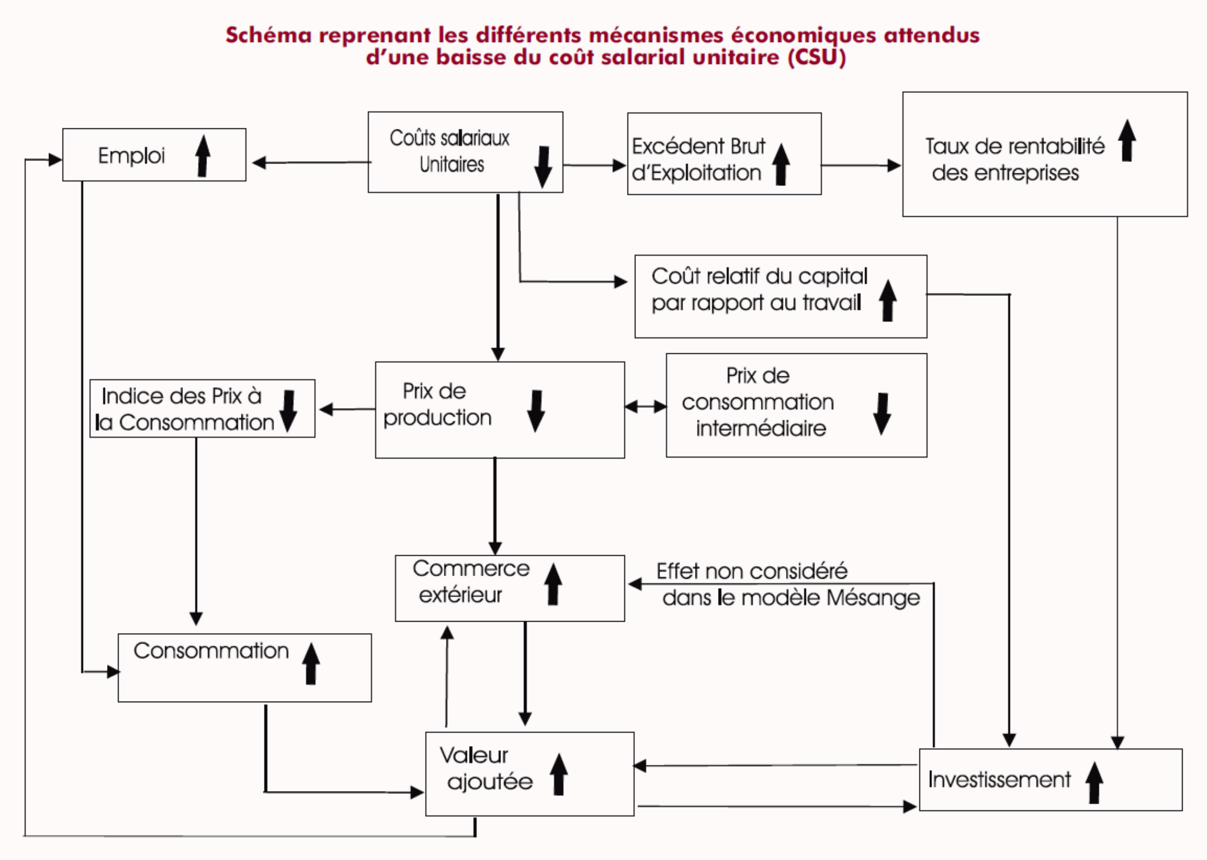
Requirement of Algorithmic Reasoning
Read first in the appendix Completeness of an Axiomatic System.

Answers to some legitimate questions require multi-step logical reasoning; these answers cannot result from a straightforward synthesis of information. This kind of reasoning is described by an algorithm, a sequence of calculation steps that take into account data values by means of choices (termed *procedural*) such as:

> « If condition *C* is met go to next step, otherwise go to step *S* ».

The result of such an execution, and therefore of the reasoning, depends on the starting values and of values calculated previously by the algorithm: it is therefore unpredictable in view of the starting data alone.

> Example algorithm (source [67])
> The economic model called "Mesange" (graph below), takes into account many mechanisms that interact to describe what happens in the French economy when wage costs are lowered. This model includes about 500 equations.
>
> When an economic policy decision requires such an algorithm, it often takes several years of work for specialists to write the program. Sometimes dozens of executions of this program with different sets of parameters will reveal economic behavior laws that are simple enough to explain to the public, sometimes they will not.



Mesange model

Predictability Requirements Nature Cannot Meet

a) The Lack of Response

Curiosity often causes Man to ask questions to which nature has no answer. We saw above the example of radioactive decay, where it is impossible know which atom will decompose first, and when. We have also seen the probabilistic nature of the positions and velocities of particles. There is also the Quantum Mechanics phenomenon called decoherence, where the interaction of a superposition of quantum states with the macroscopic environment chooses one of the superimposed solutions in an unpredictable way. Finally, there is the phenomenon of quantum energy fluctuations, the chaotic trajectories of asteroids, etc.

b) Insufficient Precision

There are cases where nature's evolution law cannot provide the precision we would like to have. The law of radioactive decay does not apply to an atom, but to a population where each atom has a certain probability of decaying in a given time interval: it cannot be made to assert anything for *one* atom.

> **« There are evolutions governed by a set law that does not make it possible to know particular events, or to know what becomes of one of the set's elements. »**

c) Relativity

In the space-time laws of Relativity, the order of occurrence of two events *A* and *B* can be different for two different observers. It is impossible to make nature reveal which event is *absolutely* the first, because there is no absolute time in the Universe (contrary to what Newton postulated in his famous book *Principia* [9]).

> **« In relativistic space-time there is no absolute time: the date-time of an event depends on the relative position of the observer and of his motion. »**
>
> **« Nor is there an absolute order of two events: this order depends on the position of the observer and on his movement. »**

d) Quantum Mechanics Entanglement

There is also *entanglement*, where two photons generated together and sharing the same energy - yet several kilometers apart - give up this energy and disappear simultaneously if only one of them is captured. This happens despite the speed limitation of a propagation of consequence to that of light, because the two photons forming the same object the disappearance of one immediately implies the disappearance of the other [96]. A possible desire to know the existence of one of the two without impacting the other cannot be satisfied.

> **« In some experiments, an entangled system can grow indefinitely without ceasing to behave as if it is entirely at the same point in space: in this case space is termed *non-separable*. »**

e) The Heisenberg uncertainty principle, Sensitivity to Initial Conditions, etc.

Conclusions About Unpredictable Evolution Outcomes

All these impossibilities to obtain the result we want, these limitations of knowledge to what nature agrees to tell us, do not call into question determinism: each cause has its consequence law. Nature always applies it without delay, but Man should accept to know it in the forms it has, not in those he would like it to have.

Thus, as we will never be able to see a particle of the atomic scale, we must content ourselves with knowing it via equations which describe its evolution, in particular the fundamental equation of Quantum Mechanics, Schrödinger's, which describes its evolution in time and space. We must renounce knowing, at a given moment, the position and the speed of the particle, of which we will never know anything but probabilities or probability densities, that is to say a blurred vision.

We must then understand that a particle can be in an infinity of places at the same time, a small volume around a given place then having a certain probability of presence. At a given position, a particle can travel at an infinity of speeds, each also probabilistic. A particle can also travel an infinity of trajectories at the same time. All these realities involve no chance, but probability distributions that limit the possible values.

The Human Psyche

The human brain has predictable logical processes (example: rational deductions) and unpredictable processes (examples: subconscious thoughts, intuitions, associations of ideas). Thought neurons are material objects, therefore always subject to natural laws when they are excited and act by interconnection. But their subconscious processes (which have a prominent role) are inaccessible to the subject, who therefore cannot understand them and even less describe their laws, despite the progress of current knowledge.

Therefore, the unpredictability of human thought is not due to its neural processes, but to the impossibility of knowing enough about its subconscious functioning, which constantly interprets information from the brain (see Thoughts are Just Interpretations of the State of the Brain by Itself).

6.5 The Three Definitions of Randomness and Chance

There are three scientific definitions of randomness and chance, unfortunately all of them negative because of the form "Is random a phenomenon *which is not*…"

1. Definition of René Thom

Mathematician René Thom, Fields Medal 1958, defined randomness in [63] as:

> "I would like to say right away that this fascination with randomness [believing that randomness exists in nature] proves an anti-scientific attitude par excellence. Moreover, to a large extent, it proceeds from a certain mental confusion, excusable among authors with a literary background, but difficult to forgive among scholars who are in principle experienced in the rigors of scientific rationality.
>
> What exactly is randomness? We can only give a negative definition: a random process is one that cannot be simulated by any mechanism, nor described by any formalism. To affirm that "randomness exists" is therefore to take this ontological [and dogmatic] position which consists in affirming that there are natural phenomena that we can never describe, and therefore never understand. […]
>
> Is the world subject to rigorous determinism, or is there a "randomness" irreducible to any description? Thus posed, obviously, the problem is of a metaphysical nature and only an equally metaphysical option is able to resolve it. As a philosopher, the scientist can leave the question open; but as a scientist, it is for him an obligation in principle – to avoid internal contradiction - to adopt an optimistic position and to postulate that nothing, in nature, is unknowable a priori [Principle of intelligibility]."

René Thom describes the effect of randomness as an impossibility of description in a a programming language, due to an impossibility of understanding and foreseeing. This description corresponds well to the reason most often responsible for the statement "It's due to chance": unacknowledged ignorance.

Conjecture: Irregularity is Not a Sufficient Criterion of Randomness

René Thom therefore qualifies as *random* any process (phenomenon, sequence of decimals of a number, sequence of elements of a set…) that cannot be modeled by an algorithm. According to this definition, the sequence of decimals of irrational numbers like $\sqrt{2}$ or π (which we know how to generate by algorithm) is not random, although it has no known regularity (if we call *regular* a sequence of decimals from which we can calculate by recurrence any decimal of rank *n* knowing a set of decimals of ranks less than *n*).

If we postulate this irregularity of the decimals of $\sqrt{2}$ and π, René Thom's irregularity is not a sufficient criterion of randomness, since we know how to generate irregular sequences of digits by algorithm; but this is a conjecture, not a demonstrated certainty.

The Case of the Lotto Draw Balls Machine

We consider random (subject to unpredictable randomness) the draws of the lotto results generated by a machine that shakes balls in a rotating sphere. Would René Thom consider it a mechanism, therefore considering its draws as non-random? Their “randomness” comes from the complexity of its processes, where each ball undergoes many shocks, too many for us to be able to predict whether it will come out or not; this randomness therefore results from *unpredictability through complexity*, a subject we discussed previously; this is no *proven* randomness.

2. Definition by Action of Independent Causality Chains - Chance by Ignorance

Two causality chains (deterministic by definition) stemming from independent origins can meet, thus creating a new situation which was not foreseeable in the course of either of the two chains taken separately.

> Example: on a stormy day, a tile falls from a roof at the exact moment when a man passes by, and hurts him. If we consider the chain of storm-tile causality independent of that of the walking man, their encounter was unpredictable. This independence is an obvious postulate, despite the fact that both stem from the same initial Big Bang of the Universe, because we know that the Universe’s evolution is unpredictable).
> See also *Remark on the Uniqueness of the Evolution of the Universe.*

A person who had not foreseen this encounter may mistakenly attribute it to chance. But a more complete definition of the circumstances, taking into account both phenomena, eliminates chance: originally, all the conditions were met for the tile to injure the man later. The astonishment or rarity of a phenomenon does not justify attributing to chance the overall result of processes that respect the deterministic laws of nature.

The only natural domains where an evolution can produce a semblance of chance are Quantum Mechanics and chaotic phenomena; both are deterministic and fall under the stochastic predictability of Statistical Determinism.

The example of the falling tile, above, shows that a forecast based on determinism must take into account all of the parameters likely to intervene in the evolution to be expected, which is often impossible. To knowingly refuse to take the big picture into account is to accept ignorance and the risk of false predictions.

The independence of causality chains must be demonstrated, as well as the attribution to chance. But let's go further.

Special Relativity shows that an event *A* cannot be the cause of event *B* if the information "*A* happened", traveling at the speed of light, reaches the position of *B* after the occurrence of *B*. But even if this information reaches the position of *B* before the event *B,* one can only assert that *A can be* the cause of *B*, not that *A is* the cause of *B*.

Then, there is the following condition for determinism to apply: a transformation must be governed by a stable law. This condition can be met by any conservative natural phenomenon, but not by a phenomenon involving the action of a living being who thinks, man or animal, as in Human Cognitive Determinism.

3. Definition of Randomness by the Amount of Information

We can also term random a number whose writing is more concise (counting the number of signs or bits, for example) than the text of any algorithm that can generate it; hence, such a number's length may not be cut down by any algorithm. Since it is absurd to use a computer language algorithm to write a string of characters longer than the number that its execution would generate, there is no interesting algorithm that can generate a given random number, which justifies René Thom's definition.

The problem with this definition is practical: given a number and an algorithm that generates it, it is impossible to be sure that this algorithm is the most concise. The above definition is therefore only of theoretical interest.

Conclusion on These Three Definitions

> **« The randomness or chance that applies to a structure or a transformation can only be defined negatively, by saying what it is not. »**
> (The unpredictability implied by chance can only be defined by an impossibility of algorithmic deduction or generation. Understanding randomness or chance with this definition requires intuition.)

Consequence

> **« There is no Chance in Physics, Whatever Happens Had to Happen. »**

Conclusion of the above: attributing what one cannot explain, a state or phenomenon, to chance is always an error, a way of not admitting one's ignorance.

Principle of Fatalism

Confirming our statements about the attributions to chance due to ignorance, here is Kant's position on page 286 of the Critique [20]:

> "Everything that happens is hypothetically necessary [postulated necessary]: this is a fundamental principle which subjects change in the world to a law, that is, to a rule applying to necessary existence.…"

Kant thinks that natural evolutions follow a principle of fatalism:

> **(1) « Everything that happens had to happen, because every evolution has a cause. »**
>
> **(2) « What didn't happen couldn't happen. »**

Demonstration: Regression of Causes

By virtue of the *Principle of sufficient reason* (abbreviated: *Principle of reason*), any observed state results from a cause (i.e. a state resulting in an evolution), which itself certainly existed and which, in turn, resulted from a cause, etc. until the beginning of the world: this is the state's *causality chain*. Since all the elements of this chain necessarily existed, each one as a consequence of the previous one and the first one as a consequence of the Big Bang, one can also go, in thought, through the whole causality chain in its normal direction from causes to consequences (from past to present) to find the observed state, which must therefore necessarily occur. And all evolutions have been subject to the laws of nature, themselves subject to the Rule of stability.

Critique of This Demonstration and Limitation of its Scope

This demonstration supposes a limitation of the phenomena to the macroscopic world, because the path of the causality chain from the past to the future is supposed to be unique, which excludes the evolutions with multiple results of Statistical Determinism.

To account for the possibility of multiple outcomes, law (1) above should be replaced with:

> **« Everything that happens *could* happen, because every evolution has a cause. »**

The Principle of Fatalism would then lose all interest, because it would be a truism.

On the other hand, what did not happen has no causal chain dating back to the Big Bang, and therefore could not happen.

Note on the Unpredictable Choices of Nature or Man
At the end of a deterministic evolution governed by the (continuous and deterministic) Schrödinger equation, the system can be in a particular state called "superposition of states". Left to itself, without external action, it will undergo (generally after a very short time) an interaction with its environment, such as an exchange of temperature or the intervention of a measuring device.

Such interactions "choose" a visible, stable final state at macroscopic scale among the superimposed states, and suppress the other states. They are impossible to describe with precision, and therefore to predict: they are not deterministic. Hence, if at the end of the deterministic evolution of the system, we consider the final choice as part of this system and of the experiment, we can no longer expect this evolution to be deterministic, since it is disturbed in ways impossible to specify. A deterministic evolution therefore ends before the final choice that determines its outcome.

More generally, one should not look for the deterministic character of a phenomenon that is impossible to describe with precision like a human thought, in which intervene subconscious cognitive processes. As no one understands these processes, we cannot try to foresee their unfolding and predict their outcome; we cannot therefore term them deterministic, although the cognitive processes are all interpretations by the brain of the state of its neurons (see *Consciousness of*), and therefore deterministic material phenomena: Kant had already noticed this paradox.

The Evolution of the Universe Since the Big Bang is not Predictable

Every law of evolution has a deterministic outcome, except when its application ends in a choice of one of the following kinds:

1. Choice of a continuous variable value (position, etc.) affected by a probability density. This choice is unpredictable if it is made in non-deterministic circumstances, like a sensitivity to initial conditions that amplifies differences.
2. Choice of one of the states of a quantum superposition by decoherence. One can consider that the result of this choice is without consequence for the subsequent evolution, the energies of superimposed states being equivalent: the evolution is thus predictable in this case.
3. Choice of one of the branches of a bifurcation. We can consider that the chosen branch depends on an enclosing system state which is deterministic, so that this choice is also predictable.
4. Choice resulting from a case of non-causal determinism, such as the unpredictable date of the radioactive decay of a particular atomic nucleus.

Since, at atomic scale (from which all laws of macroscopic evolution are deduced) there is no friction, the result of any evolution that has already started is predictable in the sense of Statistical Determinism.

But contrary to the case of the universes of Laplace and Newton, this is not enough reason for any evolution at atomic scale to have been (and still be) predictable: in case (1) above one can only predict a value with a probability interval. Sometimes the potential difference is insignificant at macroscopic scale, but sometimes it is amplified by a sensitivity to initial conditions.

Moreover, the beginning of an evolution can result from another choice, itself necessarily non-deterministic: a choice made by a living being. Human choices, for example, are unpredictable because they are subject to their subconscious, and these choices matter: think of the atomic bombs of 1945, for example. The reasoning then goes beyond the dispute between materialists and idealists concerning the intervention or not of a transcendence in human choices: even materialists' thinking has a part of subconscious unpredictability. But the unpredictability of human decisions is accounted for by this subconscious without transcendent intervention. And the Earth is teeming with living beings enjoying such freedom.

Conclusion:

> **« Strictly speaking, the evolution of the Universe is unpredictable. »**

7 Human Determinism: Brain and Consciousness

Fundamental Assumption

> **« A human decision is motivated only by the dominant value of the moment. Reason and logic are only tools at the service of this value, they provide only methods and judgement criteria. »**

Rational thinking does exist, but the effort it requires is undertaken only in the hope of a reward satisfying a value a priori.

> Example: I only undertake to look for the (rational) proof of a new mathematical theorem if I hope to be appreciated by publishing it.

We now know that this is how the human brain works.

Moreover, a thought is rational only if each of its steps respects logic, without emotional bias, even if it is justified only by an affect.

The entire text of this book on determinism presupposes these conditions of rational reasoning.

Postulate of Human Determinism

The deterministic doctrine of rational thought represents the brain as a set of processes interpreting its state of the moment, a state comprised of representations, and active and sensitive affects. Materialistic, it denies any transcendent intervention and any transmission of thought.

This doctrine recommends a *scientific method*, including the adoption of a truth by consensus criterion applied to falsifiable claims.

The rest of this chapter and the next three chapters are devoted to Human Determinism.

7.1 Consciousness and the Interpretive Brain

Here is a brief description of the nature and functioning of *object-awareness* and *self-awareness*. How does a person's mind interpret sensitive perceptions and various abstractions as impressions of consciousness? What is consciousness as a set of psychic phenomena?
Sources: [42], [44], [51], [52]

7.2 Consciousness as a Set of Interpretive Processes

The following text summarizes the functioning of the psychic faculty of consciousness. Here are some definitions we will need.

Representation

The word *representation* has two meanings:

- An act by which the subject's mind builds itself an image of a phenomenon, as it is at a given moment. It creates a relationship between the object and the mental data that represents it. The object can be external to the mind (a phenomenon) or internal (a pure concept).

The object that a subject represents to himself is *present in his mind*, in working memory. Its representation was the subject of an intuition, then of an immediate understanding, and often of a reflection aimed at deeper understanding. The subject is aware of this presence in mind.

- A result of this act: the previous set of mental data, in working memory, of which the mind can become aware by intuition, immediate understanding and reason.

Conceptualization

A representation is conscious only as a concept, the general formation process of which is called *conceptualization*.

Mindfulness – Awareness

A subject is mindful of an object or a phenomenon when he is aware of it. A phenomenon or object is *present in the mind* when its representation is in working memory and has begun to be understood, or is associated with a concept resulting from intuition, understanding, reason or imagination. Awareness of a representation is achieved through conceptualization.

Mind

The noun *mind* designates all, conscious or unconscious, considered in whole or in part, of the processes relating to the mind, intelligence and affectivity, and constituting psychic life. These processes include conscious phenomena when the subject is awake, and subconscious phenomena, present whether the subject is awake or not.

Process

A process is an action of a subject's mind; it is a sequence of operations carrying out psychic functions such as:

- Development of concepts (conceptualization);
- Cognitive functions (mental faculties of acquisition, and management and use of knowledge, including understanding and memory functions.)

  These functions translate representations of real objects into conceptual symbols, and reasons on these symbols;
- Judgments of a statement (true/false judgments and value judgments);
- Reasoning (inferring a statement from others, held to be true; building a sequence of concepts producing a desired result, etc.);
- Organization by understanding and reason of knowledge present in mind:
  - Classification (belonging to a set);
  - Recognition of a concept or a procedure (identification);
  - Arrangement (sorting elements, or relating them to other elements);
- Etc.

Process Parallelism

The psyche spontaneously executes a large number of processes in parallel (simultaneously). Example: after becoming aware of a representation:

- The mind automatically draws simple consequences such as the evaluation: "Is this good or bad for me?". This evaluation has a magnitude "good or very good?" / “bad or very bad?”
  - For each evaluation result there is an awareness threshold, below which the evaluation is ignored;
  - “Very” evaluations can trigger priority processes interrupting ongoing processes.
- The mind spontaneously searches in its memory for reminiscences that have something in common with the current representation. Each memory thus found is immediately judged in the sense of “good or bad”.

All these processes are initiated spontaneously and simultaneously without the subject being aware of them, and they run in parallel.

7.3 An old Debate: is Consciousness Transcendent?

The presentation of the recent book on consciousness [44] begins with:

"This book resumes the age-old debate about the possibility of reducing consciousness to a neural process." The author knows what he is talking about, as he is Research director at CNRS, the French National Research Center. For centuries, philosophers have wondered whether the human mind, with its awareness of the world and of itself, is a consequence of the physical functioning of the brain alone. Doesn't consciousness also result (as Descartes believed) from something immaterial, such as God? Since during a dream our thought wanders without conscious cause, and since it often creates ideas spontaneously, how not to suppose that it has transcendent faculties?”

The problem of the nature of human consciousness has a metaphysical dimension: is it exclusively material in origin, internal to our body, or does it also have non-material (transcendent) causes such as divine influence?

Descartes, Wary of the Interpretations of his Mind, Writes: “I am a Thing that Thinks”

In the 17th century, Descartes knew like Plato that Man is not aware of reality, but only of the ideas of his mind, ideas which include mental representations of the perceptions of his senses. Believing that he could be wrong, and desiring despite that to find the truth about the nature of his being made of body and mind, he started questioning his interpretations in [17]:

“So, I guess all the things I see are wrong; I persuade myself that nothing has ever existed of all that my memory, filled with lies, represents to me; I think it makes no sense; I believe that the body, the figure, the extension, the movement and the place are only fictions of my mind. What, then, can be considered true?” ([17] *Méditation seconde*) - These assumptions come under skepticism.

Although doubting everything, Descartes was certain to exist at least as "a thing that doubts”:

“So that, after having thought about it well, and having carefully examined all things, finally it is necessary to conclude, and to hold as constant that this proposition: I am, I exist, is necessarily true, each time that I pronounce it, or that I conceive it in my mind.” ([17] *Méditation seconde*)

Descartes ends up concluding that, in addition to having a material body, “corporeal substance, extended”, he also has a spirit (a soul) “thought, intelligent substance”:

“But what am I? A thing that thinks. What is a thinking thing? That is to say, a thing which doubts, which conceives, which affirms, which denies, which wants, which does not want, which also imagines, and which feels.” ([17] *Méditation seconde*)

In the two preceding passages, the "I" of "I am" obviously designates the object of self-consciousness, an expression that Descartes does not use. Unfortunately, by merely qualifying his consciousness as a thinking substance, Descartes does not explain it; and by attributing all things to God, he admits their transcendence without evidence.

A Professor Said: “No Physical Cause Explains Human Abstractions”
In 2009, the textbook of a professor of philosophy taught that “The abstract nature of human thought prevents it from resulting from an exclusively physical phenomenon: no material phenomenon creates abstraction; whatever their function, neurons are not enough to explain human consciousness, something transcendent is also needed.”
Let us now see why this widespread opinion is wrong:

> **« The material phenomenon that creates abstractions is the human interpreting brain. »**

7.4 Awareness of…

We speak of *consciousness of*… to designate the psychic mechanisms by which Man becomes aware of an object present in his mind. We talk about it with the verb *to be*: When *I am* aware of an object, it is present in my mind, I can talk about it.

Awareness of is the State of the Mind at a Given Moment

It is a "picture" of the contents of the mind. This state changes automatically as the object of consciousness changes: when I am aware that a ball is coming towards me, the image of its move in my mind changes (or is replaced) gradually.

The state where the mind is aware of something does not happen passively, it results from an intentional attention, whether this attention was triggered voluntarily (by reasoning) or by a reflex.

Awareness of Comes from Data (Information)

In my mind, the state of an object at a given moment (all of the information about it that I am aware of) appears as data called a *representation* of the object of which I am aware. This data represents both the characteristics and the psychological significance it has for me, I can describe and talk about it because I am aware of it.

Psychological Meaning
Examples of Feelings Inspired by a Thought or a Perception

- For an optimist, life makes sense and deserves effort. For a nihilist, it has no sense, and he can fall into dejection as well as into violent revolt.
- Nihilism is a doctrine of despair for which no value has reality. The nihilist denies moral, religious and social values because they are meaningless in his view. For him, no hope is allowed, no effort is justified, no authority is bearable.

The above feeling is always strongly dependent on the consequences imagined as a result of the perception or thought; the role of this imagined outcome (whether it is spontaneous or deliberate) is very important.

This representation I am aware of is the only possible origin of my understanding of the object, since my mind can only manipulate the abstractions that *it* has constructed or known since birth.

« My mind can only handle representations it has built, or has since birth ».

Therefore, the mental state *awareness of a representation* is what a subject feels when this representation is present in his mind. When I remember having been aware of something, it is data that I have in mind.

Justification: an *Awareness of* is Necessarily a Set of Data

First Reason
At a given moment, the state of a system is described by a set of variable values. If the system evolves over time (by moving, by transforming...) its state changes, and some of the variables that describe it change value.

Consciousness of is a psychic state at a given moment. It is the result for an individual of the state of some of his neurons, and of the excitations (electrochemical signals carrying information) they exchanged. At a given moment, the *consciousness of* is therefore described by a set of data, representing the corresponding neurons and the excitations emitted and received up to that moment.

There is therefore a "conscious code", specific to each individual, that describes the representation of which he is aware at a given moment. According to [42] page 205:

"The distribution of active and inactive cells makes up an internal code that accurately reflects the content of any subjective perception. This conscious code is stable and reproducible: the same neurons always discharge as soon as the patient thinks of Bill Clinton. To activate them, imagining the face of the president will suffice: most neurons in the anterior temporal cortex respond with the same selectivity to real images and mental images. A representation selected from memory is also enough to reactivate them."

Second Reason
When I am aware of something (and only if I am aware of it, which implies that I pay attention to it), I can talk about it. However, the muscles that act to speak (those of the mouth, etc.) are controlled by motor neurons. Like all neurons, these are activated by (and only by) excitation signals; they are therefore activated by data, those of the received signals coming from other neurons, etc., the origin of the chain of neurons being the *consciousness of*.

To activate a chain of neurons ending with the motor neurons of speech, the *consciousness of* can therefore only be a set of data. If the origin of the signals activating speech were an autonomous and unconscious function of the psyche, it could not emit signals leading to coherent speech, as such emission is a function of the content of consciousness alone.

The Consciousness of a Representation is That of its Concept, and Only That One

The set of data describing an object, whether concrete (phenomenon) or abstract, present in mind or in long-term memory, is its representation. Saying that the mind is aware of a concept is saying that the representation of which it is aware is interpreted by it in the form of this concept, that this is how it understands it. Representation and concept correspond to the same state of the same neurons; the notions of *representation* and *concept* are two complementary ways of describing this state, as in physics matter and energy.

Any Awareness Comes With an Affect

Each arrival of a representation in working memory provokes its conceptualization by understanding: it becomes present in the mind as a concept. This concept triggers a spontaneous evaluation that deems it "favorable" or "unfavorable", "promising" or "worrying". Depending on this evaluation and its intensity, reason eventually intervenes to go deeper into the concept and its consequences, and each step of this deepening is accompanied by a spontaneous value judgment.

7.5 Consciousness

Consciousness is the set of psychic processes allowing knowledge of the world and of oneself to a subject who is awake, i. e. attention, awareness of others and of oneself, representations and affects. Psychic functions manipulate abstract data (representations) to memorize them, reason about them and control muscular actions. From the physiological point of view, those functions are based on states and excitations of neurons.

We sometimes imagine this form of consciousness as a *virtual apparatus* grouping psychic functions. We say, for example: "The functions necessary for understanding are *in consciousness*". We also speak of *an unconscious device* for the virtual device where psychic phenomena inaccessible to *consciousness* occur; we say, for example: "The faculty of face recognition is part of the unconscious."

Consciousness as an Interpretive Process

Kant thought that consciousness functions as an interpreter whose logic is the same for representations of objects of the senses as for those of abstractions, thus independent of particular cases of phenomenon or reasoning. The brain interprets the state of its neurons and the course of the signals they exchange. Today we have the same interpretation of how consciousness works.

Awareness of Acts and Procedures

Man's mind is aware of his mental acts, thoughts and representations, an awareness evoked about self-awareness. He remembers his gestures and the procedures (sequence of gestures or mental operations) used to solve a particular problem: "I remember the way to the train station, and the method of adding two numbers."

A man aware of his actions and thoughts remembers them, and can reproduce them. He can think about them and induce methods valid for similar cases; examples: methods to add two fractions, or to calculate the derivative of a sine function. Finally, he can recognize in a sequence of actions or thoughts a particular case of a more general procedure: when I see a three-step reasoning, I know how to recognize if it is a syllogism.

7.6 Interpretation - Processes of Consciousness

Source: [43]

Thoughts are Just Interpretations of the State of the Brain by Itself

Our psyche is unable to manipulate physical objects. It manipulates only abstractions that represent them called concepts, that have only two possible origins: those we inherited from our ancestors at birth, through our genome [57], and those we built for ourselves since then - in particular, by mentally representing the world we perceive.

In my mind, it is an abstraction called *representation* that replaces an object, real or abstract. My mind cannot see my physical house, it "sees" its abstract image (a phenomenon from which a representation originated), and my mind considers it real. And it is on the concept associated with this representation of what the mind sees or imagines that it reasons whenever necessary; it is its only access to reality, it replaces it for the mind. The mind *interprets* its representations.
See *Principle of the Primacy of Knowledge over Objects (Doctrine)*.

This finding refutes the philosophical argument "*No physical cause explains human abstractions*": it is indeed such a cause, the functioning of our brain, which explains all our thinking, with its consciousness and abstractions; we verified it with recordings of brain activity.

Our nervous system transmits perceptions of our senses to our brain, which interprets them. The working memory representation of a perceived image is interpreted as an image, because we have learned since birth to interpret it that way. The letters and words of a text are interpreted as such because we have learned to read. A burning sensation is interpreted as heat and pain in the corresponding place of the body. A series of representations corresponding to a ball coming towards me is interpreted correctly, etc.

In addition, all events perceived by our external and internal senses are appreciated as "Good" or "Bad" as they are interpreted, supplemented by a "Promising" or "Worrying" expectation.

The brain can also create ideas from representations and other ideas; it needs no transcendence for that. Finally, no possible experiment can prove a transcendent action, neither on a brain nor on anything else in the Universe; we will develop this.

7.7 Computational Model of Mind

Today we can represent the low-level faculties of the mind as the following set of interconnected processors (similar to computers), operating in parallel:

- A processor of information perceived by the senses, which puts its data in working memory, then translates it into low-level qualitative judgments: favorable/unfavorable, promising/threatening, etc. This processor produces the perceptions we feel.
- A processor of intuition and understanding, which interprets perceptions and sequences of perceptions to provide the concepts of understanding, the first level of comprehension. These concepts are immediately and automatically judged in the favorable/unfavorable sense.
- A reasoning processor, that rationally assembles concepts of understanding and reason, which are also appreciated as they are generated.

- A memory processor, at the disposal of other processors, with faculties of search, synthesis, analogy, self-awareness, and memorization of the working steps of the reasoning processor, etc. This processor constantly transfers representations between short-term working memory and long-term memory.
- An affects processor, judging everything that passes through the working memory and controlling the operation of other processors, which it launches and interrupts. It is the “operating system” of the psyche, the seat of value judgments, consciousness and emotions. Like the others, the reasoning processor is at its disposal: it is never the reason that governs a person's choices, contrary to what Descartes believed.

  « Our decisions are not governed by reason, but by our affects. »

All these processors function like independent computers, sharing the same memory and mutually subcontracting partial reasoning on data provided with each call.

7.8 Scientific Rationality Prefers Materialism or an Equivalent Doctrine

The problem of the nature of human consciousness has a philosophical dimension: is it rational, i.e. of exclusively material origin and internal to our Universe, or does it also have non-material (transcendent) causes such as divine influence?

The rational answer, adopted by all scientists, presupposes the understanding of the world and its physical laws from real facts, as well as from theories whose falsity no one can prove (one can never prove the *truth*, a notion impossible to define rigorously, but one can prove the error of a reasoning, or the non-conformity of an affirmation with a particular experiment).

Scientific Definitions and Theories Exclude Divine Influence and Will

Whether or not he is a believer, a scientist cannot put forward the influence of God or of the mind, or the Idea of idealism to explain a physical phenomenon he studies: he must behave like a materialist. If he accepted the possibility of a transcendent origin or influence in our Universe, he would renounce to rationally understand certain states or phenomena from verifiable facts or falsifiable theories, thus to foresee their evolution. Since Man needs to understand situations and foresee evolutions, he cannot renounce to postulate the rationality of materialism, a doctrine that no logical or causal deduction imposes. This is why a coherent scientist can also adopt Kant's realistic doctrine, or his Transcendental Idealism which is just as rigorous in scientific reasoning as materialism.

Falsifiable

This adjective qualifies an assertion whose possible falsity can be proved.
A hypothesis (or a conjecture, or a theory) is said to be falsifiable if one can imagine (or better, create experimentally) a situation where it is disproved, even if one cannot imagine a real situation where it exists - especially because it is undecidable or speculative. Examples:

- Ohm's law "The intensity of electric current through a resistor is proportional to the potential difference between its terminals" is falsifiable;
- The statement "This forest fire is an act of God" is not falsifiable.

Our approach, in this text, will therefore be materialistic. We will postulate that:

- Thought is a consequence of the physical functioning of the brain alone, even if we do not understand all the details of this functioning.
- No influence on thought (transcendent or spiritual) exists or has existed. Thought and consciousness imply a living brain, and conversely a living brain continually thinks just because it lives, whether the subject is awake or asleep.

  « Consciousness can be explained without putting forward transcendence. »

7.9 Non-Rational Thinking is Just as Normal

The previous discussion does not imply that only rational thinking is valid. I love Mozart's music without knowing why. Like any aesthetic impression, appreciating a piece of music or a painting occurs without reflection, spontaneously and without delay. I do not see why we should always understand *why* we experience this or that: often emotion is quite enough.

8 Human Judgment

8.1 Truth

Truth of an Object Knowledge

(Source: [20] page 148)

If we define the truth of knowledge as *its agreement with its object*, there is no universal criterion of truth, valid regardless of the known object. Such a criterion should make it possible to distinguish with certainty between the meanings of an object and of the knowledge that one has of it, which is absurd since the content of knowledge is its meaning.

Truth of a Proposition

But what about the truth of a proposition? Does a text I read tell the truth about its object? To judge this, I should know with certainty the meaning of the object; but if that were the case, why bother reading the text? To check if its author is telling the truth about the object, that is, if he understands the same thing as I do? But if, not knowing the truth about the object, I read the text to learn it from its author, I have no way of knowing if it is true; I can only look in the text for contradictions with certainties that I have from other sources, or look for *formal* errors, a problem addressed in the next paragraph. Let us stop this discussion here, because it goes beyond the scope of this text.

Formal Truth (which relates to form, regardless of meaning)

(Source: [20] pages 148-149)

Since logic defines *universal* rules of understanding and reason, a proposition must necessarily respect them all or risk being false (contradicting itself in at least one case). But such respect is *formal*: the fact that a proposition does not contradict itself (i.e. that it is formally correct) does not guarantee that it is true, it can sometimes be inconsistent with its object. Pure logic does not have the means to discover, in a proposal, a possible error on the content, but only a formal error.

By definition, *formal* truth is synonymous with *logical* truth.

The Formal Truth of a Text is its Absence of Internal Contradiction
(Quote from [37] pages 56 to 58)
"Formal truth consists simply in the agreement of knowledge with itself, completely ignoring all objects and any difference between them. Hence, the universal formal criteria of truth are nothing but the universal logical characters of the agreement of knowledge with itself, i.e. with the universal laws of understanding and reason.

These universal formal criteria are certainly not sufficient for objective truth, but they must nevertheless be regarded as its *sine qua non* [the satisfaction of all these criteria is a necessary condition of existence]. Because before asking whether knowledge agrees with the object, one must first ask whether knowledge agrees with itself (according to the form). And this is the business of Logic."
(End of quote)

The formal criteria of truth in Logic are:

- The Principle of Contradiction, which determines the logical possibility of knowledge; and also the Principle of Determinability of a Concept, a consequence of the principle of contradiction;)
- The Principle of Sufficient Reason, which determines the logical reality of knowledge.

Principle of Sufficient Reason (also called Principle of Reason)

> **« Everything that exists (object) or occurs (event) necessarily has a cause due to a law of nature. »**

(Quotation from [20] page 266)
"The principle of sufficient reason [of determinism] is the foundation of all possible experience, that is, of the objective knowledge of phenomena as to how they relate to each other in the succession of time."
(End of quote)
For a full discussion see [39].

8.2 Logical Truth of an Object Knowledge

Requirements for the object knowledge:

- It should be logically possible, that is, it should not contradict itself.
  But this mark of internal logical truth is only negative, because knowledge that contradicts itself is certainly false, and knowledge that does not contradict itself is not always true.
- It should be logically founded:
  - It should follow principles:
    - ✓ Either conform to the Postulate of Causality (factual causality)
    - ✓ Or be a logical deduction from a certain proposition (logical causality).

    (See *The Two Kinds of Causal Deductions*).
  - It should have no false consequences.
    (This is a criterion of external logical truth and rationality.)

The following two rules apply: Rule 1 below, Rule 2 in the *Scientific Truth* paragraph:

Rule 1
From *the truth of the consequence* one can conclude to *the truth of knowledge P* taken as a principle, but only in a negative way: if a false consequence results from knowledge *P*, then this knowledge *P* itself is false. For if the principle is true, the consequence should also be true, since the consequence is determined by the principle.

But one cannot conclude the other way around: "If no false consequences derive from knowledge *P*, the latter is true", for from a false principle one can sometimes conclude true consequences.

Apagogical Argument (Proof by contradiction, Latin: Reductio ad absurdum)
This mode of reasoning, according to which the consequence can only be a negatively and indirectly sufficient criterion of the truth of knowledge, is called in logic the apagogic mode (in Latin: *modus tollens*).

Apagoge – Apagogic

- Apagoge: A reasoning by which one demonstrates the truth of a proposition by disproving a proposition that contradicts the one to be established.
- Apagogical: Qualifies a method of proof in which it is first supposed that the fact to be proved is false, and then it is shown that this supposition leads to the contradiction of accepted facts.

Important Consequence
Rule: it is enough to draw *a single false consequence* from an object knowledge to prove its falsehood, while a thousand true consequences do not prove the truth in all cases. The scientific truth accepted today is based on this kind of proof.

8.3 Scientific Truth

Origin of the Modern Criterion of Scientific Truth

(Source: [20] page 650)

Kant rightly notes that it is easier and more rigorous to investigate whether a proposition or thesis is *false* through a single counterexample, than to assess its truth in all its possible cases of application.

Truth by Consensus

The rule above is of great importance, because the modern scientific method of validating a theory that cannot be proven strictly with deductions results from it: *if none of the specialists to whom the theory has been submitted has been able to refute it, by experiments or reasoning, it is accepted as true*. This is a consensus truth, essentially provisional, but it is *the* accepted approach today.

« It only takes one counterexample to prove that a theory is wrong. »

« A published theory, which is falsifiable and has been examined by scholars without objection, is provisionally considered plausible. »

Rule 2

If all the consequences of a falsifiable knowledge are true, this knowledge is true *until proven otherwise*. For if there were something false in that knowledge, there should also be a false consequence.

Thus, knowing the consequence, one can suppose the existence of a principle (the possibility of an assertion of general application), but without being able to prove this principle. It is only after verifying the set of *all* the consequences that one can conclude from a principle that it is true, and one hardly ever knows all of them.

Positive and Direct Reasoning (Latin: modus ponens)
With this mode of positive and direct reasoning, the difficulty is that we cannot know *apodictically* all of the consequences. This mode of reasoning produces only plausible and hypothetically true knowledge (i.e. true by hypothesis), that is, an inductive hypothesis that "if many consequences are true, all others can also be considered true until proven otherwise."

Apodictic
Which seems subjectively necessary; which has the convincing, obvious character of a demonstrated proposition – but without being rigorously demonstrated.

Difference Between Formal Truth and Semantic Truth
A theorem proved in the context of an axiomatic is true, but its meaning and value in a real field to which the axiomatic is applied are not established by the proof, which is only *formal*. Thus, a theorem formally established in mathematics can be false or meaningless in some cases in physics, when reality is modeled by functions and equations defined with an axiomatic.

In short, the correct application of deduction rules and the existence of a theorem do not guarantee the semantics of this theorem. For any theorem (or formula, or equation...) verifications are mandatory:

- Is what the theorem asserts or predicts consistent with experimental reality? (Do experiments confirm the theory?)
- Don't the consequences of this theorem contradict another certainty? A single contradiction is enough to prove the theorem wrong.
- If the theorem, formula or equation describes a physical reality, an empirical (i.e. experimental) verification is necessary to verify the absence of a result constituting a denial.

8.4 Rationalism - Principle of Universal Intelligibility

Definition of Rationalism
Rationalism is a doctrine which postulates the Principle of Reason:

> **« Everything that exists (object) or occurs (event) necessarily has a cause due to a law of nature. »**

Principle of Universal Intelligibility (abbreviated: Principle of Intelligibility)
Consequence of the presence of the word Reason in the doctrine of rationalism:

> **« Everything that exists or happens is intelligible. »**

Rationalism is based on causality. It is the philosophical doctrine of Descartes, Kant, etc., that Aristotle called *Principle of Sufficient Reason*. It postulates that, for all observed phenomena in nature, there exists a reason that sufficed for it to exist or happen. A rejection of this principle would allow something to arise from nothingness, which seems impossible except to people who believe in a creation by God.

Object Experience – Empirical Knowledge

- Experience is first and foremost knowledge acquired through the senses, or intelligence, or both, as opposed to the mind’s innate (a priori) knowledge.
- It is also the act of becoming aware of a physical object through perception ; the object is then present in the mind as a representation interpreted by its faculties of understanding and intelligence.

Knowledge from experience is termed *empirical*.

According to the principle of reason, any reality is explained by an experience, which makes it intelligible. And since any natural phenomenon has a cause, and any cause is intelligible:

> **« Any phenomenon can be explained. »**

As a metaphysical doctrine, rationalism advocates reason, evidence and demonstration.

The Principle of Reason can be applied to draw a consequence from a fact or hypothesis; example: "If $x > 3$ then $x^2 > 9$".

The principle of reason makes sense in physics only if we also adopt the Postulate of Causality; in practice we can reason by directly putting forward this postulate.

> *Empiricism*
> Doctrine that denies the existence of axioms as principles of knowledge logically distinct from experience. For an empiricist, Man has innate principles of hereditary and cultural origin, but knowledge of truth can only be based on experience, apart from which there are only arbitrary assumptions.

Rationalism Opposes Empiricism

Rationalism opposes empiricism, postulating that all knowledge comes from a priori concepts, of which we have an innate knowledge and on which we reason independently of experience.

> (Man can only conceive of an object (real or abstract) by constructing a representation of this object from concepts he already knows to which he connects it, thus initially from *basic concepts*: this is a scientific truth. For example, the concept of "straight line" is constructed from the image of a drawn line and the attributes "infinite on the right", "infinite on the left" and "zero thickness"; the notion of "right" is a basic a priori concept.)

Basic concept
It is a concept *a priori,* understood intuitively, like *point* or *time*: it cannot be defined from simpler concepts, it is irreducible. Descartes writes in [19]:
"Some notions are so clear that they are obscured by defining them, since they are born with us…"

8.5 Karl Popper's Critical Rationalism

Critical rationalism is the current three-step scientific method for finding the laws of nature. It was proposed by Karl Popper [55]. The three steps are:

1. First, Man imagines laws to account for what he observes, and foresee what he may be able to observe.
   See *Man Defines the Laws of Nature with No Exceptions*.
2. Then Man postulates that nature will obey these new laws, in accordance with the *Principle of the Primacy of Knowledge over Objects and Phenomena*.
3. Finally, all interested scientists will check the stated laws (their theoretical calculations and experimental predictions). All they have to do is find a single error in a new law for it to be wrong.

Therefore, today:

> **« Scientific truth is proved by a consensus of lack of errors. »**

- A theory can only be called scientific if it is falsifiable.
- As long as a new law has not yet resisted attempts to prove its falsity, it is provisional, it is a proposed conjecture.

- A new scientific law can be entirely experimental, without theoretical basis, as is often the case in life sciences. If it is falsifiable, it may be considered valid provisionally as long as no scientist has raised a prohibitive objection.

  This is why the author of the law must publish it for comments, preferably on the Internet (in international sites such as https://arxiv.org), and/or in world-class journals such as *Nature* (https://www.nature.com/).

- More generally, a proposed law does not have to be understood in order to be valid. The only requirements are:
  - It should be falsifiable ;
  - It has no known objection, and does not contradict an existing law;
  - It complies with the *Stability Rule*, so that its results are reproducible.

The Ability to Think Does not Guarantee Fair Conclusions

Many very intelligent people have an exclusively literary culture. Their reasoning can then be distorted by the lack of scientific knowledge: for example, something they believe impossible is not, for lack of certain mathematical or physical knowledge.

Symmetrically, many people of scientific culture know almost nothing about humanist culture, especially philosophy. They do not know that many of the problems they face in their social and personal lives have been studied by thinkers of the past, who have proposed elaborate answers.

The problem of unbalanced culture concerns us all, preventing us from benefiting from valuable reflections and solutions already published. The availability of the Web does not compensate for ignorance, and no person can cite arguments of which he does not even know the existence.

Thus, the 2002 Nobel Prize in *Economics* was awarded to *psychologist* Daniel Kahneman for having studied this danger in detail and proposed solutions. [183].

Problems of judgment based on incomplete information are aggravated when our way of thinking uses the false or incomplete appearance of a phenomenon (its representation in our mind) as conclusive information.

To minimize the risk of not taking into account important facts, it is necessary to take advantage of the knowledge of others, i.e. to communicate and interact.

Our Judgment Uses Only What it Knows, as if What it Does not Know Does not Exist

Kant writes in [50] page 236: "One is mistaken, not because one's understanding associates concepts without rule, but because it neglects the details of an object that it does not see, and it judges that what *it is not aware of* in a thing *does not exist*."

In France, Jean Tirole, also a Nobel laureate in economics, published in 2016 a remarkable book that addresses this subject, an interesting excerpt of which can be found in [184].

8.6 Value System

Definitions of *value* in dictionary [3]:

- Evaluation of a thing based on its usefulness;
- Objective quality corresponding to a desired effect, or to a given purpose;
- Quality of what is desired or esteemed, or on the contrary rejected or feared.

Examples of values: truth, justice, love, beauty, etc.

A value is both the object of a desire and the object of a judgment: the desire is the cause, the judgment is the arbiter; if one of these two factors disappears, a value no longer exists.

In the human mind, each value is automatically associated with one or more affects on which judgments can be based.

In addition to the previous positive values, there are of course negative values corresponding to what is hated, feared, etc.

A "secondary" value can be created by a reflection or an interpretation of a situation, its importance coming after existing stronger values.

A person's values that apply to a given situation are ordered; when choosing between two values, the strongest is always preferred.

A person's values are always accompanied by apriorisms derived from his genetic heritage, culture or experience, and acting in his subconscious. In France, for example, many people fear GMOs and the fallouts from science or globalization.
See *The 3 Categories of Circumstances That Determine the Dominant Value*.

The rationality of thought is not a value, contrary to the opinion of Kant and Descartes, it is only a criterion of its logical organization. Therefore:

> **« Reason has no power in itself, it is only a tool at the service of the dominant instincts, impulses and desires of the moment. »**

8.7 The Power of Reason

We know today that what Man wants (desires) at a given moment does not depend on his reason, because *it is only a tool at the service of unreasoned desires*. What he wants depends on his psychic state, that depends only on his genetic heritage, his culture and the circumstances; these conditions determine quantities of neurotransmitters, which in turn determine neurons' states and interconnections, a global state that consciousness interprets as outcome values. We do not know how to deduce the detail of human wills from psychic states, but that is not a sufficient reason to believe in the existence of a transcendent independent will, a notion as imaginary as that of a soul seat of the spiritual.

A man aware of thinking and having a representation present in mind, only feels a psychic state of his neural network, a feeling accompanied by characteristic emissions of neurotransmitters and an impression of good/bad, promising/worrying, etc.

8.8 Culture (Definition)

At the Level of a Human Group

Culture is the set of values, beliefs and customs shared by the members of a group (people, followers of a religion, etc.) for long enough for everyone to have internalized them: they seem unconsciously natural and indisputable. This sharing results from:

- Common history;

- The geographical and climatic environment where the group has lived for generations;
- The group’s most prevalent religion(s);
- Moral laws ;
- Social customs;
- Education transmitted to children by parents or schools;
- Media information (publications, TV, social networks, etc.);
- Art forms that have been dominant for decades (literature, painting, sculpture, dance, architecture, cinema, cooking, etc.);

A culture includes, for example:

- Habits and preferences in areas such as children upbringing, food and cooking, expressions and gestures used to express one's opinion, relationships with others in family life or at work, and the discipline that each person imposes on himself – for example, to make efforts or address a complex problem;
- Values like beauty canons and honesty criteria;
- Beliefs in the areas of medicine, cosmology, religion and life after death;
- Ideologies and ethics in business, economics, politics, etc.

The culture of a human group is related to *ethnicity*, defined by its genetic and sociocultural heritage (especially language), geographical location and the awareness of its members of belonging to the same group.

<u>At the Level of One Person</u>

The culture (the acquired) comes from the person’s group, which transmitted its values, beliefs and customs, as well as knowledge and experiences from the person’s own life. But a person's culture is unrelated to his skin color or birth: *it is a characteristic transmitted by social life*.

There are differences between culture and civilization.

8.9 Civilization (Definition)

<u>A Civilization is Defined By:</u>

- A culture,
- A social organization (institutions, legislation, economic model, etc.)
- Collective achievements (infrastructure, science and technology, architecture and other collective arts, etc.).

<u>Civilization Comparisons</u>

One cannot speak of the superiority of one culture over another, but one civilization may be superior to another insofar as it allows its people to live more in accordance with their cultural and social values.

Thus, institutions allowing the reign of justice, security, solidarity, the preservation of health, education and democracy correspond to desirable values; the same is true for *collective achievements* that make it possible to heal, to learn, to entertain, to travel, to benefit from technological advances and ambitious artistic achievements.

8.10 The 3 Determinants of Values According to Cognitive Psychology

Dominant Value Issue

Kant believes that Man has the power to freely determine his actions and to impose on his will to be good, that is, to be governed by reason and duty by overcoming his inclinations. Here is a modern view that denies the existence of such free will.

> **« There is no thought that does not come from the body. »**
> (Every thought is an interpretation by the brain of its own state;
> see above *Interpretation - Processes of Consciousness*)
>
> **« Every thought is caused by emotion, continues and ends with emotion »**

Man's thought is only a tool at the service of his impulses and desires of the moment: whenever he thinks, Man seeks a solution to satisfy a desire; there is no reflection without an affective goal, and such a goal is characterized by a value that dominates all others for this reflection. This is a causality principle of human reflection, a part of human determinism. Modern psychology knows that reason, rationality, logic, and consistency are not values.

Problem of Free Thought

There are circumstances when a subject feels so unconcerned that he can think freely, without being disturbed by emotions, inclinations or prejudices. Example of such a circumstance: to calculate which day of the week fell on July 14, 1789. But, as soon as the expected result of a reflection has an emotional importance, a problem of freedom appears: can Man think freely, without constraint? When his reflection leads to a decision, is he free to choose what he wants?

The 3 Categories of Circumstances That Determine the Dominant Value
Three categories of circumstances determine the context in which our psyche (consciousness and subconscious) functions, i.e. its values:

1. The innate (genetic inheritance) [57];
2. Acquired experiences (culture received, training and education, everyday life);
3. The circumstances (context of the moment), including:
   - A real situation (examples: immediate danger, opportunity, hunger...);
   - An imagined future, determining the meaning of life or action (why go to such trouble, what hope do I have, what can happen to me...);

     Thus, a man will judge the same task unbearable, unpleasant or very bearable depending on the future he imagines if he performs it; examples:
     - ✓ *Unbearable,* if he is forced to perform it for a very long time without identifiable personal profit, like a man sentenced to hard labor;
     - ✓ *Unpleasant,* if by accomplishing it he earns enough to live, which justifies bearing the inconvenience;
     - ✓ *Very bearable,* if by accomplishing it he participates in an admirable work that will earn him the respect of his entourage.
   - The interpretation of the context and acquired experiences by the subconscious, which produces value judgments not expressed by words, but felt and taken into account.

At a given moment, a man's innate and achievements determine *what he is*; the circumstances determine *constraints, opportunities* and *the future he imagines*.

The innate changes very little during an individual's life, because the adaptation of his genome and his expression mechanisms to his living conditions is modest and slow. [57]. The experience acquired is enriched each time we learn something, and is impoverished with each memory lapse, and each distortion of a memorized information. Circumstances obviously change all the time.

Conclusion: a man acts exclusively in response to his dominant desire of the moment, which results from the value that dominates his feeling; in this sense, he has no freedom. A prisoner of war prefers to be tortured instead of revealing a secret to the enemy because his patriotism dominates his pain.

Man's Unpredictability
Genetic and psychic mechanisms can create unpredictable human behaviors because of their complexity, the influence of the subconscious, ever-changing experiences and ever-different contexts. This has nothing to do with determinism and does not prove the existence of chance.

Universals, an Important Part of Human Innate

Definition
In this text we call *universals* concepts applicable to all men, regardless of their race, geographical origin and epoch. They characterize culture, society, language, behavior, and psychology in a similar way for all human societies known in history.

Moral universals are concepts always associated with affects that automatically, instinctively, trigger a value judgment in every human mind. They concern in particular:

- Distinguishing between right and wrong;
- The prohibition of violence against others (murder, torture, rape...);
- Shame and taboos;
- The ability to identify with others;
- Rights and duties;
- Justice, fairness, honesty;
- Returning good for good and evil for evil ;
- Admiration for generosity ;
- The obligation to punish harm to society, etc.

Cultural universals do not represent the whole culture; they represent only the part of each culture common to all men (in mathematical terms: "the intersection of the various sets of values, beliefs and customs constituting the particular cultures").)

Examples of Universals

- In [149] pages 285 to 292 there is a list of 202 universals that have a connection with morality and religion. Here are some:
  - *Affection expressed and felt* (necessary for altruism and cooperation to be reinforced);

  - *Age statuses (vital element in social hierarchy, dominance, respect for elders' wisdom)*;
  - *Anthropomorphization (basis* of animism, anthropomorphic gods of Greece/Rome, attribution of human moral traits to the monotheistic God of Jews, Christians, and Muslims);
  - *Anticipation* (vital for behaviors to have future consequences), etc.
- List of about 200 universals among 373 identified by Donald E. Brown [150], of which here is a short excerpt where the universals are classified by categories:
  - Time; cyclicity of time; memory; anticipation; habituation; choice making (choosing alternatives); intention; ambivalence; emotions; self-control; fears; fear of death; ability to overcome some fears; risk-taking;
  - Daily routines; rituals;
  - Adjustments to environment; binary cognitive distinctions; pain; likes and dislikes; food preferences; making comparisons;
  - Sexual attraction; sexual attractiveness; sex differences in spatial cognition and behavior;
  - Self distinguished from other;
  - Mental maps; territoriality; conflict;
  - Sweets preferred; tabooed foods;
  - Childbirth customs; childcare; females do more direct childcare; preference for own children and close kin (nepotism)…

Origin of Universals
Universals result from a psychological structure common to all men, which the various historical paths and cultural additions have only been able to complete without modifying their characteristics.

The existence of universals is explained by a biological and genetic basis common to all humans, and an identical evolution. At a given moment in human history, universals are characteristics of a universal human nature, and of the part of that nature that has not been altered for millennia by a particular culture or historical fact. They are therefore part of the "innate" (as opposed to the rest of culture, which is part of the "acquired"). Historically, universals have evolved at the same rate as the human species, under the influence of natural and then sociocultural selection, gradually and over a period of ten to a hundred thousand years.

« Universals are an important part of human determinism. »

Consequence of the Existence of Universals: Dignity and Equal Rights
Source: [151]

All human beings have the same dignity and rights, regardless of their country of origin or citizenship, skin color, sex, religion, etc. These rights are inherent in the fact of being human, and inalienable.

This equality is enshrined in the *United Nations Universal Declaration of Human Rights* [152], adopted on 10 December 1948, and recognized today by *all* 193 member states of the United Nations. Unfortunately, there is a difference between written recognition and real democracy…

8.11 Free will

Definition of Free Will

Free will is the power to choose an act independently or to do nothing, by escaping (?) the causal determinism of nature.

Let us first note that absolute freedom is impossible: to choose, Man must first live, which presupposes limited faculties of reasoning, oriented by his genetic heritage and his knowledge (culture, experiences) of the moment. In addition, any choice is made in a context, circumstances that must also be taken into account. This context includes first all of the laws of nature, from which no physical action can be freed, then the determinants of human values that constitute the basis of all his desires (see *The 3 Categories of Circumstances that Determine the Dominant Value*).

> Being an idealist, Kant also believes in a freedom of mind based on Reason, which he also considers always free. But modern neuropsychology shows that Reason has no power, it is a tool subject to human desires from the three previous determinants: genetic, acquired (culture, experience) and context of the moment.

Concerning the causal determinism of the laws of nature, no transcendent action is possible according to our physics: human thought is not influenced by another thinking being, even if it is divine; it is born and remains within the limits of our brain. It is therefore free from any transcendent influence.

Human thought is limited by the material possibilities of the cognitive apparatus: Man can only think what his brain lets him think, with his own thinking power, his memory, his imagination, his mental patterns... He feels like he is free to choose, but that freedom is limited by these mental limits.

Man makes choices because he has a desire to satisfy: he chooses how to satisfy it. He evaluates each choice he believes possible according to his values of the moment. He feels that he is free to judge and decide. Yet he is not master of his genetic heritage or his experience, part of which is internalized and manifests itself in a subconscious way. His freedom is reduced to choices that depend on circumstances, which he will evaluate according to his innate and acquired values. His choice is therefore always reduced to the same values he is subject to, the innate and the acquired. And his judgment is not free, either: his rationality is not free by definition, since subject to universal Reason, and his irrationality results from uncontrollable affects and the power of his subconscious. Man's impression of freedom is therefore illusory, his freedom cannot be absolute.

> Let us remember here that reason is not a value, it is only a tool at the service of affects. It governs the discovery of possibilities and their consequences, as well as how to evaluate them according to values, it does not define any value.

This is how Man makes a decision (freely, he believes) based on what he knows, imagines and feels at the moment he makes it. But what he knows, imagines and feels can be strongly influenced by his entourage, superego that exerts social pressure, or by false information, like that found on the Internet.

The Internet
Such information is custom generated for each user, by applications that know his profile (his desires, fears, contact details, past purchases, searches, etc.) following previous navigations. This systematic profiling of web users is done by search tools such as Google and Bing, by social networks such as Facebook, by sellers such as Amazon, and by hundreds of specialized companies that resell user profiles. All these service providers accumulate data provided by each user to use it by influencing him, or resell it to companies or political organizations. Those who generate such tailor-made information, at each dialogue, do not do so to spread the truth, but to serve their interests, and by dint of receiving again and again information going in the same direction many Internet users are influenced and lose part of their freedom.

The user of the Web and social networks should therefore know that he can no longer trust *himself*, because he is spied on, manipulated and will be more and more so.

Philosophical Considerations on Determinism and Free Will

Traditionally, philosophy distinguishes two cases:

1. Human decisions are free when there is no coercion or law; then, nothing prevents a man from doing what he wants:
    - neither natural laws, scientific progress and the accumulation of means of doing the most extraordinary things;
    - nor moral rules, since many materialistic atheists do not feel compelled to respect them.
2. Human decisions are not free because there are moral laws, customs and legal laws.
    - Moral laws have an ancient origin, under the influence of universals and religions ;
    - Customs belong to ethnic groups, as consequences of their values ;
    - Legal laws were defined by societies at the same time as their civilization was structured.

The Thesis of Absence of Free Will is Opposed

The thesis of Man's lack of free will is opposed by some philosophers, who refuse to admit that Man is a kind of machine, that life and thought are phenomena subject to the determinism of nature. Here is what the mathematician René Thom writes in [63]:

> "If one tries to analyze why minds show such reluctance towards determinism, one can, I believe, put forward two main reasons:
> 1. Some people want to save human free will. [...]
> 2. Some feel oppressed by the growing influence of technology, and by the collusion of science and power."

The thesis of the absence of free will is also opposed by an atheistic materialist, the philosopher André Comte-Sponville in text [45], pages 42-43 (which also contains the excellent text *On the true nature of materialism and its legitimate seduction*). Unfortunately, this philosopher asserts false things by insufficient understanding of determinism: he believes in chance and the contingency of events.

It is Impossible to Explain Free Will

Freedom and free will cannot be explained; they do not result from any particular cause, they are not determined by anything because they are absences of constraints. Man is certain to take advantage of free will because he knows that nothing prevents him from thinking, and he is not aware of his preconceptions and his unconscious cognitive and affective mechanisms. Free will is a purely psychological certainty.

Determinism affirms an absence of freedom of nature: each situation determines the evolution that will transform it, and is subject to the laws of physics.

Will Has no Power in Itself

To escape the determinism of his nature, a man must have a will capable of dominating his instincts and impulses. This condition cannot be satisfied, since:

- The will is only a tool at the service of existing values;
- A man is not aware of certain values and cognitive and affective mechanisms, which nevertheless guide his desires and his thinking.

Man is Always Dissatisfied

At all times, a man has aspirations by the very fact that he lives, and he is aware of them. When he feels that these aspirations are really his own, that they have not been imposed on him, and that it depends only on him to act to try to realize them - and thus to realize himself, Man claims to be free and says he enjoys free will. His free choices are made according to his values, some conscious and others not.

> In fact, a man claims to be free of his choices while knowing that life in society imposes on him laws, customs and the pressure of the opinion of others; but as these limits to his freedom of action seem normal to him, he does not suffer too much and considers himself generally free of his choices. Or on the contrary, if he is rebellious in nature, he will find excessive the obligation to drive in accordance with the rules of priority or speed limit. These examples illustrate the subjective nature of the impression of freedom.

Free Will According to Sartre

Sartre showed in [190] that Man's consciousness notices at all times a dissatisfaction, a lack of something that Sartre calls "*lack of being*" or "*non-being*".

> This opinion is confirmed by recent research: the author of [191] confirms that the biological mechanism of satisfaction of the human brain keeps total satisfaction out of reach, allowing at best only partial satisfaction that allows certain desires to remain.

The human psyche reacts to this dissatisfaction by constantly generating physical needs and psychological desires. Some of these needs and desires cross the threshold of consciousness, thus triggering reflection, others remain unconscious while exerting influence.

For Sartre, *Man enjoys free will because he has awareness*; and his awareness escapes determinism because it allows him to think right or wrong, and even to be in bad faith when good faith would lead him to disturbing conclusions.

For Sartre, the transcendent character (i.e. escaping the deterministic laws of nature) of Man's free will need not be proven, it is a mere consequence of the way his consciousness functions. It is free *by nature*, its desires coming from Man’s "lack of being", that is to say from his psyche which notices at all times that something misses or displeases him. In short, Man enjoys his free will, but not to the point of being able to prevent himself from desiring something: even wise, he will always suffer from lack of being.

Man's free will makes him responsible for his actions, of course, but also for what he seeks to become: for Sartre, Man makes himself, freely.

By rightly noting that Man can never help but desire something, Sartre contributes to the understanding of human nature. He also follows Freud, who attributes to the unconscious of Man all his deep desires. No man can seek to direct his conscious thought in a direction contrary to his unconscious desires, which correspond to his idea of what is good for himself and for all fellow men.

The Problem of Responsibility

If we admit that Man has only an illusory free will he is never responsible for his actions, which can always be attributed to a desire or impulse he cannot master, and whose value of the moment prevails in his decision.

This reasoning may suit an individual, but it is unacceptable to the society in which he or she lives. Life in society is not possible if citizens do not respect the rules defined by culture and law. It is therefore necessary that the non-respect of such a rule be reproached to its author, which is impossible if he is never responsible.

Human society has therefore provided for "good practices", unwritten rules of life that are part of the local culture, and written laws describing obligations and providing for sanctions of wrongdoings. These rules and laws become values in every citizen, to deter him from transgressing them: I do not steal from my neighbor because it can land me in prison; I will not be forgiven if I put forward an irrepressible desire to appropriate his belongings.

With these good practices and laws, the values of each citizen include safeguards allowing him to choose among the possibilities allowed... in theory. In the name of life in society, his free will is no longer so free.

8.12 Conclusions on Human Cognitive Determinism

Schematically, human cognitive determinism comprises:

- On the one hand, General Determinism, to account for the faculty of reasoning logically;
- On the other hand, Genetic Determinism with its universals, to account for innate cognitive mechanisms. But this determinism is itself at the service of impulses and desires, and subject to errors, value judgments based on preconscious apriorisms and subconscious functions.

9 Reflections on Man's Knowledge, Judgment and Decision

Preliminary Remarks

Unlike nature:

- Man remembers the past and transmits characters by heredity; see:
  - *Genetic Program and Determinism* ;
  - *Universals, an Important Part of Human Innate*.
- Man reflects, anticipates and adapts (e.g. by sports training), while natural causality is automatic and without nuance.

Given the human faculties of memory and irrational thinking, human behavior cannot be deterministic in the preceding senses, since:

- Memory is subject to partial oversights, errors, etc.
- Human thought is not often rational, because the subconscious constantly intervenes. Moreover, the mind reasons only according to desires of which its reason is a slave; it is also a prisoner of prejudices, archetypes and cultural values.

Therefore, human determinism is very different from the determinism of nature.

9.1 Determinism of Living Beings

Definitions of Living Beings

- Among other definitions, [131] defines the living being as "An autonomous chemical system capable of Darwinian evolution." This simple definition implies the possibility for this being to subsist in its environment, to reproduce and evolve from one generation to the next under the control of natural selection. But it does not account for the many other characteristics of a living being.
- Another definition: "A living being is a structure [...] consisting, in whole or in part, of one or more nucleic acid molecules (RNA and DNA) that program vital processes; this structure constitutes the genetic heritage whose primary property is to be able to replicate."

A living being absorbs food, and transforms it into its own substance, and into thermal and mechanical energy. It adapts to its environment, defends itself against aggressions and reproduces.

A form of determinism does exist in the field of life, governed by the genetic program. Some deterministic mechanisms ensure the life of cells, others ensure hereditary replication, others ensure resistance to environmental aggressions, others adapt the being to changing living conditions. The genetic program is self-adaptive within certain limits, this self-adaptation being a characteristic of determinism in the case of living beings. We delve deeper into this topic, which strongly impacts the definition of human determinism in the appendix, in *Levels of Biological Information and Genetic Determinism*.

Genetic Determinism

At this point we can already affirm that living beings are subject to *genetic determinism*, which is adaptive and acts in the long term by mutation of the genome in heredity, or in the short term by modification of gene expression to adapt to living conditions [57]. We will return to this topic in *Conclusions on Genetic Determinism*.

See also the universals, an important set of rules of human determinism, in paragraph *Universals, an Important Part of Human Innate*.

Life, Organization, Complexity and Entropy

Life is characterized by two kinds of organizations, whose order opposes the disorder of chance or the simpler order of inanimate matter:

- Architectural, static organization:
  - *Of the genetic code*, whose structure constitutes a program that determines functions such as protein generation and enzyme specialization;
  - *Of cells*, of which there are many different specialized types (blood cells are of a different type than those of neurons, etc.).
- Functional, dynamic organization, which coordinates, for example, the thousands of chemical reactions of the vital functions of living beings. In this organization, we find both regular, periodic rhythms, such as the heart's, and arrhythmic mechanisms such as the neurological processes of the brain.

These two kinds of organizations are intimately linked, each acting on the other.

Every living being is a dissipative system: it constantly exchanges matter and energy with its environment, hence its permanent thermodynamic and chemical instabilities. These instabilities and the exchanges end only with death. Throughout his life, parts of this being are destroyed and created, instability being a necessary condition for the functioning of his vital processes and of the self-organization that allows him to constantly adapt to his environment [178].

The Second Principle of Thermodynamics

The elaboration of a living being from molecules (when it feeds or develops) constitutes a complexification, a progress towards the organization of matter. This complexity decreases the entropy of the living being that is organized, by increasing that of its environment. The second principle of thermodynamics (the necessary increase of the entropy of the global system) is respected, while the decrease in entropy of its living being part results from a particular process: the dissipation of energy and the exchange of matter by the living being, who is far from thermal and chemical equilibriums.

> *Entropy*
>
> Any transformation of an isolated system involving an exchange of energy is subject to a very general physical law: *globally, it can only become more disorganized*. This disorganization is evaluated by a quantity, the entropy, which can only increase. But a part of this system can evolve towards more organization, its entropy decreasing at the cost of an increase of that of the global system. Thus, the global entropy of the Universe is constantly increasing.
>
> **« The entropy of an isolated system that undergoes transformations with energy exchange is always increasing. »**

The complexity of living beings results from a succession of instabilities, without which life cannot subsist. Our conception of determinism must therefore take into account, in its laws of interrupt, life's requirements of instability, and of dissipation of energy and matter.

> **« Dissipative systems can evolve by self-structuring towards more complexity and diversity. »**

9.2 Thermodynamics Does Not Contradict the Materialist Doctrine

Some idealists have put forward thermodynamics to make their doctrine of divine creation of the world prevail over that of materialists:

> "Since life is born and develops by organizing itself, thus by diminishing entropy, it cannot result exclusively from materialistic processes dominated by thermodynamics, because the second principle of thermodynamics opposes such an organization; therefore the creation and development of life happens by processes escaping thermodynamics, therefore not exclusively materialistic; therefore God's transcendence is necessary".

They forget that this principle applies to *closed* systems *in the vicinity of their thermodynamic equilibrium*. But the system of a living being is in permanent imbalance; moreover it is not closed, because it also comprises its environment: there is no life without exchanges of food, work, heat, waste and gas. The decreasing entropy organization of the living part is more than compensated by the disorganization of what surrounds it.

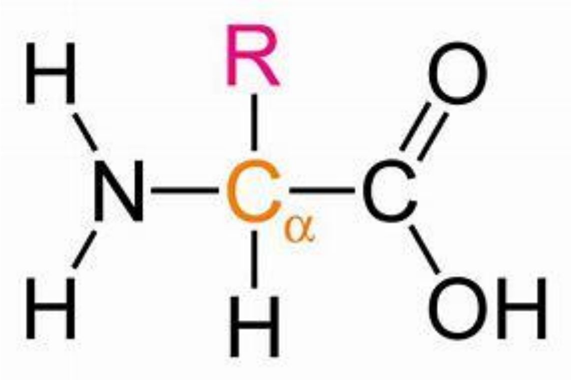
Inert food *does not transform* itself into a complex living being, it does so as part of a living being + food + environment system; the complexity created in the living being (for example when a growing baby becomes a child) is accompanied by disorganization in its environment, the entropy *of the whole* increasing indeed.

9.3 Genetic Program and Determinism

A human body has between 50 and 100 trillion cells (50 to 100 $.$ 10^{12}). Each cell in a human body consists of 23 pairs of *chromosomes*, chains of molecules responsible for heredity that include sub-chains called *genes*. In each pair, one of the chromosomes comes from the mother and the other from the father.

Amino Acid

An amino acid is a molecule comprised in most proteins. Its name comes from the fact that it carries a COOH acid function and a basic amine function NH_2. It also carries an R radical that characterizes the 20 existing amino acids.

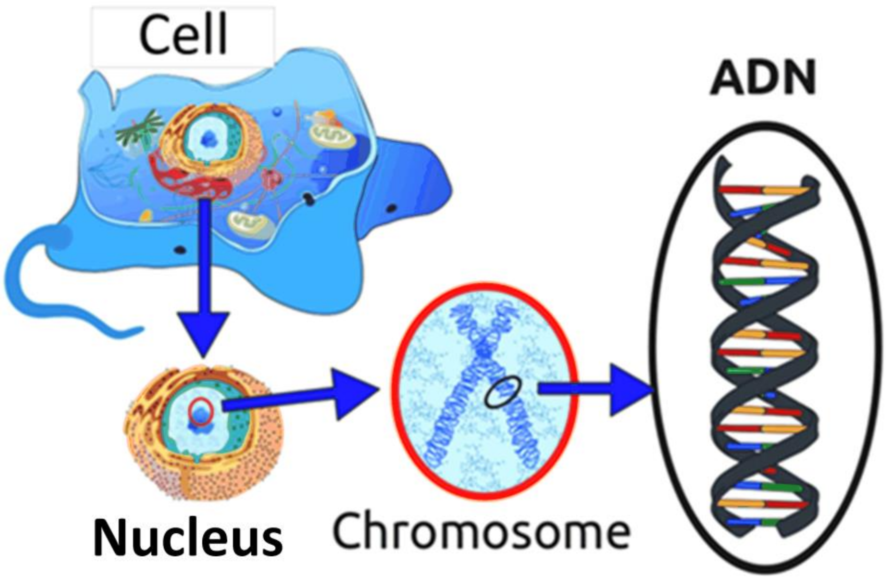


Structure of an amino acid (© Microsoft Bing Creative Commons)

Genes and Genetic Program

Genes are long chains of amino acids carrying instructions (in the computer program sense) for making about 100,000 different proteins involved in cellular life. According to [267], each of the approximately 21,000 human genes (each consisting of millions of base pairs forming a segment of DNA) participates in one or more hereditary traits, contributing to their transmission.

The structure and functions of each cell are defined by a *genetic program* whose instructions and data are stored in the DNA (ADN in French) molecule structures of chromosomes, plasmids, mitochondria and chloroplasts.



Location of DNA in a eukaryotic cell - Wikimedia Commons License
(Eukaryotes are animals, green plants and fungi)

The genome can be thought of as a program whose execution (a computer scientist would specify: *interpretation of DNA*) creates proteins and living cells through appropriate mechanisms involving RNA [268]. The existence and functioning of this genetic program make the creation of these proteins and cells a deterministic phenomenon.

> There is an analogy between the couple of mechanisms (generation of proteins by interpretation of DNA + regulation by RNA) and the couple (laws of evolution + laws of interrupt): a physical law of evolution is governed by a law of interrupt, which can initiate its execution by passing parameters to it, then stop it. Despite the infinite complexity of the mechanisms of the cellular machinery, their logic is entirely described by the DNA code, and by some sequences of the rest of the genome still poorly known: there is neither magic nor transcendent intervention [57].

All the cells of a given individual have the same genome, coming from a single initial cell, the egg. But a differentiation mechanism allows, from the initial fertilized egg and with its same genome, the creation of a large number of different kinds of cells, about 200 in humans: skin cells, muscles, blood, neurons, etc. Each type is specialized and has its own morphology and functioning. The functioning of the various genes can be blocked or activated by logical switches, the position of which (yes/no) depends on the DNA program and the position of the cell among other cells, in one part of the body.

9.4 General Determinism of Vital Functions

Sources: [316], [317]

At the atomic level, the human body, like that of any living being, works by forming molecules, for example proteins, or by associating molecules with chemical bonds. Thus, attaching a methyl radical (CH_3) to a gene of a cell (operation called methylation) can inhibit it, preventing it from expressing itself. The decision to inhibit or disinhibit a gene is made by interpretation of the DNA program and the context (such as the position of the cell in relation to neighboring cells); the decision on how much of a protein to produce is made in the same way.

A chemical bond of an attachment or detachment, being an operation of molecular biology, is governed by the Schrödinger equation, itself governed by Statistical Determinism. At atomic scale, life is therefore governed by this determinism.

> **« At atomic scale, life is governed by Statistical Determinism. »**

Molecular biology is an exact science, whose predictions of evolution are statistical. A molecular bond, for example, has a probability of establishing itself and a probability of detaching itself when it is established; depending on the context (temperature, ambient environment...) it will be more or less easy to establish or break.

But knowing the laws of molecular biology, one cannot deduce those of vital functions. Example: the liver has over 500 different functions. The transition from the laws of the atomic scale to the laws of the macroscopic scale, such as those that govern the functions of the liver, is governed by the logic of DNA and cellular mechanisms, which can therefore support a great complexity. The functioning of living beings is therefore governed by algorithms, therefore falling under General Determinism.

> **« Vital functions are governed by algorithms within the framework of General Determinism. »**

Unfortunately, this does not make it possible to assert that the actions of a living being are predictable, even in the sense of statistical certainty, since decisions of action also depend on functions that are impossible to describe precisely, such as those of the human subconscious and those of the values system.

9.5 Determinism of Heredity

Heredity means, for example, that cats breed cats of the same species: the genetic program is therefore transmitted both in the same individual from the initial egg, and from an individual to his descendants by heredity. Determinism inscribed in the genetic program guarantees the reproducibility of these two kinds of transmissions, as well as the differentiation into specialized kinds of cells.

The genetic program can only run properly in certain contexts. Thus, for example, some proteins are synthesized only if certain parts of the program have already proceeded correctly before: we find here a procedural law of interrupt.

The genetic program is interpreted for generating proteins. But this generation itself requires the presence of certain proteins. The logic of generation responds to a simple scheme of actors + regulators, analogous to the scheme law of evolution + law of interrupt. As we saw above, gene expression is governed by switches. In the long term, for example during transmission between generations, this expression is epigenetic.

Genes and Human Behavior

With each passing month, researchers discover new properties of genes regarding their influence on human behavior. Sometimes a single gene is associated with a specific behavior, sometimes it takes several genes [57]. The terrible Huntington's disease is associated with a single gene, cystic fibrosis too.

The book [57] pages 130-131 cites the D4DR gene, located on chromosome 11: the number of occurrences of this gene on the chromosome determines the level of production of *dopamine*, a *neurotransmitter*.

> *Dopamine*
> *Positive* feelings of desire, euphoria, etc. are regulated in the human brain by a molecule, *dopamine*; (do not confuse *desire* and *pleasure*: the latter uses other mechanisms than the former).
>
> *Negative* feelings are associated with *acetylcholine*, a neurotransmitter that has vasodilatory effects on the cardiovascular system, acts upon the heart rate and the gastrointestinal system, and has inhibitory effects on the activity of the central nervous system, etc.
>
> In our brain, comparison to a value produces the detectable presence and measurable abundance of an organic molecule. The creation of value (pleasant=good, unpleasant=bad) as a consequence of perceptions or thoughts, and its use in comparisons necessary for judgments, are automatic, inevitable physical phenomena - in short, deterministic.
>
> *Neurotransmitter*
> A chemical message from one neuron intended to stimulate or inhibit the activity of another neuron. Dopamine, for example, is a neurotransmitter.

Dopamine stimulates the activity of the body: its absence or too low a level leads to lethargy, while an overabundance leads to overactivity, the search for novelty, desire and risk-taking. Example cited by [135]: chickadees that are more curious than others have the same particular form of the D4DR gene as particularly curious humans.

But we should not think that the sequences of D4DR genes *alone* explain the tendency of a person to seek or not novelty and to be hyperactive or not; they explain only a small part of it. In most experiments on the relationship between genes and behavior, there are partial explanations, correlations, and it takes several genes to explain a behavior. More generally, genetics intervenes for part of the innate character of a personality trait or aptitude, let's say 20% to 60% of the variance ([57] page 4), and cultural acquisition intervenes for the rest. And the proportion varies with the trait considered and the individual. (See examples [136] and [137]). Therefore:

> **« A given individual is only partially determined by his genetic heredity at birth. »**

If a gifted but ugly scientist marries a foolish beauty queen it is not certain that their offspring will have the intelligence of the father and the beauty of the mother. It may happen, but it may also happen that one of their children has the beauty of the father and the intelligence of the mother, in addition to characters inherited from grandparents...

Evolution of the Genetic Program

As the individual develops (*ontogenesis*) and lives his life, and as we move from one generation to its descendants, certain mechanisms of protein creation and cell creation can change: a part of the genetic program is able to modify and adapt by self-programming (in fact by expression/inhibition mechanisms under epigenetics).

> *Ontogenesis*
> The set of processes that lead from the egg cell of a living being to the reproductive adult.
>
> *Epigenesis*
> The theory that a living being's embryo develops by multiplication and progressive cell differentiation, and not from preformed egg elements [316].

This adaptation by genetic self-programming has been highlighted by the research published in [138],of which here is a quote:

> "It takes just 15 generations under these conditions for the flies to become genetically programmed to learn better. At the beginning of the experiment, the flies take many hours to learn the difference between the normal and quinine-spiked jellies. The fast-learning strain of flies needs less than an hour."

Mutations
Another example of genetic adaptation, here are excerpts from [1r], an article by Roger Durand, professor of biochemistry at Blaise Pascal University (France):

> "Around the years 1946-1948, Boris Ephrussi observed that a culture of diploid or haploid yeast produces, after transplanting, in the few days that follow, a colony identical to the mother cells except, in some cases, for 1 to 2% smaller cells. « Small colony » mutants only produce small colonies. The mutation is irreversible. Treatment of wild stem cells with acriflavine increases the mutation rate from 1-2% to 100%. These mutants grow slowly because they cannot breathe, their metabolism is only fermentative, they have lost the ability to synthesize a number of respiratory enzymes."
>
> "Ephrussi had to conclude that the wild strain and the « small colony » mutants differ in the absence, in the latter case, of cytoplasmic units genetically required for the synthesis of certain respiratory enzymes."

> "In 1968, it was demonstrated that the « small colony » mutation is due to a significant alteration of mitochondrial DNA. This molecule contains 75,000 base pairs... the « small colony » mutation would correspond to an excision and amplification of DNA fragments terminated by sequences CCGG and GGCC."

These changes, called *mutations*, are sometimes due to accidents (low-probability solutions of the Schrödinger equation describing the formation of the molecule). Others are due to environmental aggressions, such as the absorption of harmful chemicals or the action of ionizing radiation (X-rays or ultraviolet rays, for example). Often, mutations are inoperative and their harmful consequences are nullified by DNA repairing mechanisms such as enzymes of the "S.O.S. system" [139]. Other mutations are necessary for the adaptation of the individual to his environment, such as those that produce antibodies of resistance to infection.

Other examples of mutations:

- The adaptation of many insects to pesticides, the growing resistance of many bacteria to antibiotics, and virus mutations.
- The inhabitants of Asian countries, which for centuries have had a diet richer in starch than that of Europeans, have in their genome additional copies of a gene facilitating the digestion of starch, while Europeans do not have these copies: the genome adapts to lifestyle habits and these adaptations are transmitted between generations.

9.6 Evolution of a Population

A population *evolves* when individuals carrying certain characters (e.g. height, weight) have more offspring than other individuals; these characters then become more frequent in subsequent generations.

When the genetic characteristics of a population change over time, that population is said to undergo *biological evolution*. When such an evolution corresponds to an improvement in survival or reproductive capacities, we speak *of adaptation* of this population to its environment. Natural selection (studied by Darwin [140]) promotes the survival and multiplication of the best adapted populations, and disadvantages others.

When the evolution of a living species *A* produces individuals sufficiently different from those of that species, but sufficiently similar to each other to constitute a species *B*, *speciation* is said to exist. Individuals of species *B* have many things in common with their ancestors of species *A*. Biodiversity is the result of many successive speciations.

> Note: it is wrong to claim that "Man descends from Ape": the truth is that they have a common ancestor.

<u>Evolution Due to a Change in Gene Expression</u>

Sources: [316], [317]

Article [141] describes the results of recent research showing that Darwinian evolution by genetic mutations, which acts in the long term (over thousands of years), *is accompanied by an evolution due to a mutation in gene expression*, that is, the way in which the cellular machinery interprets the program of genes to make proteins. This mutation of expression sometimes comes from a very simple process affecting a single gene, and producing a result from the next generation, or even after a few months;

sometimes the mutation involves a set of genes; sometimes it even acts immediately [142].

The research report [143] confirms that it is sometimes enough for a simple methyl radical (CH_3, only 4 atoms) to bind to a gene to inhibit its expression, producing considerable effects on the body. There are several kinds of "chemical switches" that trigger or inhibit the expression of a gene, with important effects on most non-infectious conditions (cancer, obesity, neurological disorders, etc.). These triggers or inhibitions can have an effect throughout the life of the body, or only for a while. These are "all-or-nothing" effects, perfectly deterministic and analogous to the effects of software switches on computer programs, and to the action of an interrupt law on a law of evolution or a law of state transition.

The development of an organism by ontogenesis is determined by a hierarchy of genes, each level of which controls the level below. This hierarchy promotes the evolution of certain forms of organs, and prohibits others. A given gene hierarchy is most often hereditary, leading to the fact that from the next generation all descendants have the same hierarchy, commanding the same expression of genes.

Example 1
The genes of the PAX6 family determine the development of the eyes in beings as different as Man and Fly.

Example 2
In the Galapagos Islands, all the fringillidae (birds of the finch family, bullfinches and goldfinches) descend from the same ancestor from the mainland. But they are very different from continental fringillidae, by the shape and size of their beak (adapted to the foods available on these islands), as well as by the general size of some birds, significantly larger and providing more robustness, and by other characteristics testifying to an adaptation. Translated excerpt:

> "In the course of 30 years, the annual measurement of fringillidae has shown that both beak and body sizes have changed significantly. But they have not varied in a continuous and progressive way; natural selection has groped, often changing the direction of evolution from one year to the next."

The researchers found that all these developments were explained by a higher expression of the BMP4 gene, which produces an amount of protein (also called BMP4) proportional to the expression of the gene. By artificially increasing the production of this protein in chicken embryos, they obtained larger chickens with significantly stronger beaks, which confirmed that it is indeed BMP4 that is the origin of these rapid evolutions.

The discovery of the importance of gene expression in evolution, and the fact that a modification of expression (sometimes of a single gene) can determine a very short-term evolution, constitute *a fundamental recent development of the theory of evolution*, which until now considered only the mutation of the genome, with its long-term effects.

We now know that *new species of living beings can appear as a result of an evolution in the expression of existing, unmutated genes*.

Scientists have discovered that the genes necessary for paws and fingers to appear, which is essential for an aquatic animal to get out of the water and move on land, have existed for a long time in very old fish (such as *Tiktaalik, below*) when an evolution in their expression allowed the growth of these new kinds of organs and the exit from the water of new animals, the tetrapods.

Tiktaalik, ©Microsoft Bing Creative Commons pawfish

We also know that a lifestyle habit, a significant change in lifestyle or intensive training leads to an adaptation of the body by modifying the expression of genes in the individual concerned. This alteration has consequences such as:

- The adaptation of certain neurons, which can multiply and multiply their synapses, to adapt the body to a frequent practice (such as a pianist who exercises 8 hours a day, an athlete who trains frequently, etc.).
- Adaptation of organs (muscles, bones, etc.).

9.7 Conclusions on Genetic Determinism

Determinism exists indeed in the field of life, governed by the genetic program. Some deterministic mechanisms ensure the life of cells, others ensure hereditary replication, others ensure resistance to environmental aggressions, others ensure adaptation to changing living conditions. The genetic program is self-adaptive within certain limits, this self-adaptation being a characteristic of determinism in the case of living beings.

We can affirm that living beings are subject to *Genetic Determinism*, which is adaptive and acts in the long term by mutation of the genome in heredity, or in the short term by modification of gene expression when adapting to living conditions [57].

See also the universals at the origin of an important part of human determinism, in *Universals, an Important Part of Human Innate*.

Therefore, living beings have a *Genetic Determinism* that controls all vital functions. The genetic code, received at birth and interpreted to generate the proteins of vital functions, also contains the structuring information of the brain, whose consciousness will interpret the state of its neurons in all psychic functions. The genetic code therefore contains all the information of the human character: it is a program written with the 4 letters *A, C, G* and *T*; all of the human heritage transmitted between generations can therefore be written in the form of a program, its complexity being fully described in 3 billion base pairs.

> **« In living beings it is a *Genetic Determinism* that controls all vital functions. »**

The rest of the human character, including its need for social life and the corresponding abilities, comes from what each man learns from birth, which is transmitted between generations by culture and generates *Cultural Determinism*.

> **« Above the level of Genetic Determinism there is a cultural determinism acquired since birth. »**

The Rebuttal of Idealists' Objection About the Need for a Transcendent Intervention

Some Idealists refuse to believe that biological matter (cells with their structure - whatever it is - and their vital processes) can alone generate and support life without transcendent intervention (divine or otherwise, but in any case escaping natural determinism). They think that there is an *essence*, a *vital principle*, a kind of *immaterial and non-deterministic specifications* resulting from a purpose that pre-exists living beings and defines their characteristics.

The reason for their refusal is that the traditional materialistic model, which makes life a consequence of matter, seems to them incapable of accounting for the richness, beauty and freedom they associate with the essence of life.
See *On the true nature of materialism and its legitimate seduction*.

How Matter May Have Fathered Life

We now know that the correct explanation *includes algorithms in addition to the biological material in which their software executes its genetic code*, and that it is this code-based software inscribed in DNA (i.e. this information) that determines all manifestations of life:

- Exchanges with the outside of food, waste, heat, mechanical energy, and information in the form of perceptions and verbalizations;
- Replication and repair of damaged genetic code;
- Cell differentiation allowing the creation of specialized cells from stem cells;
- Adaptation to changes and aggressions of the environment, etc.

The Essence of Man

It is this software - the data and logic of the genetic code - that constitutes precisely the essence of Man [57]. One of the reasons why materialistic philosophers fail to convince idealists is that, in their model of the living, they forget to mention this software level between the level of biological matter and that of noble functions such as the mind's; this omission prevents them from explaining the richness, the complexity and the unpredictability of the living. We know today that psychic functions like consciousness and self-awareness are properly described by software mechanisms (see *Awareness of*). For their part, idealists, for whom the essence of Man is spiritual – not software – do not accept to reduce man to his cells, purely material objects, even driven by a genetic program.

Non-Algorithmic or Unpredictable Psychic Mechanisms

See first *The 3 Categories of Circumstances That Determine the Dominant Value*.

« Reason has no influence on human decisions, it is only a faculty at the service of a person's desires and impulses. »

« Man often looks for a good reason to do what he wants, it is not reason alone that dictates his decisions. »

9.8 Algorithmic Psychic Mechanisms

A psychic mechanism is termed *algorithmic* or *computable* if it can be simulated by a computer. This is the case, for example, for arithmetic mental calculation, and also for pure deductive reasoning that can be simulated by calculating propositions or predicates (calculation methods taught in Logic). The psyche contains [88]:

- Non-calculable numbers and problems: see [0]
  There are real numbers and problems that are non-computable;
- Non-algorithmic, sometimes subconscious mechanisms, such as:
  - Remembering a souvenir;
  - Intuition;
  - Affects;
  - Spontaneous recognition of images, sounds, symbols, structures or procedures;
  - Associations of ideas, made consciously or not, allowing reasoning by analogy, intuitions, inexplicable thoughts, certainties or affects ;
  - Representations of realities such as images or procedures, and representations of abstractions.

At the lowest level, these psychic mechanisms are deterministic, because they include only underlying neural mechanisms of molecular biology, which are deterministic. But *in practice* they can be impossible to describe by an algorithm because we do not know enough about their processes (especially subconscious ones), and because the effort of writing the algorithm would be disproportionate to its interest. We have seen in *Determinism Does Not Guarantee Predictability* that the structurally deterministic character of a process does not necessarily lead to a predictable outcome.

Thus, from a person's memories, a rapprochement of ideas, an intuition or a certainty can arise from his state of the moment, defined by his health, his feeling of hunger or thirst, his recent affect, etc. The moment before or the moment after, in a slightly different context, thoughts would be different.

We also know that the unconscious constantly entertains thoughts that are beyond the control of consciousness and have no rational origin.

10 Appendix

10.1 Newton’s Laws – Maxwell Equations

Newton’s Universe

Newton conceived of the Universe as matter existing in a spatial continuum and a temporal continuum, but without a privileged position for Earth: contrary to the model of the Greeks, Earth was no longer the center of the world, and no reference of space and time was privileged; there was no longer any distinction between Heaven and Earth, no more perfect, eternal and immutable sphere. The physical laws (limited to the laws of *Classical Mechanics*, at the time) were the same throughout the Universe: the same laws of attraction governed the Earth-Sun system and the fall of bodies on Earth; the universal laws of motion governed the fall of apples and planetary orbits. These orbits that Kepler had taken years to determine by trial and error, Newton would demonstrate their equations in an hour.

Newton’s 4 Laws

Newton's laws are the foundations of Classical Mechanics that theorizes the forces and motions of objects that have mass. They are *deterministic*: they allow the expectation and prediction of the movements of macroscopic systems knowing initial conditions. They are also universal: the same laws apply everywhere, for all bodies (terrestrial or celestial), in the past, present and future, so they are laws of Special Determinism.

But nowadays Newton's laws are only approximations, valid only at macroscopic scale and at small speeds:

- These laws do not apply as such at atomic scale, for which there is Quantum Mechanics (which falls under Statistical Determinism);
- They only apply for speeds that are negligible compared to the speed of light. For higher velocities, there is Special Relativity when there is no gravitational field, and General Relativity when there is such a field.

Newton’s laws of motion are:

1st Law

A body that is motionless or moving in a straight line at constant speed will remain motionless or will keep the same velocity vector as long as a force does not act on it": this is the *Law of Inertia*.

From the point of view of determinism, a uniform linear movement is a stable state, which will not change until a force acts on the body. And a stable state being, on a macroscopic scale, its own cause and consequence, is a human abstraction that does not exist in nature; man has defined it for the simplicity of certain reasoning.

2nd Law

A mass M with velocity vector $\boldsymbol{v}$ affected to a vector force $\boldsymbol{F}$ undergoes an acceleration of vector $\boldsymbol{a}$ such that:

$$\boldsymbol{F} = M\boldsymbol{a} = d\boldsymbol{p}/dt$$

where:

- $\boldsymbol{v} = d\boldsymbol{r}/dt$ is the derivative of the vector position $\boldsymbol{r}$ with respect to time t;

- $\boldsymbol{p} = M\boldsymbol{v}$ is the momentum vector, $d\boldsymbol{p}/dt$ being its derivative with respect to time t;
- $\boldsymbol{a} = d^2\boldsymbol{r}/dt^2$ is the acceleration vector, derived from $d\boldsymbol{r}/dt$ with respect to time.
- (The derivative of momentum is proportional to the force, at any time t).

3rd Law
When two bodies interact, the vector force $\boldsymbol{F}_{12}$ exerted by the first on the second is the opposite of the vector force $\boldsymbol{F}_{21}$ exerted by the second on the first":

$$\boldsymbol{F}_{12} = -\boldsymbol{F}_{21}$$

(It is the law of equality of action and reaction, valid at all times t).

Universal Gravitation Law (Law of attraction, or on Earth: Law of falling bodies)
Two material points of masses M and M' at a distance d attract each other with a force F given by:

$$F = G\frac{MM'}{d^2}$$

where G is the *Universal Gravitational Constant,* $G = 6.67 \cdot 10^{-11}$ Nm^2/kg^2.

Universal Constant
The value of G is the same throughout the Universe, for all objects, regardless of the matter from which their mass is made, and regardless of the importance of this mass.

Classification of Newton's Laws as Laws of Evolution or Laws of Interrupt

- The 2nd law and the law of gravitation are evolution laws, because they describe forces that cause accelerations.
- The1st law and the 3rd law are interrupt laws, because they describe conditions that are sources of constraints.

Maxwell's Equations

Maxwell's four equations (laws) accurately describe all electromagnetic phenomena at macroscopic scale. Published by James Clerk Maxwell in 1864, these fundamental equations provide a complete description of the production and interaction of electric and magnetic fields.

10.2 Axiomatics and Logical system

Definition

An axiomatic is a formal and syntactic organization (a logical system) of a set of rules for deductive reasoning.

Example: Axiomatic of Euclid's Geometry
Source: *Euclid Elements* (4th to 3rd century B.C.) [36]

The first 5 axioms of Euclidean geometry are:

1. Through two points we can pass a straight line and only one;
2. A line segment can be extended indefinitely;
3. One can build a circle by giving its center and radius;
4. All right angles are equal;

5. Through a point exterior to a straight line we can pass a straight line parallel to it and only one.

Dropping or modifying the 5th axiom made it possible to define geometries other than Euclidean geometry, which has zero space curvature:

- Hyperbolic geometry (with negative curvature) ;
- Elliptical geometry (with positive curvature) ;
- Riemannian geometry (with curvature varying from point to point) used by Einstein in 1915 in General Relativity (see [0]: 3-sphere).

Example of a Postulate From the First Book of Elements
"If a straight line, falling on two straight lines, makes [the sum of] the inner angles on the same side smaller than two right angles, these straight lines, extended to infinity, will meet on the side where the sum is smaller than two right angles."

Euclid's axiomatic geometry is a remarkably accurate and complete representation of the usual physical space, on which all of classical physics and all of Newton's work are based.

Applying an Axiomatic to the Structured Description of a Science

Axiomatics is a method of structured presentation of a science by logical deductions from the principles on which it is based. The result of this method is *an axiomatic*.

Therefore, *the theorems of an axiomatic do not produce any new truth*: they are implicitly contained in its definitions; they are logical consequences, and add only new presentations, new rapprochements.

Consistency of an Axiomatic

An axiomatic is said to be *coherent* if any theorem deduced from its axioms (and/or other previously proved theorems) is non-contradictory, and does not contradict any other theorem or axiom of that axiomatic.

Gödel demonstrated the impossibility of proving the coherence of an axiomatic as a theorem of this axiomatic, that is, without resorting to axioms or rules of deduction external to the axiomatic.

Completeness of an Axiomatic System

An axiomatic is said to be *complete* if one can prove that any logical proposition deduced from it (theorem), or stated a priori by forming it from its basic notions in accordance with its rules of syntax, is either true or false; the eventual proof must be of finite length and must use only axioms, theorems and rules of deduction of the given axiomatic.

But unfortunately again, Gödel showed that *any axiomatic defining a minimum of integer arithmetic allows the statement of an infinity of undecidable propositions*. Such a proposition is either true or false, but there is no proof based on the axioms of the axiomatic and applying its rules of deduction to prove it.

> **« In an axiomatic, some logical propositions that make sense are undecidable: they cannot be demonstrated or refuted. »**

10.3 Quantum Physics – Quantum Mechanics

The Energy of Electromagnetic Radiation is Quantified – Photon

At the end of the 19th century, the laws of evolution of physics - those based on Newton's laws as well as those based on Maxwell's equations - were continuous and expressed with differential equations. But by looking for the distribution of the intensities of energy radiated by a black body as a function of frequency, Planck realized that no *continuous* function was satisfactory.

> *Definition of a Black Body*
> A black body is a body that absorbs all the radiation energy it receives, reflecting nothing; that is why it appears black. A surface covered with a layer of black smoke is a pretty good black body: it retains 97% of the electromagnetic radiation received.

In 1900, Planck found a mathematical solution that suited perfectly, but that he could not explain; it was the *Law of Quantification of Electromagnetic Energy:*

> **« A quantity of electromagnetic energy of frequency ν is a discontinuous multiple of a minimum energy quantity proportional to ν. »**

Planck called this minimum *quantum of energy*, hence the name Quantum Physics. He found that, for each radiated frequency, the energy of this "grain of energy" was proportional to this frequency, with the same coefficient of proportionality for all frequencies, a coefficient he called *h*: the energy of one quantum of a frequency ν was therefore $h\nu$.

Planck Constant
h is a universal constant, one of the most important in all of Physics.
h is called *Planck constant*, and its value is $h = 6.62618 \cdot 10^{-34}$ joule **.** second;
$h\nu$ is called *quantum of action* (an action being the product of an energy by a time).
This quantum of electromagnetic energy, this "grain of light"," was later called *a photon*. The energy *E* of a photon of frequency ν is therefore $E = h\nu$.
This is the first equation of Quantum Mechanics.

> **« The energy radiated by a monochromatic light of frequency ν for a certain period of time is always multiple of a quantum of energy $h\nu$. »**

Einstein's Final Explanation of the Duality of Electromagnetic Radiation

Planck's solution, consistent with experimental findings, was purely mathematical: it did not explain the physical reason for quantification. But Einstein proved in 1905 that, for each frequency ν, *it is the electromagnetic radiation itself that consists of discrete "grains" of energy*, each of energy $h\nu$. The granularity of electromagnetic energy was therefore a reality, not a mathematical artifice.

> Very high frequencies do not carry thermal energy, which excludes the paradoxical possibility of infinite radiated energy resulting from Maxwell's equations; these equations were therefore called into question in the case of thermal radiation spectra by the Planck-Einstein theory.

The Photoelectric Effect
The power of a radiation of frequency ν is proportional to the number of photons of energy $E=h\nu$ per second, emitted by a source and absorbed by a target. Einstein's

reasoning was based on the *photoelectric effect*, discovered in 1887 by Hertz: an illuminated metal surface ejects electrons.

> But this ejection occurs only if, for each metal, the light *frequency* is high enough: with too low a frequency, even a high *intensity* light does not eject electrons. Now, since the energy of a photon of frequency ν is $E = h\nu$, and the frequency characterizes *the color* of the light, it was therefore this radiation color that counted, not its intensity: the reality of the granularity of the electromagnetic waves was thus demonstrated.
>
> An electron is ejected from an atom of a given metal only if it receives a sufficient energy impulse, depending on the metal: a single energy quantum $h\nu$ is sufficient if it is large enough, a large amount of energy from photons of too low a frequency will not act.
>
> **« The color of a monochromatic light is our perception of the frequency of its electromagnetic wave. »**
>
> Thus, in 1905, after demonstrating the atomistic hypothesis of the granularity of matter by explaining Brownian motion, Einstein demonstrated the granularity of electromagnetic waves.

The explanation of the photoelectric effect earned Einstein a Nobel Prize in physics.

> *Einstein's Nobel Prize*
> Einstein did not receive a Nobel Prize in 1921 for the discovery of Relativity ("Special Relativity" in 1905, and "General Relativity" in 1915). Special Relativity was deemed too simple to be worth the prize, and General Relativity did not find a physicist in Sweden capable of understanding it during the First World War.

Duality of Electromagnetic Radiation

The explanation of the photoelectric effect had a fundamental consequence: depending on experiment, electromagnetic radiation must be considered sometimes as a *continuous* phenomenon governed by Maxwell's equations, and sometimes as a *discontinuous* (quantified) phenomenon described by Planck and Einstein: it has a *dual* behavior.

> **« Electromagnetic radiation has two possible behaviors: depending on experiment, it sometimes appears continuous as waves, sometimes quantified as particles. »**
> (At macroscopic scale the laws of evolution are continuous, but at atomic scale some laws are discrete, as we saw above.)

The extreme smallness of the constant h, and therefore also of a quantum $h\nu$ regardless of frequency ν if it is not too high, explains our perception of a continuous variation of a quantity of light energy. At our scale, atoms are also too small for matter to appear discontinuous.

Laws of Nature Justifying the Existence of Quantum Physics

The previous paragraph shows that electromagnetic energy is quantified, and that at atomic scale there are phenomena, such as the photoelectric effect, which have no equivalent at macroscopic scale. It is therefore important to go deeper into the physics of the atomic scale and of the scope of the quantification phenomenon.

The 20th century was for physicists a revolutionary era, on astronomical scale with Relativity, as well as on atomic scale with Quantum Mechanics. The latter highlighted the following 8 rules.

1. At macroscopic scale the laws of evolution are continuous, but at atomic scale some laws are discrete, as we saw above

Some physical laws are discrete (i.e. discontinuous), like the law of quantification of electromagnetic energy. In such a law, one or more variables can only have values multiple of a quantum, unlike for example a duration, whose value can vary by an arbitrarily small quantity.

« In Quantum Physics some evolution laws are discrete. »

2. Schrödinger's Fundamental Equation of System Evolutions, and its Solutions

Quantum Mechanics, the essential mathematical tool of Quantum Physics, has a fundamental equation for system evolution, the Schrödinger equation. At atomic scale, any evolution in time and space is governed by this differential equation, which can have several solutions, or even an infinity.

« In Quantum Physics the laws of evolution have several solutions, even an infinity. »

Definition: State Vector of a Quantum Physics Object

The state vector of an object at atomic scale includes all its descriptive variables that may change over time *t*. It is therefore a vector function of *t*. Since the values of these variables can be quantic, the object will be termed *quantum object*.

Evolution Over Time and Space of the State Vector of a Quantum Object

The Schrödinger equation describes the evolution over time and space of the state vector of a quantum object as a function of the total energy of the system. It can have several solutions, or even an infinity, whose interpretation is probabilistic. See [0]

Linear Combination

A linear combination of two variables of the same type X and Y (e.g. both real numbers) is a function F of these variables calculated by multiplying each by a coefficient and summing. With scalar coefficients (real or complex numbers) a and b, a linear combination is of the form $F = aX + bY$.

We can extend this definition to a set of n variables $X_1, X_2... X_n$ and n coefficients $a_1, a_2... a_n$ by defining $F = a_1X_1 + a_2X_2 +...+a_nX_n$.

We can extend this definition further by replacing the *variables* X by vectors $\boldsymbol{V}$ with p dimensions of components $V_1, V_2 ... V_p$, all defined on the same set (e.g. the field of real numbers or the field of complex numbers), and where each component V_j is a function, for example a function of time $V_j(t)$.

By definition, a vector $\boldsymbol{V}$ is said to be a linear combination of k vectors $\boldsymbol{V_1}, \boldsymbol{V_2}... \boldsymbol{V_k}$ if there exist k numbers $a_1, a_2... a_k$ such that

$$\boldsymbol{V} = \sum_{j=1}^{j=k} a_j \boldsymbol{V}_j$$

Finally, consider an *infinite* sequence of functions of several variables such as $F_1(x; y; z)$, $F_2(x; y; z)$, $F_3(x; y; z)$... We can define a linear combination F of the same variables, which is an infinite linear combination of the functions F_1, F_2, F_3... via coefficients a_1, a_2, a_3...

$$F(x; y; z) = a_1F_1(x; y; z) + a_2F_2(x; y; z) + a_3F_3(x; y; z)\ldots$$

Properties of the Schrödinger Equation

Since any linear combination of solutions of the Schrödinger equation is also a solution, some physical evolutions produce several results at once, or even an infinity. All those solutions exist at the same time in the particular state of mass-energy that we have called above states superposition. Such a superposition is *coherent*, in the sense that its various coexisting states share the evolution's initial energy. Therefore:

- The ammonia molecule NH_3 can be synthesized with two states at once, one where the nitrogen atom N is above the plane of the 3 hydrogen atoms H, and the other state where it is below.

  « In Quantum Physics, a system transformation can produce an infinity of coherent states that coexist and share the same energy. »

- A moving particle can travel an infinite number of trajectories at once, each associated with a certain probability density. Thus, an electron or a photon can pass through two slits at once, producing interference.

  « A particle that moves between two points can travel an infinite number of trajectories at once, leaving and arriving at the same time. »

  At a given moment, a particle can be at an infinite number of positions at once, again with their probability densities, and have an infinity of speeds... The notions of exact position (point), trajectory (line) and velocity (vector with a certain magnitude) are replaced in Quantum Mechanics by neighborhoods with blurred progressive contours.

  « At a given moment, a particle can be at an infinite number of positions at once, with their probability densities. »
  Thus, a free electron moving near a material object can have a non-zero probability of presence inside that object, below its surface. This property is used in field effect transistors.

  « At a given moment, a moving particle can have an infinite number of velocities at once, with their probability densities. »

  « In Quantum Mechanics, the notions of exact position, trajectory and velocity are replaced by neighborhoods with blurred progressive contours. »

  In practice, the statistical distributions of positions and velocities are quite narrow, with almost all possible values being very close to their average values.

- The Schrödinger equation describes a *unitary* evolution in space and time, that is, with a total probability of presence constant and equal to 1.

  « In Quantum Mechanics, an evolution conserves mass-energy. »
  (A system evolution can neither increase total mass-energy, nor decrease it. This is the same rule as the rule attributed to Lavoisier: "Nothing is lost, nothing is created, everything is transformed".)

This conservation of mass-energy applies, in Quantum Mechanics as in macroscopic physics, to any closed system that subject to a transformation.

- During an evolution, *its result (single or multiple) does not exist*: it is the end of evolution (the decoherence), for example during a measurement, which generates this result.

  This is how Schrödinger's cat is not both dead and alive until you open your box. It dies when it receives the poison (and if it receives it), but we can only know what happened to it by opening the box.

  « In Quantum Mechanics, the result of an evolution (variable values) does not exist *during* evolution, but only *afterwards*. »
  (During evolution these values are not defined.)

At macroscopic scale, the fundamental equation of mechanical evolution is that of Newton's second law, describing the displacement of a body of mass *M* in space and time under the influence of a mechanical force *F*. At atomic scale, this law is replaced for particles with mass (i.e. other than photons) by the Schrödinger equation, where the force is that of an electromagnetic field acting on an electrically charged particle.

> **« At atomic scale, gravitational attraction is negligible compared to electrical attraction or repulsion. »**

3. The Interpretation of Evolution Results is Necessarily Probabilistic

The evolutionary results of the Schrödinger equation constitute a set. The elements of this set have predetermined probabilities (or probability densities) to appear if we renew the experiment that measures them a large number of times. That is why we had to introduce a particular determinism to govern them, Statistical Determinism.

> **« In Quantum Mechanics, the states resulting from an evolution form a predetermined set of coherent superimposed states. »**
> (Each state has a certain probability of appearing when decoherence occurs.)

4. Completeness of the Schrödinger Equation – Wave function

The Schrödinger equation is fundamental: it describes all possible evolutions in time and space of a system whose spin is not taken into account (the spin is a property of particles of "rotation about its own axis", that exists only at atomic scale). Such a description is that of the wave function calculated by the equation, a function that is *complete*: it describes mathematically everything that can be known about the state of the system (the values of all of its variables), the system being too small to be seen on a macroscopic scale.

> **« In Quantum Physics one can see and understand everything only with mathematical formulas. »**

5. Retention of State Information From an Evolving Conservative System

The Schrödinger equation that describes evolution is deterministic and symmetrical with respect to time, that is, invariable if we change the direction of time from *t* to *–t*. From a known state of evolution of a system, we can therefore in thought trace the course of time back to the origin of this evolution: *nature "remembers" its evolution*. The state of the system being completely described by the wave function calculated by the equation, we can (in theory) find any past value of this function, including all of the initial descriptive information of the system:

« The evolution of a conservative system retains its descriptive information. »

6. Correspondence Between Macroscopic and Atomic Scales

Since the Schrödinger equation is fundamental, any evolution of the macroscopic scale (necessarily governed by laws of Newton's group and/or by equations of Maxwell's group) may be interpreted as evolutions at atomic scale governed by the Schrödinger equation.

- The time symmetry properties of the Schrödinger equation also exist at macroscopic scale.
- There are methods of converting evolution equations of the macroscopic scale into equations of the atomic scale. We can therefore study the evolution of a system of the atomic scale as if it were at macroscopic scale by converting its evolution equations.

« Nature ignores the notion of scale. One can deduce the evolution equations of a system at atomic scale from the equations at macroscopic scale. There is no inconsistency between the laws of evolution of different scales. »

7. Entanglement and Non-Separability of Space

Two or more evolution solutions of a system, generated at the same time and sharing the same energy, can be *entangled*. Entanglement is another original state of mass-energy where the system can extend in space to infinity during its evolution, while behaving, causally, as if it were concentrated at a point in space. Any action on one part of a system (e.g. a photon of a set of entangled photons) acts *at the same time* on all the other parts, even if they are miles away [96]. In this case, the speed of propagation is not limited to that of light because there is no energy propagation, the entire system undergoes the action at the same time. The space occupied by the system is then termed *non-separable*.

« At atomic scale, several particles created together and sharing the same energy, can evolve together described by the same wave function: they are *entangled*. An action on one of them reverberates on the others in zero time, regardless of distances. »

Thought Experiment ([272] page 126)

Consider a box full of light whose interior is made of mirrors such that a photon cannot escape from it. This box is placed on the plate of a hypersensitive weighing machine capable of measuring the energy (therefore the equivalent mass, because $E = mc^2$) of a photon. At some moment, a small hole opens and a photon – only one – comes out of the box.

Question: Does the weighing machine signal the exit of the photon, the box being now lighter?

Answer: No, not until the photon has been absorbed. As long as it exists and moves at the speed of light its state is correlated with the weighing machine, whose weight therefore does not change. But as soon as it is absorbed by something, after traveling out of the box 1 cm, 1 m or 100 km, the box has lost its energy and the scale signals it.

This answer is not surprising. If we consider the closed system of the initial box, whether a photon remains in it or comes out does not change its mass-energy. The principle of energy conservation of this system therefore imposes that its mass-energy remains constant even if the photon exits the box. However, when the photon is absorbed by an object external to the box system, this system obviously loses a mass equivalent to the photon's energy.

This loss is not instantaneous, it occurs when the information of the absorption event reaches the box, at the speed of light. This is a difference between a closed system with assembled elements and an entangled system with elements sharing the same energy: in the latter, the destruction of one of the entangled elements is passed on to all the others instantly.

8. Uncertainty and Indeterminacy Constraints - Quantum Fluctuations

According to the Heisenberg uncertainty principle, it is impossible to measure simultaneously (in the same experiment) both values of certain pairs of quantities of a system: {position and velocity according to a given direction}, {angular orientation and momentum} or {energy and duration}.

The incompatibility of the simultaneous determination of an energy and a duration can be interpreted as *an instability* or *an indeterminacy of the energy*: two identical measurements of energy separated by too short a time interval are not necessarily reproducible. At atomic scale, any point in space, within an atom just like between two galaxies, has an unstable potential energy density, subject to quantum fluctuations all the more important when measured for a short time.

> **« At every point in space there is a potential energy density. »**
>
> **« The potential energy density at a point is not determined: it is unstable, its possible variations are limited by Heisenberg's uncertainty principle. »**

Heisenberg Uncertainty Principle: Complements

One of the most important laws of Quantum Mechanics is *the Heisenberg uncertainty principle*, a theorem that limits the possible accuracy of a simultaneous measurement of the variables of certain couples called "conjugates".

Simultaneous Measurement of Position and Momentum Along an Axis

Thus, Δx and Δp respectively being the uncertainties along the x-axis on the position of a moving particle, and on its momentum (product $p=mv$ of its mass m by its velocity v), the uncertainty principle imposes that the product $\Delta x \,.\, \Delta p$ is at least of the order of magnitude of $\frac{1}{2}\hbar$, where:

- h is the Planck constant $h = 6.6261 \,.\, 10^{-34}$ joule . second (one of the fundamental constants of the Universe);
- $\hbar = \frac{h}{2\pi} = 1.054589 \,.\, 10^{-34}$ joule . second ($\hbar$ is pronounced h-bar).

The formula of this condition is:

$$\Delta x \,.\, \Delta p \geq \frac{1}{2}\hbar, \quad \text{where } \frac{1}{2}\hbar = 0.527 .\, 10^{-34}\ \text{joule.second}$$

Example

An iron atom having a radius of 1.26 angstrom (1Å = 10^{-10} m), suppose that the imprecision on the position of an electron is of the same order, or $\Delta x = 1Å$. Thus, the uncertainty about the momentum of the electron is at least:

$$\frac{\frac{1}{2}\hbar}{\Delta x} = 0.53\ .10^{-24}\ \text{kg.m/s.}$$

Since the rest mass of the electron is 0.9 . 10^{-30}kg, the uncertainty about its speed is 0.6 . 10^{6} m/s, i.e. 600 km/s! On the other hand, if we accept an uncertainty of 1 mm on the position (enormous uncertainty compared to the size of an atom), the uncertainty on the speed drops to 6 cm/s.

The uncertainty on two simultaneous measurements shall be understood axis by axis. Thus, the *component* along the *Oz* axis of the pulse, p_z, can be measured at the same time as the component according to the *Ox* axis of the position, *x*, without the limitation $\Delta x\ .\ \Delta p_z \geq \frac{1}{2}\hbar$.

Consequence of the Heisenberg Uncertainty Principle on Initial Conditions

The doctrine of physical determinism defines the evolution of a system from its initial state, and its applicable law of evolution. And when it is impossible to integrate a differential evolution equation, an approximate solution is calculated step by step from the initial state.

But, according to the Heisenberg uncertainty principle, it is impossible for a given system to know at the same time with precision the two variables of certain couples such as {position + momentum – i.e. position + speed}. So how can one have acceptable initial conditions?

The answer depends on the difference between *knowing by experimental finding* and *arbitrarily defining*: the Heisenberg uncertainty principle cannot prohibit definition, it applies only to physical quantities, especially measurements.

Why Didn't we Already Know the Heisenberg Uncertainty Principle?

The uncertainty principle expresses a form of incompatibility between the precisions of simultaneous determinations of the position along a coordinate axis, and the momentum (pulse) along that axis. The momentum *p=mv* is not the velocity alone, the mass intervenes just as much. If this mass is tiny, as is the case for particles of atomic physics, the limitation ≥ is difficult to satisfy; but if the mass is of the order of a kilogram (~10^{30} times greater than that of an electron) it is satisfied in all experiments of everyday life: this is why the *Heisenberg uncertainty principle* never prevents us from measuring simultaneously (at macroscopic scale) mass and velocity with excellent accuracy.

Simultaneous Measurement of Energy and Duration – Energy Instability

The precision limitation of two simultaneous measurements also exists for another pair of conjugate variables, *the energy ΔE* and *the duration Δt*:

$$\Delta E . \Delta t \geq \frac{1}{2}\hbar$$

This inequality can be interpreted as *an instability or an indeterminacy of energy*: for a particle to remain at a certain level of energy (for this level not to change too much, hence if ΔE is small enough) the particle (or its measurement) must have sufficient time.

This condition was important, at the first moments of the Universe, for certain atomic syntheses to be possible despite the shocks with very high energy photons, which could disassemble the composite particles (e. g. atomic nuclei) created.

Quantum Energy Fluctuations Due to the Heisenberg Uncertainty Principle

> **This paragraph is quite technical: for explanations see [0]**

The energy instability due to the Heisenberg uncertainty principle allows empty space to be the seat of *quantum fluctuations* of energy. Each fluctuation can materialize (spontaneously or in response to an excitation received: particle or radiation), by creating mass-energy as two particles (one particle and one antiparticle of opposite electric charge): it "borrows" an energy *ΔE* from the potential energy of surrounding space for a very short time, of the order of $\frac{\hbar}{\Delta E}$, and then returns it.

> **« Everywhere, the "vacuum" of the Universe contains potential energy whose fluctuations create ephemeral pairs of particles. »**

The energy *ΔE* is that of the emission of a particle-antiparticle pair, or of an integer number of photons (or more generally of bosons or fermions). The pair's electromagnetic field exerts an attractive or repulsive force on any charged object, and communicates to it an energy $h\nu$ for each photon of frequency ν exchanged.

> The reassembly of a pair's particles is rapid and inevitable in a flat space-time, or in a space-time with a very low relativistic curvature. But at the very beginning of the Universe, when the ultra-dense space-time had a strong curvature, and especially during the short and brutal period of inflation, the particles of a pair could be separated too quickly to attract and disappear, they were able to last. This phenomenon continues today when a black hole "evaporates", despite a mass that can be millions of times greater than that of the Sun.

> **« A black hole evaporates spontaneously, and faster and faster as its mass decreases. »**

The presence of such a pair of opposing charges creates a polarization and a relativistic deformation of the vacuum, thus also a field that acts on the electric charge and/or color of a particle.

> The action of a field on a particle *decreases* with the distance of the particle when the field is electromagnetic or gravitational. But a *color* field's action on a quark, *grows* with distance (which is absolutely contrary to intuition and traditional determinism!): to separate the quarks of a pair the energy required increases with the distance between them, and as soon as this energy is large enough to separate the two quarks, it is absorbed by the creation of a new pair of quarks, a new quark appearing to stick to each of the two former separate quarks! This phenomenon therefore prevents quarks from being isolated for more than a tiny fraction of a second. See *Confinement* in [0].

The spontaneous appearance of mass-energy extracted from the surrounding space is of such short duration that one cannot observe the particles produced, hence their qualification as *virtual*. Nevertheless, this phenomenon is indirectly proven by its effects on ordinary particles.

10.4 Philosophical Consequences of Quantum Mechanics

- The phenomenon of quantum fluctuations is therefore not a law of evolution, but a law of interrupt governing the spontaneous birth of a pair of particles with no cause other than the instability/indeterminacy of a space point's energy density.

  « An example of causeless determinism: quantum fluctuations. »

  « Energy instability/indeterminacy may cause state transitions. »

- The appearances of particles in the fraction of a second that followed the Big Bang explains their combinations in matter that have lasted to this day: without them we would not exist.

  It may even be that the Universe was created by a quantum fluctuation [109].

- Vacuum, a space without matter or energy, exists nowhere: neither within an atom, nor in intergalactic space (which contains about 6 protons/m^3).

  A tiny free electron, for example, is constantly surrounded by a cloud of virtual particle-antiparticle pairs, and their electromagnetic field affects its properties in a perceptible way.

  General Relativity demonstrates that interplanetary and intergalactic vacuums are not empty spaces, they are energy-containing media that are deformable. And every point of space is traversed by electromagnetic radiation from stars and particles.

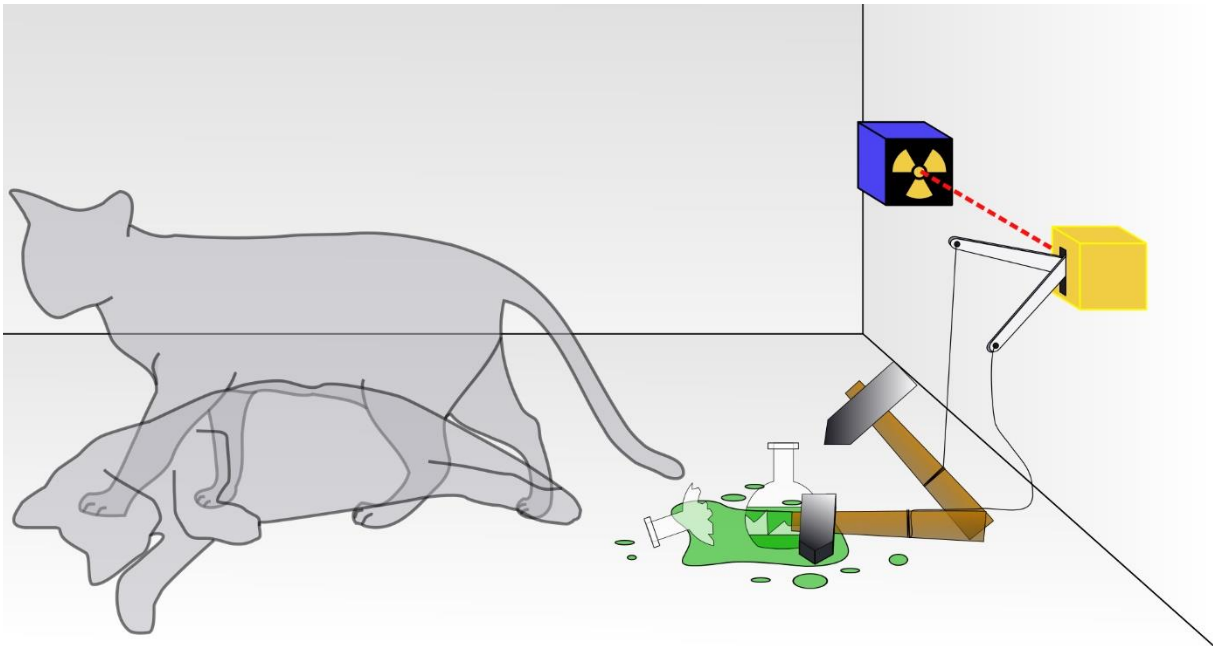
  « Vacuum, space without matter or energy, exists nowhere. »

Schrödinger's Cat

(Source: [97])

Schrödinger's cat experiment was imagined in 1935 by Erwin Schrödinger, in order to highlight supposed shortcomings in Quantum Physics' description of the world.

Schrödinger's idea is to place a cat in a closed box [...]. This box is equipped with a system intended to kill the cat. This system consists of a vial of poison, a small amount of radioactive material and a Geiger counter. When the first decay of a radioactive nucleus occurs, the Geiger counter reacts by triggering a mechanism that breaks the vial and releases the deadly poison. Thus, the decay of a radioactive nucleus, a microscopic process, results in the death of the cat, a macroscopic event.



Schrödinger's cat experiment - © By Dhatfield - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=4279886

The decay of a radioactive nucleus is a purely quantum process, described with a probability of occurrence. It is impossible to predict which nucleus will decay first, or when this decay will occur. The only thing we can calculate is the probability that a number of nuclei have disintegrated after a given time. For example, we can choose a radioactive sample in such a way that after five minutes there is a 50% chance that a nucleus has decayed and a 50% chance that nothing happened.

[Phase 1]
So let's close the box and wait five minutes. Since radioactive decay is expressed in terms of probabilities, the fate of the cat can only be described in similar terms. After five minutes, we can predict that there is a 50% chance that the cat is dead, and a 50% chance that it is alive, but we cannot be certain of its condition.

In the traditional interpretation of Quantum Mechanics, the cat is then neither dead nor alive: it is in a superposition of these two states. It is only when we finally open the box [Phase 2] that one of the two possible states becomes [for us] reality. The cat is then either alive or dead.

The traditional interpretation of Quantum Mechanics therefore poses a problem. It is possible to imagine that a particle is in a superposition of states, each affected by a certain probability. On the other hand, this becomes very difficult when considering a macroscopic object such as the cat. The idea of an animal neither dead nor alive, but in a superposition of these states, is rather difficult to accept.

Comments on This Experiment and its Conclusion

- What is the cat's condition?
  - Phase 1: it is a dynamic state, reflecting evolution: *superposition* of a "dead" state (probability 50%) and a "living" state (probability 50%). But this state cannot be considered a result, because as long as the experiment lasts (the

cat's box remains closed) its result does not exist. At atomic scale a result is always created by a measurement, before it does not exist.

- Phase 2: This is a macroscopic state, EITHER dead OR alive. The opening of the box puts an end to the experiment: its result can be announced.

▪ The idea of a superposition of states "living cat" + "dead cat" shocks our common sense. Quantum mechanics provides for superposition only as a virtual state from which one exits through an interaction (such as a measurement) with the system environment.

▪ But very many experiments of multiple states have been observed since 1935, for example [96]. We must therefore accept the reality, at atomic scale, of a virtual mode of existence of coherent states, the state of matter where the system has retained the values of variables, such as total mass and total electric charge, that it had before the generation of correlated particles.

▪ The lifetime of a superposition of states is usually extremely short for a macroscopic system, too short to be measured. For an atomic scale system it is all the shorter the more its interactions with its macroscopic environment are important, because of its size, thermal agitation, contact with a measuring instrument, etc.

  Example: in the Rigetti quantum computer, the duration of a superposition of states at a superconductivity temperature of 1°K is a maximum of 90 µs (90 microseconds) [98].

Conclusion
The interpretation of the results of Quantum Mechanics is not obvious. It took years after the publication of the Schrödinger equation in 1926 to clarify it.

10.5 Principe of Correspondence Between Macroscopic and Quantum

« There is, between the laws of Quantum Physics and the laws of macroscopic physics deduced from them, a principle of compatibility called the *Correspondence Principle.* »

According to this principle, when the system considered is large enough for quantum effects to be negligible, the predictions of Quantum Physics must be the same as those of macroscopic physics for all variables (called "observables") of Quantum Physics that have a limit equivalent in classical physics.

Observables and eigenvalues
The variables of classical physics (position, speed, energy, etc.) are represented, in Quantum Mechanics, by mathematical noncommutative operators called *observables* that depend on the devices of the experiment, hence their name. As a mathematical being, an observable's value is an eigenvalue, the set of which forms a basis of the space of states. (Definitions of these terms are in [0]).

The continuity of passage between Quantum Physics and macroscopic physics is due to the gradual elimination of probabilistic inaccuracies in Quantum Physics due to the number of particles taken into account, their variations compensating each other better and better.

The correspondence between the physical laws of two different scales must, however, be considered between *successive scales*:

▪ Between macroscopic physics and Quantum Mechanics;

- Between Quantum Mechanics and quantum electrodynamics;
- Between quantum electrodynamics and quantum chromodynamics.

This principle of correspondence is a consequence of:

- The uniformity of nature (see *Stability Rather Than Universality*) ;
- The fact that nature ignores the concept of scale, a human abstraction used to represent phenomena, understand them and foresee them, then predict their evolution.

There are also mathematical rules for going from equations of macroscopic physics to equations with noncommutative operators of Quantum Mechanics, and then from there to Quantum Electrodynamics, etc.

Note on Phenomena Visible Only in Quantum Physics

The existence of the principle of correspondence does not preclude certain phenomena from appearing only in Quantum Physics. This is not surprising: when looking at an object under a microscope, some details appear only beyond a minimum magnification; before that minimum, they exist but are negligible.

10.6 Principle of Complementarity

The above *Principle of Correspondence* is supplemented by the *Principle of Complementarity*, enunciated in 1928 by Niels Bohr. Example: the behavior of phenomena such as light is sometimes corpuscular and sometimes undulatory, depending on experiment. No contradiction here, there is a *wave-particle duality*: the law of evolution that applies depends on the experiment in addition to the nature of its physical object.

Wording of the Principle of Complementarity

> **« One cannot observe corpuscular and wave behavior together, as these two behaviors are mutually exclusive and constitute complementary descriptions of the phenomena to which they apply. »**
> Analogy: there is no experiment to accurately measure simultaneously the components along the same axis of the position and the velocity of a particle (Heisenberg uncertainty principle). But for reasoning and calculations, nothing prevents us from arbitrarily defining both position and speed.

Conclusion

Quantum mechanics is valid even for large and complex systems; but its use as a mathematical tool is only practical for atomic scale systems.

10.7 Metaphysical Interpretation of Copenhagen

At atomic scale one cannot see anything, the size of an atom being of the order of one angstrom (10^{-10} meter). one must therefore visualize the physical structures and behaviors according to the mathematical formulas that describe them. These representations are so strange, so confusing, that it took several years to figure out how to interpret them.

The so-called "Copenhagen Interpretation of Quantum Mechanics" is by Niels Bohr, who was Danish. Bohr and his colleagues thought that:

- Man cannot know reality, he has access only to the representations he makes of it: this is the doctrine of Plato (allegory of the cave) and Kant (transcendental idealism). Therefore he must not reason on reality, but only on the phenomena accessible to him. He must even accept that physical laws yield multiple results, such as those of the Schrödinger equation.

  Thus, the value of a variable of the quantum state *does not exist* between two measures (circumstances where only the inaccessible reality exists); it exists only after a measurement that created it.

  « At atomic scale it is the measurement that creates a variable's value; before it did not exist. »

  We may even go further:

  « Particles exist only when they interact. »

  An atom electron of a given layer can be anywhere on its orbital (i.e. orbit), each position having a probability density; same remark for a free electron in motion: as long as nothing interacts with it, its properties do no exist. We can be certain of the existence of an electron only when it interacts with another particle, thus revealing its position, speed and kinetic momentum with the probabilities of the Schrödinger equation and the uncertainties of the Heisenberg uncertainty principle. Similarly, the existence and characteristics of a photon are only certain when it is captured or emitted.

  « At atomic scale any measurement disturbs the measured quantities; it is irreversible and must be taken into account when designing the experiments. »

  The human description of the phenomena and laws of the atomic scale is therefore the only one we have, because its mathematics are our only way of "seeing" them.

- Quantum Mechanics has 6 postulates, and they are only an axiomatic whose results are consistent with the measurements. They allow predictive calculations of the probabilistic values of the variables.

  The wave function of a conservative system contains all the information available about it until the evolution is interrupted by a decoherence. Since this wave function is unitary, the amount of information is conserved during the evolution.

- Niels Bohr's advice: don't waste your time speculating on the philosophical significance of Quantum Physics, stick to the tools of Quantum Mechanics and trust their results.

This doctrine is now "official", in the sense that it is the most popular. It rejects the metaphysical interpretation of the postulates of Quantum Mechanics, considered a simple tool to be applied without asking ontological questions.

10.8 Special Relativity

The Theory of Relativity changed the very foundations of physics, redefining the notions and properties of space, time, matter, energy, gravitation and even causality, which became relative to the observer. It is simpler to name the only two parts of physics that escape Relativity (Thermodynamics and Statistical Physics) than those that it impacts!

Quantum mechanics and Relativity are the two bases of modern physics. The first governs the infinitely small and constitutes the foundation of Newton's and Maxwell's macroscopic physics, which are deduced from it; the second governs the extension of macroscopic physics to the infinitely large astronomical scale.

But from the standpoint of determinism, the object of this text, the Relativity Theory of 1915 is governed by Special Determinism, like Newton's physics of 1687 [9]. That is why we only address it in the appendix of this book, merely quoting some remarkable principles and laws that illustrate that determinism.

Concept of Relativity

A train runs at a uniform speed. A passenger at the window of a car of this train drops a stone on the embankment. Neglecting atmospheric friction, relative to the passenger the stone falls straight, and relative to the embankment it covers a parabola. Its trajectory is therefore relative to the system of axes (called *reference system*) in relation to which it is considered. Hence the name Relativity. Hence a first principle of Relativity:

> **« There is no absolute trajectory, a trajectory can only be defined with respect to a reference system. »**

Example of Application
Newton's law of inertia states:
« A body, motionless or moving in a straight line and without rotation on itself, will remain motionless or keep the same velocity vector as long as, from the outside, no force and no torque act on it ».

Consider a reference system, supposedly fixed because defined relative to distant stars. In this reference system, the law of inertia can be applied for a motion with respect to these fixed stars.

But in a reference system related to Earth, these fixed stars describe large circles in an astronomical day: the law of inertia cannot apply to them, because their circular motion implies a centrifugal force. Therefore:

> **« The expression of certain physical laws depends on the reference system. »**

Galilean Reference System
For the law of inertia to apply, it is therefore necessary to choose a reference system with respect to which the directions of fixed stars do not rotate. Such a reference system will be called *Galilean*, named after Galileo, one of the founders of Dynamics (a part of Mechanics that studies the relations between forces and the movements they produce).

Principle of Special Relativity

The law of Special Relativity is a deterministic law of physics that Einstein called the *Principle of Special Relativity*:

> **« The phenomena of nature are governed by the same laws in all Galilean reference systems. »**

A particular law is fundamental in physics:

« In all Galilean reference systems light propagates in a vacuum at the same speed, *c*. »
(*c* = 299,792,458 meters per second exactly in a vacuum, it is a constant of the Universe (about 300,000 km/s).

Example of application: if an observer moving parallel to a light ray measures the speed of this ray, he will find the same value *c* = 299,792,458 m/s regardless of his own speed, even if this speed is 99% of the speed of light, and regardless of the direction of his displacement relative to light and of the light's color (frequency). No relative velocity is ever added to, or subtracted from the speed of light.

« The speed of light is a constant of the Universe. »

<u>Theory of Special Relativity</u>

The theory of Special Relativity describes how to design and calculate the displacements that, relative to an observer, take place in a straight line at a constant speed *V* parallel to the x-axis of a reference system. The calculation formulas are:

$$x' = \frac{x-Vt}{\sqrt{1-\frac{V^2}{c^2}}}; \quad y'=y; \quad z'=z; \quad t' = \frac{t-\frac{V}{c^2}x}{\sqrt{1-\frac{V^2}{c^2}}}$$

These formulas describe the passage from an *event* at position (*x; y; z*) at time *t* in the fixed reference system, to that same event at position (*x'; y'; z'*) at time *t'.*
We can see that:

« The spatial coordinates (*x; y; z*) and (*x'; y'; z'*) depend on time, and time depends on the position considered. »
(This is why we speak of 4-dimensional space-time.)

When the absolute value of the velocity *V* is very small with respect to *c* (which we note $V \ll c$), as is the case in our usual speeds, the formulas are those of our *usual principle of Additivity of Speeds*:

$$x' = x - Vt; \quad t' = t$$

<u>Effects of Relativity on Velocities, Lengths, Durations, Masses, etc.</u>

1 - « A relative velocity is always less than c. »

2 - « Lengths contract »
A length L_F in the fixed reference system becomes, in the reference system moving at speed *V*:

$$L_M = L_F \sqrt{1 - V^2/c^2}$$

The contraction affects only the lengths (the dimension parallel to the displacement), the width and height perpendicular to this displacement being unchanged. A fixed observer sees a rotating circle with a reduced circumference, although its radius is unchanged.

3 - « Time expands with a constant multiplier coefficient »
A duration τ in the fixed reference system becomes, in the reference system moving at speed *V*:

$$\tau' = \frac{\tau}{\sqrt{1-V^2/c^2}}$$

(one hour in the fixed reference system lasts longer in the mobile system: $\tau' > \tau$).

« An observer finds that a clock that moves relative to him runs slower. »

This is why a moving particle has a longer average lifespan than at rest.
See also *The Traveler Paradox* .

This is also why GPS satellites have high-precision clocks that lag behind equivalent terrestrial clocks: in GPS receivers it is therefore necessary to calculate a relativistic correction.

The orbit of satellites is not a straight line, but the formula for time expansion still applies, because it does not require that the reference system of motion be Galilean.

« A common time in different locations does not exist. »

« The Universe has neither a common time, nor a common date. »
We cannot know what is happening *now* on the Sun, because the light takes ~500 s (8min. 20s) to reach us; we see what happened 8min. 20s ago.

4 - « Mass-energy equivalence »

« A mass at rest *m* is equivalent to an energy E: *E* = *mc*²**. »**
Energy and mass are two forms of the same physical object, *mass-energy.*

In the Universe, mass-energy density originates:

- 5% in *masses of bodies* (stars, gases, dust, etc.);
- 27% in *dark matter*, transparent and not emitting light, that acts on ordinary matter only by gravitational attraction;
- 68% in *vacuum energy* ("dark" energy), of unknown physical nature but due to space itself. Its effect is a negative pressure, which accelerates the expansion of space.

The equation $E=mc^2$ governs the conversions of:

- Mass into energy (examples: heat emitted by the Sun to the detriment of its mass, nuclear energy converted into electricity);
- Or energy into mass (example: decay of a high-energy gamma photon into a pair of electron + positron particles).

5 - « Mass-energy increases with speed »

« A mass at rest *m* has a relativistic value m_R at velocity V: $m_R = \frac{m}{\sqrt{1-V^2/c^2}}$ »

The mass therefore increases with relative velocity, and tends towards infinity when *V* tends to *c*. That's why:

« The speed of a heavy object is always less than *c*. »
(Infinite energy would be necessary for it to reach the speed of light.)

« The consequences of an astronomical event propagate in space at the speed of light. »

> Example: the fusion of two stars into a black hole (with a colossal release of electromagnetic energy, and an emission of gravitational waves), can become visible to the Earth tens of thousands of years after its occurrence.

6 - « Each reference system has its own time »

Consider a train that travels at a constant speed, and suppose that a fixed observer *on the embankment* sees two flashes (simultaneous events) at two points *A* and *B* of the track located at equal distances on either side of him.

If an observer *on the train* also sees them, at a moment when the train is halfway between *A* and *B*, and the train is moving in the direction from *A* to *B*, he sees *A* moving away and *B* moving closer; he therefore perceives the flash of *B* before the flash of *A*.

Simultaneous events relative to the track are therefore not simultaneous relative to a moving train: a reference system linked to the track and a reference system linked to the train each have their own time:

> **« An hour or a duration only make sense relative to a specific reference system. »**
> This law is fundamentally different from the law of the Newtonian Universe of Special Determinism, where time and duration are the same everywhere.

7 - Simultaneity does not exist physically:

- Neither on the scale of the Universe, where there is no universal, absolute time;

  « The notion of absolute order of two events makes no sense. »

- Nor, in a given reference system, between two different places, because they are separated in the causal sense by the time that light takes to go from one to the other.

Our erroneous impression of absolute time and space (fundamental postulates of Newtonian physics and Kant's philosophy) comes from assumptions of velocities that are all negligible in relation to the speed of light *c*, and of a Euclidean space (flat, i.e. without deformation).

10.9 General Relativity

Einstein's Two Theories of Relativity

Einstein published his theories of Relativity in two stages:

- 1905 - Special Relativity, at the age 26 ;
- 1915 - General Relativity.

Special Relativity assumed a relative displacement with respect to an observer with a constant velocity vector, thus without acceleration. General Relativity lifts this restriction by taking into account accelerations, especially that due to gravitation.

Time Flow, Relativity and Determinism

The notion of determinism governing evolutions is based on the passage of time, without which it cannot be conceived. But Special Relativity shows that for two observers in motion relative to each other time flows at different speeds, and the notion of simultaneity no longer has the usual meaning.

Even more serious, there are situations where, for an observer located at point *M*, event *A* precedes event *B*, while for an observer located at another point, *P*, it is event *B* that precedes event *A*. When the observer in *M* becomes aware of event *A he will not yet know that B will happen*, while when the observer in *P* knows that *B* has happened *he will not yet know that A will happen.*

Under these conditions, what happens to causality and determinism? Could we not consider that the time dimension plays the same role as the three dimensions of space, so that both events *A* and *B* were certain in advance for an observer *outside* this 4-dimensional space?

This is what Einstein believed, therefore admitting Philosophical Determinism, which claims that the totality of the past and the future form a single causal chain, *and that there is no objective flow of time, there are only flows relative to reference systems*.

> Note: Kant and Newton believed in a single, universal time. They could not accept the idea of looking from outside space-time, a power reserved for God and a purely speculative idea.

In addition, the proven irreversibility of certain phenomena, such as the growth of entropy, implies that time passes.

General Relativity shows that when a movement between two points *A* and *B* crosses a gravitational field, the speed of time flow changes with respect to a movement between the same points not crossing such a field, because its trajectory is different. The curvature of space changes due to the field, the light propagates there according to a different trajectory, and the unit of length at a point changes with the gravitational field at that point. Countless experiments have shown that General Relativity perfectly describes the Universe by stating that:

> **« The Universe is not an empty and homogeneous space. It is a medium distorted by the gravitational field of stars, interstellar dust and galaxies. »**
> (It is this space deformation that prevents light propagation from being in a straight line in the vicinity of a heavy celestial body, and makes time flow slower.)

John Archibald Wheeler summarizes the influence of mass-energy on gravitational fields, and of these on free-falling movements of bodies:

> **« Matter tells space-time how to bend,**
> **space-time tells matter how to move. »**

Einstein's Equation

This reciprocal influence is described by Einstein's equation, whose apparent simplicity conceals a system of differential equations linking curvature and mass-energy:

$$G^{\mu\nu} = \frac{8\pi G}{c^4} T^{\mu\nu}$$

where:

- $G^{\mu\nu}$ is a tensor (array of 4 rows x 4 columns) describing the curvature of spacetime at a point;
- G is the universal gravitational constant, $G = 6.67 \cdot 10^{-11}$ Nm^2/kg^2 ;
- c is the speed of light ;

- $T^{\mu\nu}$ is a tensor describing the density and flow of matter-energy at that point.

The Traveler Paradox
Consider two twins, Peter and Paul. Peter remains on Earth while Paul leaves (and travels at a speed lower than the speed of light, of course). Paul travels a trajectory that eventually brings him back to the starting point on Earth, where Peter waits for him. The twins notice that Paul, the traveler, has aged less than Peter: time passed more slowly for Paul than for Peter.

10.10 Quantum Electrodynamics - Virtual Particles

Quantum Mechanics is non-relativistic, in the sense that it assumes that gravitation has no effect on masses, that particles cannot be created or destroyed, and that their velocities remain low enough for space and time not to be relativistic. To overcome these hypotheses, *Quantum Electrodynamics was created*.

Quantum electrodynamics synthesizes Quantum Mechanics, Special Relativity and Maxwell's equations of classical electrodynamics. This theory mathematically describes the interactions of electrically charged particles (electron, proton, quark...) with an electromagnetic field and with other charged particles.

Quantum electrodynamics provides one of the most accurate verifications of the mathematical postulates and methods of Quantum Mechanics. It has been verified with extraordinary precision in many experiments, for example by providing the value of the magnetic moment of an electron with a relative accuracy of 10^{-8}. This is the precision of a measurement of the distance from Paris to New York accurate to a few centimeters!

Not only is this precision an interesting feature of General Determinism in Quantum Physics, but Quantum Electrodynamics also sheds light on other aspects of Quantum Physics. Thus, for example, the interaction between two charged particles exchanges "virtual photons", each representing a quantum of energy. These photons are *virtual* because there is no way to capture them to see them. They act as quantified forces that transmit their energy between two interacting moving particles, whose velocity vector changes direction and magnitude when they emit or absorb such a photon. Thus, a force can act between two particles, for example during a shock, by transmitting one or several quanta of energy, and *this action is perfectly deterministic in the context of General Determinism, that takes into account quantified discontinuities*.

Antiparticles
Another addition to Quantum Mechanics, Quantum Electrodynamics introduces, for each particle, an *antiparticle* of same mass and spin, but with opposite electric charge, magnetic moment and flavor: the positron thus corresponds to the electron, the antiproton to the proton, etc. A particle that encounters its antiparticle can annihilate itself with it by releasing an energy equal to the disappeared mass, in accordance with Special Relativity ($E = mc^2$). Conversely, a photon of electromagnetic energy can sometimes turn into matter, for example into an electron-positron pair. Finally, an electron and a positron can associate into an atom called *positronium*, where the positron is the "nucleus" around which the electron rotates.

Unfortunately, Quantum Electrodynamics is an unfinished science. There are cases where it predicts infinite, physically unacceptable values. This problem has been solved in special cases by a method called *renormalization*, which involves taking into account the interaction of a charged particle with its own electromagnetic field, and using certain mathematical tricks. The underlying problem is that, despite the successes and accuracy of the completed part of this science, there are still unexplained phenomena that theorists are working on, including a quantum theory of gravity.

10.11 Levels of Biological Information and Genetic Determinism

Nowadays, certain vital mechanisms, for example in humans, are explained by a model that has proved fruitful: the information processes associated with them. This model is that of DNA, described below.

At the highest level and as a first approximation, our rational mind functions like a program in the computer that is our brain: rational thinking is processing information.

« Any rational mental process can be described as information processing. »

This is a rough description, quite deterministic, also evoked in *Algorithmic Psychic Mechanisms*.

Note: the functioning of the mind-program in the brain is quite robust: within certain limits, neurons can die or lose connections without the program and its results being affected.

Genetic Software Information

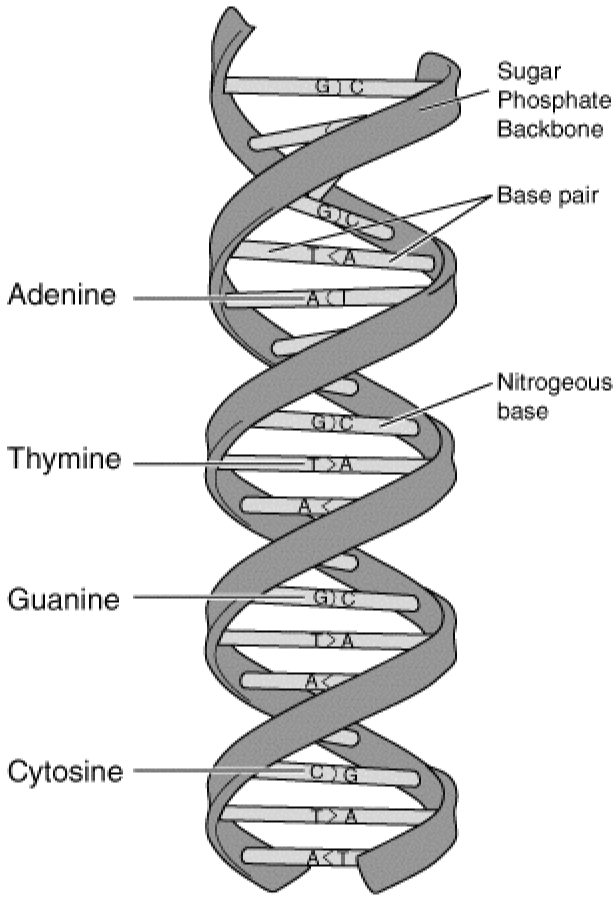
The processing of DNA (deoxyribonucleic acid) genetic information takes into account *complementary* molecular structures: a given molecule can only interact with a molecule whose structure is complementary to it, that is, which can form chemical bonds with it. The structure of a molecule therefore defines with which other molecules it can interact: *the structure defines the function, which defines the actions* in which a molecule can appear. A hierarchy of structures and functions thus appears, from top to bottom:

- Each cell contains a nucleus (diameter of the order of 6 μm, or $6 \cdot 10^{-6}$ m) in which there are *chromosomes* (23 pairs in humans), whose structure carries the information controlling biological functions. A human chromosome is about 8 m long with a diameter of 0.5 μm.

  In the tiny volume of each cell's nucleus, the ultra-compact structure of the DNA molecule stores all the information describing the construction and functioning of the individual's body, including his brain. This information is identical in all its cells, although there are many kinds of cells: skin, muscles, blood, etc.
- A chromosome contains about half of its weight of DNA. The giant DNA molecule has a double helix shape comprising about 3 billion base pairs in humans. Each helix is an exact copy of the other, a redundancy that makes it possible to repair potential "errors" occurring during cell reproduction.
- The DNA molecule contains sequences of bases (segments) called *genes*, smaller molecules whose structure (the order in which the bases appear in a sequence path) represents the information that defines:
  - All body structures, for example those of the brain or the eye ;

- All biological functions, just as the instructions of a program and their order define the program's logic. The DNA processing mechanisms interpret this logic to produce the proteins (of about 100,000 different kinds) that command biological functions.

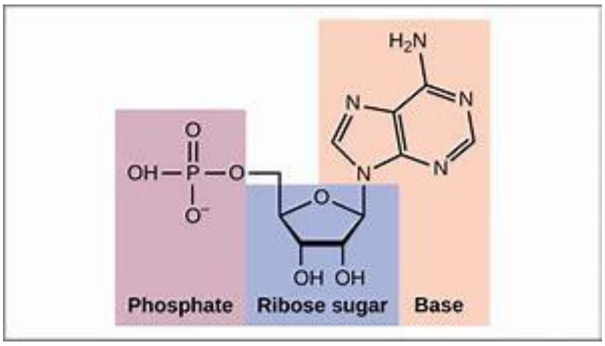
The language in which genetic information is encoded is extremely simple: its vocabulary has only 4 basic "words", with which the instructions of the gene sequences are written. These words are built from 4 nitrogenous bases called adenine ($C_5N_5H_5$), cytosine ($C_4N_3H_5O$), guanine ($C_5N_5H_5O$) and thymine ($C_5N_2H_6O_2$), represented by the letters *A, C, G, T*.



The structure of DNA
Source: [http://www.genome.gov/Pages/Hyperion//DIR/VIP/Glossary/Illustration/base_pair.shtml]
[http://www.genome.gov/Pages/Hyperion//DIR/VIP/Glossary/Illustration/Images/dna.gif (file)] *'''License:'''

Each strand of the double helix of DNA is a chain of elementary units called nucleotides. A nucleotide consists of a sugar, a phosphate group and one of the nitrogenous bases *A, C, G* or *T*.

The two strands of DNA are connected by hydrogen bonds between a base of one of the strands and a complementary base of the other. A base *A* is always associated with a base *T*, and a base *C* is always associated with a base *G*.



Nucleotide (License © Microsoft Bing)

A sequence of genetic code may, for example, contain the *word string ATTCGCA*, and a string may be extremely long, long enough to describe logic of arbitrary length.

- Genes build proteins using RNA (ribonucleic acid) according to the programs encoded in their structure; they can be thought of as tiny computers that drive the formation of proteins by cellular machinery.
- Proteins are the constituents of muscles, lungs, heart, bones, etc. All of the mechanisms of our body involve proteins.

The modeling of non-psychic vital mechanisms by program code information processing is so satisfactory that these mechanisms appear as deterministic as computer software. The complexity of vital processes and software can be considerable without impacting their perfect determinism, which is independent.

In the cellular machinery, genetic information is transmitted in a single direction, from DNA sequences to proteins. This process is perfectly deterministic in the way it deduces events from their causes.

Sequences of genetic code should not be interpreted as sequences of sentences containing only instructions. Indeed, in computer program execution there is no clear distinction between *instructions* (performing an operation) and *data* (numbers, strings, images, etc.); instructions manipulate data. A computer can interpret data in an ad hoc program called an "interpreter"; then, if the interpreted data changes, the logic of the program they constitute changes, and so does the end result.

Example interpreter: MAPLE, a scientific computing application [145].

There are also *program-generating* applications, that interpret data provided by a man to write a program in a high-level language for him. This language will then be *translated* by a compiler program into a language executable by the computer's processor, or *interpreted* by a specific interpreter program. This approach simplifies as much as possible what a man must express to obtain a program suitable for particular needs, by adapting this expression to the application (statistical analysis of data, for example).

The same applies to DNA, *which can also be considered data interpreted by the cellular machinery*. This is why, for example, we can take a gene (and therefore its code) from a living species and introduce it into the DNA of another species to improve its resistance to a disease, which produces a genetically modified organism (GMO).

DNA and the cellular machinery form a combination of hardware + software capable of adaptation and self-organization - both structural and functional - because it sometimes functions as an interpreter, sometimes as a program generator.

Complements: *Evolution Due to a Change in Gene Expression* and *DNA and RNA*.

Conclusion

There is, in living beings, a *genetic determinism* that controls all vital functions. The genetic code, received at birth and interpreted to generate the proteins of vital functions, also contains the structuring information of the brain, whose consciousness will interpret the state of its neurons in all psychic functions. The genetic code contains all the information of the human character: it is a program written with the 4 letters *A, C, G* and *T*; all of the human heritage transmitted between generations can therefore be written in the form of a program, its complexity being coded in 3 billion base pairs.

> **« In living beings all vital functions are controlled by *genetic determinism* »**

The rest of the human character, including his need for social life and the corresponding abilities, comes from what each man learns from birth, which is transmitted between generations by culture and generates *cultural determinism*.

> **« Above the level of genetic determinism there is a cultural determinism acquired since birth. »**

10.12 Principle of Determinability of a Concept

This principle states that a concept can always be defined completely, and sometimes also in a way that distinguishes it from others.

Definitions

Concept

A concept is an abstraction that represents a collection of objects with common properties. Concepts are essential to logical reasoning.

Example: concept of "dog", representing all dogs by common properties: quadruped, mammal descendant of wolf, etc. It is *nameable*: it was given the name "dog". The human mind can only reason on nameable ideas, whatever is not nameable being a feeling.

- The concept is the most elementary form of thought, to be distinguished from more elaborate forms such as judgment.
- It is a general idea, a class, a whole, as opposed to a representation, which is a personal mental image. Example: concept of "mother".
- A concept is the product of a conscious reducing process of intelligence comprising comparison, reflection and abstraction; it is the opposite of intuition and should not be confused with essence.

Remark

The mind understands a concept, basic or not, innately, but represents it as one of its particular concrete cases in space and time: I can only imagine a straight line as the image at that moment of a drawn straight line; I represent an integer only as a property of multiplicity of a set (called its *cardinal*) or of a rank (called *ordinal*) in an ordered sequence of elements.

The notion of concept can be understood two ways:

- *From its meaning*, with the list of all necessary conditions (i.e. the rules of understanding) that a nameable object must satisfy to be part of the general class defined by the concept.
- *From its extension*, with the list of all objects having all of the above properties (but also perhaps others, deliberately ignored).

See also Basic concept.

Predicate
A predicate is a quality, a property in so far as it is affirmed or denied of a subject. Synonym: *attribute*.

Principle of Non-Contradiction (also called Principle of Contradiction)
Definition: A contradiction is an opposition between two incompatible facts or assertions, or the logical result of such opposition.

The Principle of Contradiction postulates that a thing cannot both be and not be from the same standpoint, that a proposition cannot be both true and false.
The principle is worded: *the opposite of true is false*.
Symbolic Logic notation: $p \,.\, \neg p$ = false ($\neg p$ stands for *NOT* p).

A system state exists or does not exist; it cannot exist partially.

An event happens, or does not happen; it has happened, or has not happened. Nothing can change an event *X* that happened, and only nature could have caused it in application of a law of evolution. Any hypothesis such as "If event *X* had not occurred..." is pure conjecture.

Principle of the Excluded Third, also Called the Excluded Middle
There are only two cases of logical value. A proposition (assertion) *p* can only be:

- True, and then the opposite proposition *non-p* ($\neg p$) is false ;
- Or false, and then the opposite proposition *non-p* ($\neg p$) is true.

Principle of Identity
This logical principle affirms the unity, coherence and stability of an object that exists. The principle of identity states: *"What is, is; what is not, is not."* A thing (object, situation, event) *is* (exists, takes place or has taken place), or *is not* (does not exist, does not take place or has not taken place).

Physical existence has conditions of possibility in time and space:

- A certain permanence (existence for a non-zero time);
- The occupation of a non-zero volume of space.

If the thing is, it is identical to itself, not to anything else: it is the only reality for this thing. One can always *imagine* a different world, or conditions in which an object that exists would not exist, or that an event that did not take place would have taken place, etc., but it would be pure imagination.

Principle of Determinability of a Concept
This principle is a consequence of the above *Principle of the Excluded Middle*.

In the *Critique of Pure Reason* [B12] page 518, Kant writes:

> "Any *concept,* vis-à-vis what is not contained in it, is indeterminate and is subject to the *principle of determinability of a concept* according to which, from two contradictorily opposed predicates, only one can apply to it - a principle which is itself based on the Principle of Contradiction and is therefore a purely logical principle which disregards any knowledge content and considers only the logical form."

Translation: a concept is a set of information elements; it is indeterminate in relation to any element that does not belong to it. The principle of determinability states that in any couple of opposing judgments (such as "Charles killed Henry" and "Charles did not kill Henry") only one *possibly* applies to a given subject, according to the Principle of Contradiction.

> Applies *possibly*: the judgment "Charles killed Henry" does not apply to the concept "Augustus", which represents an emperor who died centuries before Henry's birth; compared to Augustus it is indeterminate.

So, given a concept *C* and the set of possible predicates *P*, there is a subset *P(C)* of predicates of *P* that apply to *C*, therefore determine *C*.

But this determination is not necessarily unique, there could be other concepts *X, Y*... to whom the same *P(C)* predicates apply, perhaps at the same time as additional predicates. To determine *C* uniquely it is therefore necessary that there be a predicate *U* of *P(C)* which applies only to the concept *C*; if such a predicate *U* exists, *C* has *complete determinability*.

Example: Complete Determinability of an Atom's Electrons
The quantum state of an atom's electron is defined by 4 quantum numbers:

- Principal quantum number, for the atomic layer of energy;
- Azimuthal quantum number, for the shape of an atomic orbital (trajectory);
- Magnetic quantum number, for the orientation of the orbital in space ;
- Spin quantum number, for the kinetic moment of the electron.

According to Pauli's Exclusion Principle:

> **« Two fermions cannot be in the same quantum state at the same time, described by the same quantum numbers. »**

Un atomic electron, being a fermion, must be the only electron with 4 given values of the quantum numbers. This is why, for example, two electrons tend to avoid each other: on the same energy subshell of an atom there are a maximum of two electrons, and their spins are opposed to respect the exclusion principle.

10.13 Miscellaneous

DNA and RNA

Source: UMass Chan Medical School *What is RNA?*
https://www.umassmed.edu/rti/biology/what-is-rna/

Let’s begin with the basics. Deoxyribonucleic acid (DNA) is a molecule you may already be familiar with; it contains our genetic code, the blueprint of life. This essential molecule is the foundation for the “central dogma of biology”, or the sequence of events necessary for life to function. DNA is a long, double-stranded molecule made up of bases, located in the cell’s nucleus. The order of these bases determines the genetic blueprint, similar to the way the order of letters in the alphabet are used to form words. DNA’s ‘words’ are three letters (or bases) long, and these words specifically code for genes, which in the language of the cell, is the blueprint for proteins to be manufactured. DNA is also extremely stable (amazingly, intact DNA has been isolated from frozen wooly mammoths that died more than 10,000 years ago!), which is why these are the blueprints used to transmit genetic information from generation to generation.

To ‘read’ these blueprints, the double-helical DNA is unzipped to expose the individual strands and an enzyme translates them into a mobile, intermediate message, called ribonucleic acid (RNA). This intermediate message is called messenger RNA (mRNA), and it carries the instructions for making proteins. When the cell no longer needs to make any more of that protein, the mRNA instructions are destroyed. Since the DNA blueprints remain intact, the cell can go back to the DNA and make more RNA copies when it needs to make more proteins.

The mRNA is then transported outside of the nucleus, to the molecular factory responsible for manufacturing proteins, called the ribosome. Here, the ribosome translates the mRNA using another three-letter word; every three base pairs designates a specific building block called an amino acid (of which there are 20) to create a polypeptide chain that will eventually become a protein. The ribosome assembles a protein in three steps:

- During initiation, the first step, transfer RNA (tRNA) brings the specific amino acid designated by the three-letter code to the ribosome.
- In the second step, elongation, each amino acid is sequentially connected by peptide bonds, forming a polypeptide chain.

  The order of each amino acid is crucial to the functionality of the future protein; errors in adding an amino acid can result in disease.
- Finally, during termination, the completed polypeptide chain is released from the ribosome and is folded into its final protein state. Proteins are required for the structure, function, and regulation of the body's tissues and organs; their functionality is seemingly endless. Human cells make nearly 100,000 different kinds of proteins, each with its own unique messenger RNA sequence.

<u>Reminders on Gauss's Law (reading not required)</u>

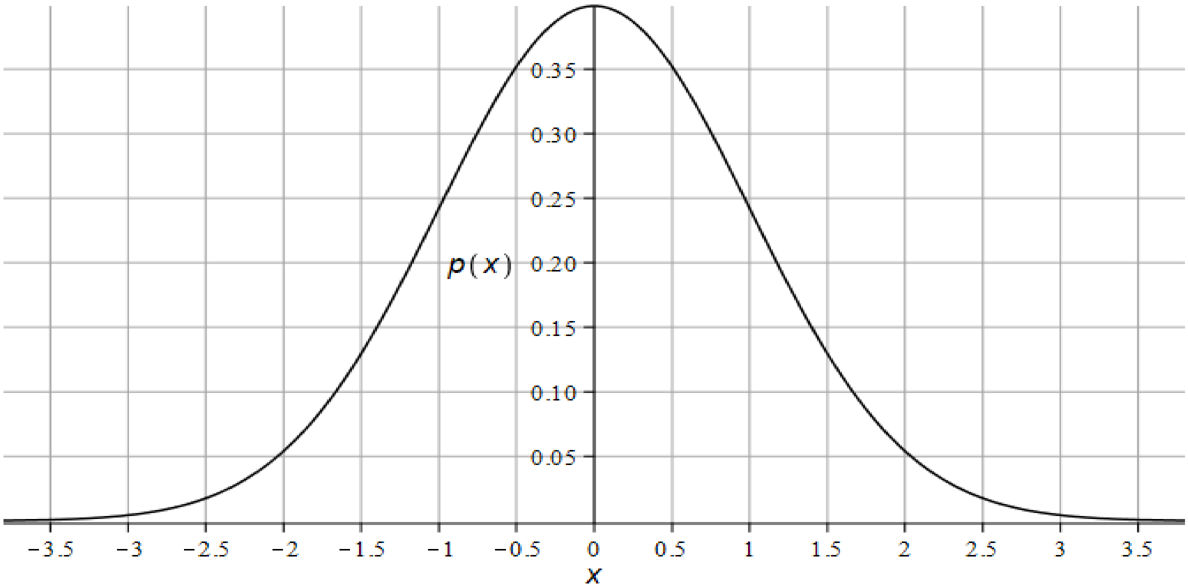
Consider a one-dimensional space where the position of a point *Q* is identified by its abscissa *x*. The function of *x* known as "Gauss Law" or "Normal Distribution Law" is:

$$p(x) = \frac{1}{\sqrt{2\pi}} e^{-\frac{x^2}{2}}$$

This function represents the probability density *p(x)* in the vicinity of the abscissa *x*, such that the probability of finding the point *Q* between *x* = *a* and *x* = *b* is:

$$p(a \leq x \leq b) = \frac{1}{\sqrt{2\pi}} \int_a^b e^{-\frac{x^2}{2}}\, dx$$

The graphical representation of the probability density *p(x)* is:



Probability density $p(x) = \frac{1}{\sqrt{2\pi}} e^{-\frac{x^2}{2}}$. The average position is *x*=0

The probability of a position x_0 in an interval of width *dx* around x_0 is:

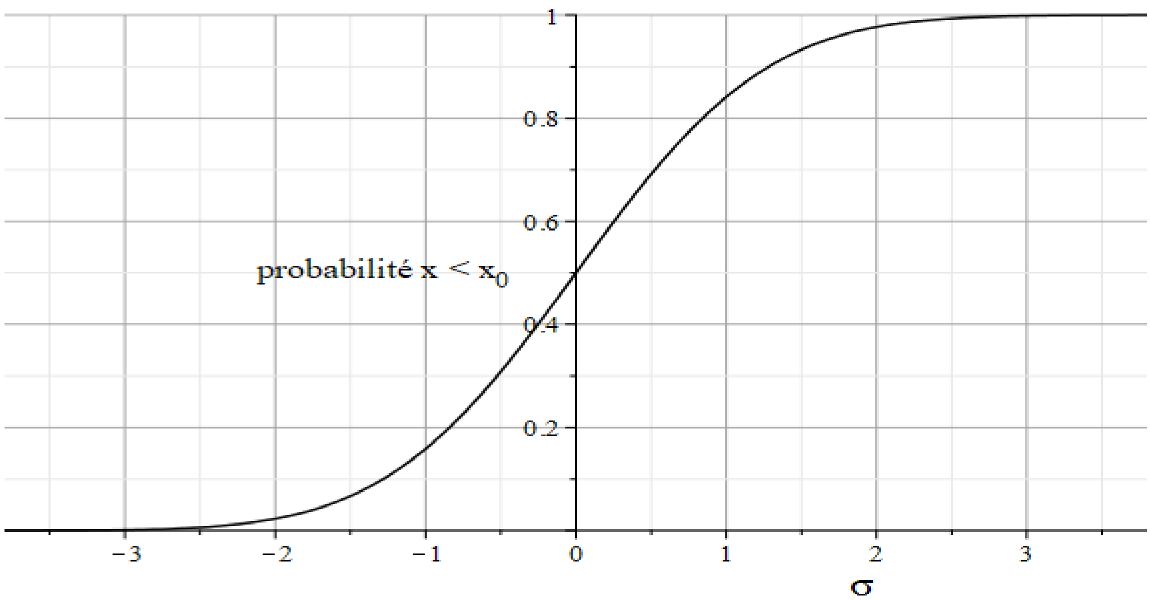
$$prob\left(x_0 - \frac{dx}{2} \leq x \leq x_0 + \frac{dx}{2}\right) = p(x_0)dx$$

The certainty of finding x *somewhere* (-∞<x<+∞) results from the equality:

$$\frac{1}{\sqrt{2\pi}} \int_{-\infty}^{+\infty} e^{-\frac{x^2}{2}}\, dx = 1$$

The probability of finding a value *x* less than x_0 follows Gauss law:

$$prob(x < x_0) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{x_0} e^{-\frac{t^2}{2}}\, dt$$



Gauss law: probability of position $x<x_0$ (average position is x=0)

Paradox of Achilles and the Tortoise

In the 5th century B.C., the Greek philosopher Zeno "demonstrated" that motion does not exist objectively, by saying this:

> "The fast Achilles cannot catch up with a tortoise which started racing before him, because while he covers the initial distance which separates him from the tortoise, the latter advances and covers a new distance which Achilles must then also cover, etc. The number of Achilles' catching steps is therefore infinite, even if each step lasts only a short instant. He cannot catch up with the tortoise, because for an infinity of instants an infinite time is required."
>
> And Zeno, who did not know the mathematical concept of convergent series, deduced from this that motion does not exist objectively!

Mathematical Solution

Let *D* be the initial distance between Achilles and the tortoise at the start of the race (time *t*=0). Achilles runs at a constant speed *V,* and the tortoise at a constant speed *v*. Achilles takes a time $t_0 = \frac{D}{V}$ to reach the tortoise's position at time 0.

But during time t_0 the tortoise has traveled a distance $vt_0 = v\frac{D}{V}$.

Achilles travels this new distance in time $t_1 = \frac{v\frac{D}{V}}{V} = v\frac{D}{V^2}$.

During the time t_1 the tortoise covers a distance vt_1, which Achilles then covers in $t_2 = \frac{vt_1}{V} = v^2\frac{D}{V^3}$, etc. We see that after the initial time $t_0 = \frac{D}{V}$, Achilles runs successive times in geometric progression with ratio $\frac{v}{V}$ for a total of $T = \frac{D}{V}(1 + \frac{v}{V} + \frac{v^2}{V^2} + \cdots)$.

Let $x = \frac{v}{V}$ and let S_n be the sum $S_n = 1 + x^1 + x^2 + x^3 + \cdots + x^n$ where x<1.

So $xS_n - S_n = x^{n+1} - 1$, and $S_n = \frac{x^{n+1}-1}{x-1}$.

When *n* tends to infinity, x^{n+1} tends to 0 and S_n tends to $\frac{1}{1-x}$: the sum S_n is not infinite, the series S_n is convergent. If, for example, Achilles runs 10 times faster than the tortoise, S_n tends to $\frac{1}{1-0.1} = 1.11$, and Achilles will catch up with the tortoise in a time $T = 1.11\frac{D}{V}$, then he will pass it.

Triggering Inflation: Great Unification Theories

Source: [0].

Principle of Inflation

The phenomenon of inflation is an expansion (i.e. growth of the radius) of the Universe at an exponential rate for a tiny fraction of a second (~10^{-32}s), begun very shortly (~10^{-35}s) after the Big Bang.

Details of the Course of Inflation

About 10^{-36} seconds after the Big Bang, the vacuum energy of the Universe had strongly dominated other forms of energy for long enough for the equations of General Relativity (exactly: Friedmann's equations) to admit a particular, unstable solution, where *the rate of expansion of space occurs with constant matter-energy density*:

> **« Inflation: as it increases in volume, space creates matter-energy in the same proportion, its density remaining constant. »**

Of course, the matter-energy created comes from somewhere, there is no magical creation from nothing. Expansion results from a negative pressure, *that creates matter-energy at the same time as it expands space. This matter-energy comes from the energy of the "empty"* space *itself, which decreases.*

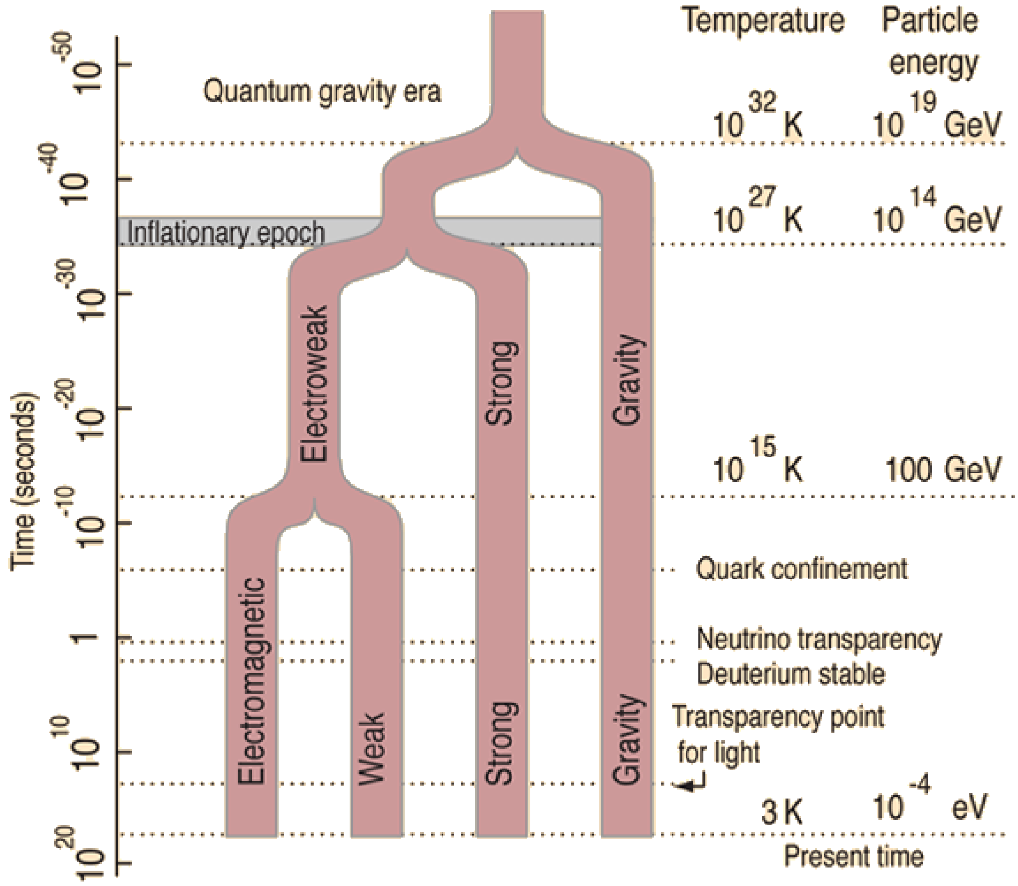
> Analogy: the kinetic energy of a falling body comes from the decay of the potential energy of the gravitational field whose force causes it to fall.

During the inflation phase, the potential energy of each point in the Universe could become as negative as necessary, to fuel inflation by decreasing. It should be noted that here "vacuum energy" is gravitational potential energy, always negative.

The Drop in Temperature of the Universe after the Big Bang

The temperature of the Universe did not stop falling between the Big Bang and Inflation. The physical explanation for triggering this inflation is provided by the *Great Unification Theories* (GUT): at sufficiently high temperatures, such as the energy k_BT of the particles reaches or exceeds 10^{16} GeV (~10^6 joules), the three strong, weak and electromagnetic interactions are unified.

When the temperature drops below the threshold of an energy of 10^{16} GeV, the plasma of the Universe undergoes a phase transition that separates the strong interaction from the other two interactions, which remain unified into an electroweak interaction.



Separation of fundamental forces - © Microsoft Bing Creative Commons

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- [1b] Article *Antiquité – Naissance de la philosophie* par Pierre Aubenque
- [1c] Article *Descartes (René) 1596-1650* par Ferdinand Alquié
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- [1e] Article *Âme*
- [1f] Article *Boscovich*
- [1g] Article *Cinétique des fluides (théorie)*
- [1h] Article *Spectroscopie*
- [1i] Article *Statistique (Mécanique)*
- [1j] Article *Démographie*
- [1k] Article *Populations animales (dynamique des)*
- [1l] Article *Particules élémentaires – Fermions*
- [1m] Article *Ondes gravitationnelles*
- [1n] Article *Nucléosynthèse*
- [1p] Article *Trous noirs*
- [1q] Article *Génome – introduction*
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Vocabulaire de la Critique de la raison pure - Dictionnaire des idées de Kant

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[42] Stanislas Dehaene - *Le code de la conscience* - Odile Jacob, octobre 2014 (427 pages) - Le professeur Dehaene est normalien (mathématiques), docteur en sciences cognitives et titulaire de la chaire de Psychologie cognitive expérimentale au Collège de France.

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[44] Michel Bitbol - *La conscience a-t-elle une origine ?: Des neurosciences à la pleine conscience: une nouvelle approche de l'esprit*, Flammarion 2014 - 748 pages

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[51] Michael S. A. Graziano - *Consciousness and the Social Brain* - Oxford University Press, 2013, 268 pages - An account of recent research on consciousness, this book presents a new theory on its nature and functioning, as well as on the functioning of "consciousness of the other" and "self-awareness". Director of a psychology laboratory at Princeton University (http://www.princeton.edu/~graziano/), Professor Graziano offers here an extremely clear cognitive neuroscience text.

[52] Steven Pinker - *How the Mind Works* (Penguin books - 2015, 660 pages)
The author is a professor of psychology at Harvard, and a researcher in cognitive psychology. He also taught at MIT and Stanford.

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[57] Sir Michael RUTTER - *Genes and Behavior – Nature-Nurture Interplay Explained* (March 2008) - Blackwell Publishing.
Quotes:

- Page 14:

  "…because the effects of genes are indirect, it is not possible to reduce everything to the molecular level. Organisms are made up of a hierarchy of organizational levels. There is a precise causality chain linking the product of a gene to the actions of that gene within the organism, but the causality chain then passes through several different levels of organization. At each level, the chain is

transformed and obeys different rules. The complexity starts with the fact that any given gene can have several rather different effects …

[…] The protein products of genes do not act in isolation but participate in the formation of complex networks and structures which are then integrated into an overall hierarchical organization. Moreover, with multifactorial traits (and these account for the great majority of behaviors of interest) there is an interplay with the environment that may involve gene-environment correlations, genetic influences on sensitivity to the environment, and the effects of the environment on gene expression."

Correlation (noun) – Definition:

- Relationship existing between two things, two notions or two facts, one of which implies the other and vice versa;
- Necessary relationship that is established between a notion and its opposite.

- Page 83

  "…genetic influences may lead people to be more or less emotional in functioning, more or less impulsive in their style of reacting, more or less sociable and outgoing in their personality, more or less stable or labile in their mood, and more or less assertive or aggressive in their interpersonal interactions. All of these traits are quantitative, rather than of a presence or absence variety. In other words, the world does not divide up into individuals who are aggressive and those who are not; rather, people simply vary in the likelihood that they will feel or behave aggressively."

- Page 222

  "The workings of the mind must be based on the functioning of the brain, and the brain's structure and development (as with any other bodily organ) will be shaped by both genes and environment. It is necessary that we get rid of the notion that there are some behaviors that arise from outside the body, and which have no biological substrate. The effects of genes are all-pervasive - which, of course, is not to say that the effects will usually predominate over the influences of the environment."

(End of quotes)

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http://gallica.bnf.fr/ark:/12148/bpt6k96200351/f1n294.pdf?download=1

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[88] Calcul des propositions ou des prédicats
Ces sujets de logique formelle sont abordés dans l'ouvrage [12] au paragraphe *Logique – Compléments modernes et critique des idées de Kant sur ce sujet*.

[96] Article *Cette étonnante Mécanique quantique*, discours d'Alain Aspect du 17/06/2002 - http://www.academie-sciences.fr/pdf/membre/s170602_aspect.pdf .
Deux photons jumeaux, dits « intriqués » car produits ensemble d'une façon qui leur confère un état quantique global et qu'ils partagent un même quantum indécomposable d'énergie, *se comportent comme une particule unique, inséparable*: toute mesure de l'état de l'un correspond toujours à l'état de l'autre, quelle que soit leur distance ; et une action sur l'un d'eux se répercute sur l'autre en un temps nul – donc inférieur au temps qu'il faudrait à la lumière pour l'atteindre.

L'état quantique décrivant les deux photons est unique: il ne s'agit pas de deux états identiques, mais d'un état représentant les deux photons *ensemble* ; c'est ainsi, par exemple, que leurs directions de polarisation opposées sont prises en compte toutes deux en tant qu'ensemble. Lorsqu'une expérience agit sur la polarisation de l'un des photons, elle agit aussi instantanément celle du second photon, même s'il est loin du premier, car la polarisation de l'ensemble doit rester la même, comme son énergie. Si on mesure les polarisations des deux photons, les résultats sont toujours corrélés, conformément aux équations de la Mécanique quantique.

On sait même produire des groupes de plus de 2 photons intriqués, puisqu'en 2004 on a réussi à produire un tel groupe avec 6 photons
(Source: Scientific American - August 2007 pages 78-79, article The Gedanken Experimenter- Quantum Weirdness)

C'est ainsi que des chercheurs ont réussi à transmettre l'un des photons à 144 km de l'autre sans détruire l'intrication avec son jumeau resté au laboratoire.

Par contre, *cette propriété de corrélation préservée lors d'une évolution d'un des photons ne peut servir à transmettre instantanément un message*: le récepteur d'une suite de photons ne peut en déduire quoi que ce soit concernant le message de l'émetteur du fait de la corrélation ; celle-ci se constate après coup, en comparant l'émission à la réception, elle ne permet aucune transmission instantanée d'information. La transmission instantanée de messages n'existe qu'en science-fiction.

L'expérience d'Alain Aspect prouve que pour certains phénomènes:

> **« Space is not separable: there are phenomena for which the notions of different locations or finite size do not apply. »**

C'est là une modification fondamentale du principe de causalité et du déterminisme.

Cette expérience illustre le *Principe de correspondance* selon lequel *certaines équations et certains modèles de raisonnement de la physique quantique sont également valables à l'échelle macroscopique*. Dans l'expérience précédente, tout se passe comme s'il existait une propriété fondamentale de la physique appelée « conservation de l'intrication des photons d'une paire indépendamment de leur distance », propriété due au fait que ces photons sont décrits par la même fonction d'onde de Mécanique quantique.

Un raisonnement relativiste sur l'indépendance entre deux événements et leur relation de causalité éventuelle montre que des observateurs différents peuvent voir deux événements *A* et *B* dans l'ordre *A puis B* pour l'un et *B puis A pour l'autre* !

[97] Site *Astronomie & Astrophysique - Chat de Schrödinger*:
https://www.astronomes.com/le-big-bang/chat-schrodinger/

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"The author proposes a big bang model in which our Universe is a fluctuation of the vacuum, in the sense of quantum field theory. The model predicts a Universe which is homogeneous, isotropic and closed, and consists equally of matter and anti-matter. All these predictions are supported by, or consistent with, present observations."

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A Nobel Winner Pioneers the Personal Genome http://www.newsweek.com/id/34370

Quote: “If personal-genome sequencing becomes widespread, » he says, «it will make people more compassionate. We'll understand why people can't do certain things,» he continues. «Instead of asking a child to shape up, we'll stop having unrealistic expectations. If a child's genome shows that his awkwardness or inattention or limited intelligence has a genetic basis, we'll want to help rather than be mad. If a child doesn't finish high school, we treat that as a failure, as his fault. But knowing someone's full genetic information will keep us from making him do things he'll fail at."

[138] Article *Lots of Animals Learn, but Smarter Isn't Better*
The New York Times du 06/05/2008 -
http://www.nytimes.com/2008/05/06/science/06dumb.html?_r=1%26th=%26oref=slogin%26emc=th%26pagewanted=print

[139] La femme ayant deux chromosomes X et l'homme un seul, plusieurs maladies neurologiques sont plus répandues chez l'homme que chez la femme, car celle-ci a moins de chances d'avoir subi des mutations des deux exemplaires d'un même gène. Il y a là un effet réparateur: chez la femme, la présence de l'exemplaire sain d'un gène annule parfois l'effet d'une mutation de l'autre.

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Extrait traduit: "Fumer altère de manière irréversible l'expression de certains gènes, notamment parmi ceux qui contribuent à la réparation des chaînes ADN et ceux qui combattent le développement du cancer du poumon. Cette altération se produit chez certains fumeurs en quelques années. Elle est accompagnée d'altérations réversibles et d'altérations partiellement réversibles."

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Newsweek Dec. 1, 2007. https://www.newsweek.com/changing-portrait-dna-94585

[145] MAPLE Application Software 2017 - http://www.maplesoft.com/ - This software allows you to perform formal mathematical calculations such as the derivation of functions or the resolution of systems of differential equations. MAPLE interprets keyboard-typed strings by recognizing commands (execution orders) and data, and displaying on the screen the results of executing those commands with that data. Thus, if asked for the derivative of the function ax^2 with respect to x, MAPLE responds $2ax$.

Similar application program:
MATLAB - https://fr.mathworks.com/products/matlab.html

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- Book *The Science of Good and Evil - Why People Cheat, Gossip, Care, Share, and Follow the Golden Rule*" by Michael Shermer (Times Books, 2004).
  This book is an account of recent research on the advent of moral rules.

- Article citing research that confirms that of this book: "*Is 'Do Unto Others' Written Into Our Genes?*" - The New York Times of 18/09/2007, http://www.nytimes.com/2007/09/18/science/18mora.html?th=&emc=th&pagewanted=print

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[151] Universals:

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- [149] page 60.

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Abstract: Experimental and theoretical analysis have by now established the existence of self-organization, from the molecular (e.g. self-assembly) to the macroscopic level (e.g. chemical oscillations and pattern formation). There is increasing awareness that self-organization is likely to provide the key to understanding the marked polymorphism of matter in the mesoscopic and macroscopic levels as well as many phenomena in the life sciences such as evolutionary processes, the development of patterns and the principles underlying the brain function. This publication concentrates on phenomena observed in the life sciences that take place far from equilibrium. Also included are oscillating chemical reactions because they provide a well characterized paradigm for self-organization of direct relevance to biology. Furthermore, some specific ordering processes operating near chemical equilibrium, such as molecular recognition, are included in the essay because they are a prerequisite for the biological function.

[183] Daniel Kahneman, prix Nobel d'économie 2002 - *Thinking, Fast and Slow* - Penguin Press (2012) – L'auteur reproche à la plupart des gens de croire que ce qu'ils savent ou voient est tout ce qui existe (WYSIATI: What You See Is All There Is) en oubliant de chercher au-delà.

[184] Jean TIROLE, prix Nobel d'économie 2014 - *Economie du bien commun* – Editions PUF (2016)
Cet ouvrage présente les problèmes actuels d'économie (chômage, déficit, inégalités, fiscalité, marchés…) dans un style remarquablement facile et agréable à lire. La principale difficulté des décisions économiques venant aujourd'hui d'une information insuffisante des décideurs, il présente ce sujet dans l'extrait ci-dessous.

(Citation de la page 32)

Nous croyons ce que nous voulons croire,
nous voyons ce que nous voulons voir

Nous croyons souvent ce que nous voulons croire, pas ce que l'évidence nous conduirait à croire. Comme l'ont souligné des penseurs aussi divers que Platon, Adam Smith ou le grand psychologue américain du XIX^e siècle William James, la formation et la révision de nos croyances servent aussi à conforter l'image que nous voulons avoir de nous-même ou du monde qui nous entoure. Et ces croyances, agrégées au niveau d'un pays, déterminent les politiques économiques, sociales, scientifiques ou géopolitiques.

Non seulement nous subissons des biais cognitifs, mais qui plus est, il arrive assez fréquemment que nous les recherchions. Nous interprétons les faits au prisme de nos croyances, nous lisons les journaux et recherchons la compagnie de personnes qui nous confortent dans nos croyances, et donc nous nous entêtons dans ces croyances, justes ou erronées. Confrontant des individus à des preuves scientifiques du facteur anthropique (c'est-à-dire lié à l'influence de l'homme) dans le réchauffement climatique, Dan Kahan, professeur de droit à l'université de Yale, observa que les Américains qui votent démocrate ressortent encore plus convaincus de la nécessité d'agir contre le réchauffement climatique, tandis que, confrontés aux mêmes données, de nombreux républicains se voyaient confortés dans leur posture climatosceptique [1]. Plus étonnant encore, ce n'est pas une question d'instruction ou d'intelligence: statistiquement, le refus de faire face à l'évidence est au moins aussi ancré chez les républicains disposant d'une éducation supérieure que chez les républicains moins instruits ! Personne n'est donc à l'abri de ce phénomène.

1 - Dans son article «*Ideology, Motivated Reasoning, and Cognitive Reflection*, *Judgment and Decision Making», 2013, n° 8, page 407-424. Plus précisément, Kahan montre que les capacités de calcul et d'analyse réflexive n'augmentent pas la qualité de la révision des croyances sur le facteur anthropique. Rappelons qu'en 2010 seulement 38% des [électeurs] républicains acceptaient l'idée d'un réchauffement climatique depuis l'ère préindustrielle et seulement 18% y voyaient un facteur anthropique (c'est-à-dire une cause humaine).

(Fin de citation)

[190] Jean-Paul Sartre - *L'Etre et le néant* - Gallimard (1943)

[191] Gregory Berns - *Satisfaction: The Science of Finding True Fulfillment* – Henry Holt & Company, New York (2005)

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"O profondeur de la richesse, de la sagesse et de la science de Dieu ! Que ses jugements sont insondables, et ses voies incompréhensibles !"

[203] Book *Our Mathematical Universe* by Max Tegmark - (Alfred A. Knopf, New York, 2014).

[267] Article *How many genes are in a genome?* by Ron Milo and Rob Philips
http://book.bionumbers.org/how-many-genes-are-in-a-genome/
from the book *Cell Biology by the Numbers* (Dec. 2015).

[268] Source: *Encyclopédie Universalis* [1q]
The notion of cell applies to systems where two different kinds of nucleic acids linked to protein structures [DNA and RNA] coexist. In this case, it is the DNA of a chromosome that will be *the depository* of the genetic information, while the RNA will intervene in *the expression* of this information, in fact its translation into proteins at the level of ribosomes, cytoplasmic particles loaded with RNA. RNA acts as an on-off switch to allow or inhibit the expression of each gene. It can act as an enzyme by catalyzing reactions.

Like DNA, RNA is composed of nucleotides, but it is a class of molecules whose shape is sometimes a folded strand (like a protein), sometimes a double helix like DNA.

[272] Carlo Rovelli – *Par delà le visible: La réalité du monde physique et la gravité quantique* (2015)

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https://plato.stanford.edu/archives/win2019/entries/qm-relational/

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https://physicsworld.com/a/information-converted-to-energy/ - Extract:

« *A thought experiment proposed by James Clerk Maxwell in 1871*
Maxwell envisaged a gas initially at uniform temperature contained in a box separated into two compartments, with a tiny intelligent being, later called “Maxwell’s demon”, controlling a shutter between the two compartments. By knowing the velocity of every molecule in the box, the demon can in principle time the opening and closing of the shutter to allow the build-up of faster molecules in one compartment and slower ones in the other. In this way, the demon can decrease the entropy inside the box without transferring energy directly to the particles, in apparent contradiction of the second law of thermodynamics.

Among the many responses to this conundrum was that of Leó Szilárd in 1929, who argued that the demon must consume energy in the act of measuring the particle speeds and that this consumption will lead to a net increase in the system’s entropy. In fact, Szilárd formulated an equivalence between energy and information, calculating that $k_BT\ln 2$ (or about 0.69 k_BT) is both the minimum amount of work needed to store one bit of binary information and the maximum that is liberated when this bit is erased, where k_B is Boltzmann’s constant and T is the temperature of the storage medium. »

[313] Livre *La révolution inachevée d'Einstein – Au-delà du quantique* par Lee Smolin (Dunod 2019). C'est un excellent ouvrage, didactique et passionnant à lire. C'est aussi un livre à thèse défendant le réalisme naïf d'Einstein et de Smolin lui-même contre l'interprétation antiphilosophique de Copenhague défendue par Bohr et Heisenberg, et résumant des pistes de recherche dans ce domaine.

[316] Book *Epigenetics – How Environment Shapes Our Genes*
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[317] Book *The Genetics Revolution – How Modern Biology is Rewriting Our Understanding of Genetics, Disease and Inheritance* par Nessa Carey – Icon Books, London

[318] Article *Study shows neutrinos can exhibit quantum superposition states* – https://watchers.news/2016/07/21/study-shows-neutrinos-can-exhibit-quantum-superposition-states/ in *The Watchers* - Thursday, July 21, 2016

[B67] Book *The Emperor's New Mind* by Roger Penrose, English mathematician and physicist famous for his black holes research in collaboration with Stephen Hawking (1989 - Oxford University Press)

[B12] Livre *Critique de la raison pure* (1781 et 1787) par Emmanuel Kant
(traduction Alain Renaut - Flammarion, 3e édition, 2006 - 749 pages – 9.30€).

[B123] Article *IS WAVE PROPAGATION COMPUTABLE OR CAN WAVE COMPUTERS BEAT THE TURING MACHINE?*
http://journals.cambridge.org/action/displayAbstract;jsessionid=64E637A7273855F16C9DA940957B4681.tomcat1?fromPage=online&aid=113911 - Quotation:

> "In 1983 Pour-El and Richards defined a three-dimensional wave *u(t,x)* whose amplitude *u(0,x)* at time *t*=0 is computable and amplitude *u(1,x)* at instant *t*=1 is continuous but not computable."

Article *An ordinary differential equation defined by a computable function whose maximal interval of existence is non-computable*
https://www.researchgate.net/publication/251299818_An_ordinary_differential_equation_defined_by_a_computable_function_whose_maximal_interval_of_existence_is_non-computable

[B268] Article *The Computational Theory of Mind* by Michael Rescorla (Stanford)
https://plato.stanford.edu/entries/computational-mind/