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Homeopathy confronted with physics

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Abstract:

Calculation of the *characteristic action* of homeopathic preparation indicates that this *action* is outside of the *quantum domain* as defined by Planck's constant. Therefore, quantum physics cannot be applied to homeopathy. Moreover, calculation of the increase of entropy resulting from homeopathic dilution and succussion indicates that these processes have the effect of erasing part of the *molecular information*. And that therefore, these processes do the exact opposite of inscribing information in homeopathic solution.

Kewwords: Homeopathy, quantum physics, thermodynamics, information theory, action, entropy, dilution, water memory

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Thanks

A study presented in September 2017 by the *Scientific Council of the European Academies of Sciences* concluded that there was no solid and reproducible proof of the effectiveness of homeopathic products. And that the scientific claims of homeopathy are implausible and incompatible with the established concepts of chemistry and physics. This article reinforces this conclusion by showing (a) why quantum physics cannot be invoked to explain homeopathy, (b) why the homeopathic processes of succussion and dilution have the effect of erasing information instead of memorizing some *message* and (c) why there are no molecules of the active ingredient left beyond 12 CH and therefore no longer any physical effect either.

After two centuries of pseudoscientific wandering, hasn't the time come to bury homeopathy at the graveyard of hypotheses refuted by the facts?

The author would like to thank *The International Journal of Homeopathy* for the intellectual honesty and courage it shows in accepting to publish this article which so openly condemns homeopathy**.**

Instructions for use:

This text has two reading levels. At the first level, the facts are presented without equations, with notions of physics reduced to a minimum. It constitutes the body of the text. At the second level, the facts are presented in a quantitative way using elementary calculations (not going beyond the mathematical high school level). This second-level text appears in boxes on a grey background with the symbol ⚠ in the upper left corner. The reader unfamiliar with physics or mathematical language can skip these boxes and still get a good idea of the argument presented here. They will, however, miss the essential part of the demonstration which can only be quantitative to be really convincing.

This lack of familiarity with the scientific quantitative — which could be qualified as mathematical-scientific illiteracy, for lack of a better word — is unfortunately very widespread in our supposedly technological societies. It makes the individual easily susceptible to allegations of all kinds. And it suits all pseudoscientific impostures (such as homeopathy or astrology) which thus easily persist in the shadow of this ignorance. Samuel Hahnemann, founder of homeopathy, was suspicious, like the plague, of those he disdainfully called *arithmeticians*…

1. Quantum homeopathy?

1.1 Introduction

A revealing anecdote is reported by Dr. René-Philippe Halm[a][5]. It would have happened during the last *Congress of the International Homeopathic League* in Berlin. A participant stands up and asks the following question: *"Why do you attach so much importance to the old principles of homeopathy when everywhere here, we only talk about the application of quantum physics to explain homeopathy?"* [b]

The question is raised: will homeopathy finally find its scientific explanation in the arcana of quantum physics?

This incessant quest for any scientific legitimacy is part of the purest homeopathic tradition. It goes back more than two centuries with Hahnemann and consists of hanging on like a lifeline to the latest advances in physics. All the physical theories have thus been called upon over the years: thermodynamics, magnetism, electromagnetism, atomism and, the most recent, chaotic and quantum physics. And soon, hold on tight, it will be the theory of superstrings! But these attempts, so far, have all been in vain.

Although a homeopath himself, Dr. Halm had doubts about the validity of all these references to quantum physics:

"As far as quantum physics is concerned, he says, *we have witnessed and are still witnessing the same type of analogical reasoning which, let us remember, is not scientific reasoning. Not being a great specialist in quantum physics, we took the liberty of soliciting the most renowned quantum physicist in France, to whom we sent all the literature concerning amalgams quantum physics and homeopathy. Here is Professor Lévy-Leblond's response: "*

> *"Mr. Secretary General,*
> *I read with great interest and a mixture of amusement and irritation the articles you sent me.*
> *I can only confirm that your fears are absolutely founded, and that these articles have no serious scientific value. The references to quantum theory here are purely rhetorical and, moreover, are based on an already old and outdated presentation of the basic ideas.*
>
> *Perhaps most irritating is that the authors claim to be advancing only a qualitative metaphor, which after all would be admissible (but would certainly not be worth publishing in a professional journal), while all discursive strategies aim on the contrary to make explanations taken seriously, by asking physics to back them up with a pure argument of authority."* **[c]** [5]

Addressing his fellow homeopaths, Dr. Halm concludes: *"Isn't common sense to let real specialists talk about what they know? And if you have an intuition, to consult before writing anything?"* [5]

1.2 The quantum domain

But Professor Lévy-Leblond could have gone further by explaining why homeopathy as it is defined with its extreme dilutions and its "energizing" succussions, is squarely outside the quantum domain. In other words, if homeopathy works, the explanation cannot come from quantum physics. Why ?

To answer this question, we must first define what is meant by *"quantum domain"*. This is precisely the title of Chapter 1 of *" Quantique: Rudiments "* [9], the introductory manual to quantum physics by Professor Lévy-Leblond. He there applies himself to determine the limits beyond which the classical theories are incapable to account for typically quantum effects and where recourse to quantum theory becomes necessary.

Planck's constant is the physical quantity at the heart of this definition. It has the dimension of a quantity called *"action"* in physics. As such, the Planck constant is the natural standard for any characteristic action of a physical system. *Box 1* provides a quantitative definition of this fundamental physical constant.

Box 1. *Planck's constant*

⚠ *Planck's constant* $\hbar$ (we say "H-bar") fully characterizes quantum physics. Its *normalized* value:

$$\hbar = 1.05\times10^{-34} \text{ joule-second}$$

has the dimension of a mass M multiplied by a length L squared, divided by a time T, or ML^2/T. This corresponds to the dimension of a quantity called *"action"*, in physics **[d]**. As such, *Planck's constant* is the natural standard for any *characteristic action* of a physical system.

What is an *action*? Unfortunately, this physical quantity does not have an intuitive meaning as obvious as that of *speed* or *mass*, for example, or even *energy*. As it is expressed in joule-seconds (symbol: J-s), it can be defined as the action of an *energy E which is exerted for a certain time Δt*. But it can also be defined as the *action* of *an impulse p which is exerted over a certain distance Δx*.

The constant h was introduced by Max Planck [14] when he discovered while studying *blackbody radiation* that light of frequency f was emitted not continuously, but discretely, by *packets of energy* $E=hf$, called *quanta*. (Its *normalized value* $\hbar = h/2\pi$ is nowadays more commonly used.) This discovery laid the foundations of quantum physics.

The first role of Planck's constant is to delimit the domain of validity of classical theories. These theories were developed before 1900, when the value of $\hbar$ was unknown. They describe a world as if Planck's constant were zero. But however small it may be, this nonzero value of $\hbar$ changes everything. It appears in all manifestations of typically quantified phenomena (electronic structure of the atom, quantification of energy, spectral distribution of the black body, photoelectric effect, wave-particle dualism, spin of quantons, tunneling effect, entanglement of quantum amplitudes, phase decoherence of the quantum wave, vacuum fluctuation, etc.) and in all the fundamental equations of the theory. Some examples of which can be found in Box 2.

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[a] Dr. René-Philippe Halm is Secretary General of the *Conférences de Monaco* (devoted to "complementary or alternative therapeutics") and founding member of GIRI (*Groupe International of Research on the Infinitesimal*).

[b] Free translation of the original text in French.

[c] Free translation of the original text in French.

[d] Any physical quantity can be expressed in the form of a combination of basic physical quantities such as *mass M*, *length L*, *time T*, *electric charge Q*, *temperature K*, etc. It is this *combination* that is called the *dimension* of a *physical quantity*. For example, the *dimension* of *speed* is L/T, that of *force* is ML/T^2, that of *energy* is ML^2/T^2, that of *electrical current* is Q/T , that of *entropy* is ML^2/T^2K , etc. The dimension that interests us here, that of *action*, is ML^2/T.

Box 2. *Some fundamental equations of quantum physics showing the ubiquity of Planck's constant ħ*

⚠ Note: It is not necessary to understand all these equations to understand the rest of the text! The goal here is rather to show the mathematical formalism of quantum theory and the key role played by Planck's constant $\hbar$. In a universe where $\hbar$ is equal to zero, all these equations would cancel out and there would be no quantum physics. Similarly, when the characteristic action of a system is very large with respect to $\hbar$, these equations practically cancel. They are then of no use to describe this system and no quantum effect can be observed.

Planck-Einstein quantum:	$E = \hbar\omega$
de Broglie wavelength:	$\lambda = 2\pi\hbar/p$
spin of the electron:	$\frac{1}{2}\hbar$
Bohr radius:	$r = \hbar^2/me^2$
photoelectric effect:	$E_{max} = \hbar\omega - W$
Heisenberg inequalities:	$\begin{cases} \Delta p \cdot \Delta x \geq \hbar \\ \Delta E \cdot \Delta t \geq \hbar \\ \Delta J \cdot \Delta\varphi \geq \hbar \end{cases}$
quantum tunneling:	$P_s = \lvert\phi_0\rvert^2 e^{-\frac{2ps}{\hbar}}$
black body spectral distribution:	$\rho_T(\lambda) = \frac{16\pi^2\hbar c}{\lambda^5}\frac{1}{e^{\frac{2\pi\hbar c}{\lambda kT}} - 1}$
angular momentum operator :	$\widehat{J_z}\lvert\psi_0\rangle = m\hbar\lvert\psi_0\rangle$
Schrödinger equation:	$-\frac{\hbar^2}{2m}\nabla^2\Psi + V\Psi = i\hbar\frac{\partial\Psi}{\partial t}$
Hamilton equation :	$i\hbar\frac{dC_i(t)}{dt} = \sum_j H_{ij}(t)C_j(t)$
Dirac equation	$i\hbar\frac{\partial\Psi}{\partial t} = \frac{\hbar c}{i}\left(\sum_j \alpha_j \frac{\partial\Psi}{\partial x_j}\right) + \alpha_4 mc^2\Psi$
[e]Lévy-Leblond–Newton equation :	$\begin{cases} \hbar\sigma(\boldsymbol{\partial})\varphi + 2m\chi = 0 \\ i\hbar\partial_t\varphi - mU\varphi - \hbar\sigma(\boldsymbol{\partial})\chi = 0 \end{cases}$

The omnipresence of $\hbar$ in all the fundamental equations of quantum theory ensures that a physical system exhibits typically quantum effects only when its *characteristic action* is of the order of $\hbar$. Recourse to quantum theory is therefore necessary in this case to describe and explain it.

But when the *characteristic action* is very much greater than $\hbar$ (greater than $50\hbar$, say), quantum theory becomes superfluous since no quantum effect is ever observed when *characteristic action* is so high. Classical theories are then sufficient to describe the system. (In Box 3, we show why we never observe any quantum effect when the *characteristic action* of a system is very large compared to $\hbar$.)

Conversely, if a combination of physical magnitude provided a *characteristic action* that was zero or very small compared to $\hbar$, this would be devoid of any physical meaning. The smallest action connected to a particle is equal to $\frac{1}{2}\hbar$, corresponding to the spin of quarks and leptons. We know of no real phenomenon characterized by a non-zero action less than $\frac{1}{2}\hbar$. Consequently, no physical theory can account for situations where the action would be lower than this value, for lack of being able to observe such situations experimentally. Physics, let not forget, is an experimental science.

Box 3. *Quantum tunneling effect*

⚠ The *quantum tunnelling effect* illustrates why we never observe *quantum effect* when the *characteristic action* is very large compared to $\hbar$.

If you throw a ping-pong ball at a concrete wall one meter thick, what is the probability that this ball crosses the wall and ends up intact on the other side of the wall?

What question ! you would say. *No chance, of course.*

And you would be absolutely right.

Or almost… Because quantum physics is not so categorical.

A *quanton* of mass m which moves with a speed v towards a wall of thickness s has a probability P_s of ending up on the other side of the wall. This probability P_s is expressed more precisely by the following equation:

$$P_s = P_0 e^{-\frac{2mvs}{\hbar}}$$

where P_0 is the probability that the particle hits the wall and where e^x is the exponential function, with e = 2.71828. (Scientific calculators have a key to calculate e^x.)

The important thing here is the *characteristic action A* equal to the product *mvs*:

$$A = mvs$$

If the wall had zero thickness, then s would be 0. As well as A. And the probability P_s that the particle "crosses" the wall would be:

$$P_s = P_0 e^{-0} = P_0 \times 1 = P_0,$$

which is exactly equal to the probability of hitting the wall.

Of course! Since if $s = 0$, there is no wall (!) and the particle continues on its merry way as if nothing had happened. And in this case, we cannot really speak of a tunneling effect and therefore of no quantum effect either. In fact, there is no effect at all! We are right here in the non-science domain where there is nothing special to say.

If the *characteristic action A* were of the order of $\hbar$ (equal to 1 $\hbar$, say), then the probability that the particle passes through the wall would be:

$$P_s = P_0 e^{-2} = P_0 \times (0.135),$$

or 13.5% of its probability of hitting the wall. This quantity is not negligible. This is a real *tunneling effect*, a typically quantum effect that classical physics does not predict. We are now right here in the quantum domain.

And our ping-pong ball? It goes through the wall? Yes or no ?

To find out, it suffices to evaluate its *characteristic action* mvs. Assuming that the mass m of the ball is 1 g, that its speed v when hitting the wall is 1 m/s and that the wall has a thickness s of 1 m, then $A = 10^{-3}$J-s or 10^{31} times Planck's constant $\hbar$. The probability that our ball crosses the wall is therefore:

$$P_s = P_0 e^{-2\times10^{31}} \approx P_0 \times 10^{-10^{31}} \approx 0.$$

That's one chance in $10^{10^{31}}$! Might as well say none. If we had tried since the beginning of the Universe (i.e., 13.8

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[e] The name of Professor Lévy-Leblond associated with this fundamental equation of quantum physics, shows that Dr. Halm was not mistaken in addressing him to have an expert opinion in quantum physics...

billion years or 4.4×10^{17} s), at the rate of one throw per second, we would still have only 1 chance in $10^{10^{31}}$ [f] of having seen our ball go through the wall once. We can therefore say, without any risk of being wrong, that no one has been able to observe such a phenomenon. This is why quantum theory predicts that there is no tangible chance of observing a quantum effect when the characteristic action of a system is very large compared to $\hbar$ (more than $50\hbar$, say [g]). Beyond $50\hbar$, we are no longer in the *quantum domain*, but in the *classical domain*. Where classical physics is perfectly suited to describe the system. And in this case, this classical physics predicts that a ping-pong ball will never pass through a meter thick concrete wall.

I told you at the beginning you were right...

In summary (and as schematized in Box 4), the *quantum domain* is defined as where systems have *characteristic action* of the order of $\hbar$ (between $\frac{1}{2}\hbar$ and $50\hbar$, say).

When this *action* is much greater than $\hbar$ (more than $50\hbar$), we fall into the *classical domain* where recourse to quantum theory is superfluous and where classical theories are sufficient to account for the system.

And if this *characteristic action* were much less than $\hbar$ (less than $\frac{1}{2}\hbar$), we would then fall into an *unknown domain*, devoid of any physical meaning. A kind of *terra incognita* or *no science land*.

Box 4. *Planck's constant delimits three domains of physics*

If the action is **greater than 50ℏ**	→ **Classical domain** We never observe quantum effect in a system where the action is greater than $50\hbar$. The classical theory is then sufficient to describe this system and quantum theory is superfluous.
If the action is **between ½ℏ and 50ℏ**	→ **Quantum domain** We can observe quantum effects when the action of a system is of the order of $\hbar$. Quantum theory is then necessary to describe or explain this system.
If the action is **smaller than ½ℏ**	→ **Unknown domain** We do not know of any system having a non zero action less than $\frac{1}{2}\hbar$. This domain is therefore unknown to physics. If we discovered such a system, we cannot say whether quantum theory would be able to describe it correctly.

1.3 The quantum domain is not necessarily microscopic

It should be noted — contrary to what we sometimes hear — that the delimitation between the classical and quantum domains does not coincide with that which separates the macroscopic world from the microscopic world. This is the mistake that Colin [1] makes when he wants to demonstrate why quantum physics can be applied to homeopathy:

"Quantum physics, he says, *primarily concerns the study of microscopic and ultramicroscopic phenomena. (...) We can clearly see that the homeopathic medicine, prepared by dilution and succussion, falls entirely within this framework, all the more so since the high homeopathic dilutions belong to the ultramicroscopic domain.*" [h][1]

Wrong. Quantum physics only concerns phenomena whose *characteristic action* is of the order of $\hbar$, regardless of whether these phenomena are microscopic or macroscopic. It is not because a system is microscopic that it is necessary to resort to quantum theory to describe it. And conversely, it is not because a system is macroscopic that it is automatically excluded from a quantum explanation. It all depends on the value of the *characteristic action* at work, compared to $\hbar$. Phenomena such as superfluidity (see Box 5), superconductivity, black body radiation, laser effect, radioactivity, etc., although macroscopically observable, each fall under quantum physics because for each of them the *characteristic action* is of the order of $\hbar$.

Conversely, the speed distribution of molecules of a gas as a function of temperature, for example, can be described without recourse to quantum physics despite the fact that the molecules involved are ultramicroscopic. Another example: the diameter of the atomic nucleus — yet 100,000 times smaller than the atom (!) — was obtained by completely classical methods, etc.

Box 5. *Superfluidity, an example of a macroscopic quantum system*

⚠ Lévy-Leblond [9] gives this example of a system which, although macroscopic, nevertheless requires quantum processing because its *characteristic action* is of the order of $\hbar$:

Helium, at normal pressure, liquefies at the very low temperature $T_l = 4.2$°K (or –269°C). It undergoes, at an even lower temperature, a phase transition which gives it curious properties. Below the "lambda point", with a temperature $T_\lambda = 2.18$°K, helium becomes *superfluid*, i.e., it flows with zero viscosity. It can thus, by capillarity, flow spontaneously outside of a vase where one claims to keep it. (Is that macroscopic enough for you?)

Lévy-Leblond wonders if this phenomenon is quantum in nature. To find out, he checks whether the *characteristic action* of superfluid helium is indeed of the order of $\hbar$.

The transition temperature T_λ provides us with an energy $E = kT_\lambda$ (where $k = 1.38\times10^{-23}$ J/°K is Boltzmann's constant, which plays somewhat the same role in thermodynamics as Planck's constant in quantum physics). We also have the density of helium $\rho = 1.46 \times 10^2$ kg/m3. Using the mass of the helium atom $M = 4$ amu = $6{,}7 \times 10^{-27}$ kg, we obtain, by dimensional analysis, the *characteristic action* $A = M^{5/6}(kT_\lambda)^{1/2}\rho^{-1/3}$, i.e., $A = 1{,}7\times10^{-34}$ J-s or $1.6\hbar$.

We are therefore right into the *quantum domain*. This leads to the conclusion that a quantum explanation of superfluidity is necessary.

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[f] This number — $10^{10^{31}}$— is so big that even divided by 10^{17}, it is still roughly equal to itself (!):

$$10^{10^{31}}/10^{17} = 10^{10^{31}-17} \approx 10^{10^{31}}.$$

[g] One of the highest *characteristic actions*, giving rise to an observable quantum phenomenon, is that of the alpha radioactivity of Samarium 147, the value of which is approximately $43\hbar$.

[h] Free translation of the original text in French.

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1.4 The homeopathic action

To judge the relevance of using quantum physics to explain homeopathy, we will have understood that we must first evaluate the *characteristic action* of a homeopathic system and compare it to $\hbar$.

The way to achieve this is to determine the *characteristic* parameters of the system and to evaluate a combination of these parameters which corresponds to the dimensions of an action, i.e., to the product ML^2/T of a mass M by a length L squared, divided by a time T.

In the case of homeopathy, the three underlying *"principles"* must be considered: similarity, individualization and preparation. (It would be more accurate in fact to call these three *"principles"*, *"conjectures"*, therefore not scientifically proven, but which homeopaths, Hahnemann the first, have elevated to the rank of *"dogmas"*.) The first two *"principles"* do not lend themselves, by their qualitative nature, to a quantitative evaluation of their *characteristic physical action.* Only the "preparation" part, which is presented in a double process — dilution and succussion — lends itself to a quantitative physical analysis. We will therefore concentrate on these two processes in an attempt to evaluate their *characteristic action*.

1.5 Homeopathic dilution

Hahnemann thought that one could dilute an ingredient in a liquid indefinitely and that this ingredient, always present and more and more finely fractionated, became more and more penetrating.

> *« Liquid medicine do not become by their greater and greater attenuation, weaker in power but always more potent and penetrating. »* [4]

This *"principle"* of diluting an ingredient into finer and finer components was formulated by Hahnemann around 1796 when we had no idea of the atomic nature of matter. Even Lavoisier, the illustrious chemist almost contemporary with Hahnemann, was still identifying the constituent elements of matter without being able to determine their dimensions. The atom, as the ultimate and indivisible element, was then only a hypothesis.

In 1811, Avogadro put forward the hypothesis that <u>any</u> gas confined in a certain enclosure, at a given temperature and pressure, would consist of a very large number N_A of *entities*. (See Box 6.) But we still did not know the value of N_A, nor the size of these mysterious *entities*!

Box 6. *Definition of Avogadro's number*

In an enclosure of volume V, at a given temperature T and at a given pressure p, the number of *entities* of <u>any</u> gas is always the same, whatever its nature. *Avogadro's number N_A* was defined as the number of *entities* included in a gas with volume $V = 22.4$ liters, temperature $T = 0°\mathrm{C}$ and pressure $p = 101$ kPa. The mass of these N_A entities, expressed in grams, is equal to the relative weight of the few dozen elements that we knew at that time. This amount of material is called a *mole*. A mole of hydrogen weighs 1g, a mole of carbon 12g, a mole of water 18g, etc. A big step had thus been taken in our understanding of matter even if we still did not know the value of N_A.

In 1905, for lack of direct proof, the atom was still considered a hypothesis. Until we analyze the erratic movement of a grain of pollen suspended in a liquid, already observed by the botanist Brown in 1827. This movement seems to be the result of billions of collisions coming from the atoms which are agitated. Under the microscope, we do not see the atoms, but only the movement of the grain of pollen tossed about by the atoms. A bit like watching a huge beach ball from very high up being tossed about by thousands of barely visible people. Based on this assumption, Einstein [2] calculated that the pollen grain should move away gradually on average from its starting point. And that this distance Δx as a function of time is inversely proportional to the square root of Avogadro's number N_A. Three years later, in 1908, Jean Perrin [13] [i] measured the displacement Δx of colloids in a liquid and was thus able to determine the value of the Avogadro number. (See Box 7.)

Box 7. *The Value of Avogadro's Number*

And Avogadro's number is... (drum roll)...:

$$N_A = 6.022 \times 10^{23} \text{ molecules per mole!}$$

As a mole of carbon (C) weighs 12 g, the mass of a carbon atom is therefore:

$$m_\mathrm{C} = 0.012\ \mathrm{kg}/N_A = 1.99 \times 10^{-26}\ \mathrm{kg},$$

that of a hydrogen atom (H) is: $m_\mathrm{H} = 1.66\times 10^{-27}$ kg, etc.

If we know the mass m of an atom and the density ρ of a solid made up of these atoms, we can therefore estimate the dimension d of the atoms:

$$d = \sqrt[3]{m/\rho}$$

For example, graphite (C) has a density ρ of about 2.2×10^3 kg/m^3, so the diameter d_C of the carbon atom is

$$d_\mathrm{C} = \sqrt[3]{1{,}99 \times 10^{-26}/2{,}2 \times 10^3} = 2.1 \times 10^{-10}\mathrm{m}.$$

That d_H of the hydrogen atom is about 10^{-10} m. The smallness of atoms may explain why Hahnemann believed that matter could subdivide indefinitely. If he already had the opportunity to observe under the microscope the dissolution of granules in water, he must have seen them disappear before his eyes when their diameter fell below 0.5 micron (5×10^{-7}m). This is the resolution limit of optical microscopes, which corresponds to the wavelengths of visible light which range from 0.4 to 0.7 microns. However, atoms are still 5,000 times smaller!

After more than a century of work on the structure of matter, we finally had direct proof of the existence of these atoms and we could finally know their mass and their dimensions!

Which incidentally also made it possible to calculate the number of atoms (or molecules) of the active ingredient that remained at the end of a homeopathic dilution. (See an example of this calculation in Box 8.)

Box 8. *How many atoms of the active ingredient are left in a 30 CH homeopathic product?*

Homeopathy claims to treat certain diseases using extremely low concentrations of certain substances. Take for example a bottle of *phosphorus* 30 CH. The expression "*phosphorus* 30 CH" indicates the level of concentration of phosphorus in the homeopathic product. One CH means one part phosphorus diluted in 99 parts of water. 30 CH means that we have thus proceeded to 30 successive dilutions of 1 CH. One can wonder how many atoms of phosphorus (**P**) remain at the end of these 30 dilutions.

To find out, let's take a 1 cm^3 beaker and fill it with phosphoric acid H_3PO_4 (which will be easier to dissolve later in water than pure phosphorus). How many **P** atoms are

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[i] The discovery was made in 1908 but published a few months later, in 1909. There was no Internet then...

there in this cm^3?

The density of H_3PO_4 is 1.8 g/cm^3. The mass of a H_3PO_4 molecule is 98 amu (for "*atomic mass units*") or

$$(98\ \text{amu})(1.66\times10^{-24}\ \text{g/amu}) = 1.6\times10^{-22}\ \text{g}.$$

The number of molecules is therefore

$$(1.8\ \text{g/cm}^3)/(1.6\times10^{-22}\ \text{g}) = 1.1\times10^{22}\ \text{molecules/cm}^3.$$

Since there is one **P** atom per molecule, we therefore have about 10^{22} **P** atoms in our little one cubic centimeter beaker.

Now take a 100 mL beaker. Let's pour in 99 mL of water (H_2O) and the contents of our beaker of phosphoric acid. After having mixed everything well (you can even shake it, if you want…), we thus obtain 100 mL of a **1 CH** phosphorus solution still containing 10^{22} **P** atoms.

Let's set aside our beaker of **P 1 CH** and use another 100 mL beaker into which we pour 99 mL of H_2O. Let's take our 1 mL beaker and draw 1 mL of **P 1 CH** solution from the first 100 mL beaker. This beaker now contains 1% of the **P** atoms of our **1 CH** solution, i.e., 10^{20} **P** atoms. Let's pour it into our 99 mL of H_2O to obtain a **2 CH** phosphorus solution. After only 2 dilutions, we reached a concentration of around 100 *ppm* (*parts per million*), or 100 atoms of **P** per million other atoms. (See Table 1.) This corresponds to the lethal dose of the most toxic products such as hydrocyanic acid.

At **3 CH** we have 10^{18} atoms left and the concentration of **P** is 1 *ppm*. Most products have virtually no detectable effect below this concentration.

At **4 CH**, there are still 10^{16} **P** atoms left, which may seem like a lot, but it is a million times less than at the beginning. And so on, subtracting 2 from the exponent of 10 at each dilution....

Table 1. *Number of phosphorus atoms remaining after each dilution of one CH*

1 CH	10^{22}
2 CH	10^{20}
3 CH	10^{18}
4 CH	10^{16}
5 CH	10^{14}
6 CH	10^{12}
7 CH	10^{10}
8 CH	10^{8}
9 CH	10^{6}
10 CH	10^{4}
11 CH	100
12 CH	1
>12 CH	0

At **10 CH**, only 10^4 or 10,000 **P** atoms remain; at **11 CH**, there are 100 left, then at **12 CH**, there is only one left!

Beyond **12 CH**, there are only increasingly low probabilities of finding a single phosphorus atom. (See Table 1.) Might as well say that there is nothing left… [j]

1.6 The characteristic action *of a homeopathic dilution*

For dilutions greater than 12 CH, there is no longer any molecule of the active ingredient. Difficult in this case, to assign a *characteristic mass M* in play, if not a zero mass. Which automatically leads to a zero *characteristic action* which places us well below the *quantum domain*, in an unknown domain of physics. We therefore cannot, here, associate some quantum effect with these extreme dilutions.

Some have invoked vacuum fluctuation (see Box 9.) to explain any effect of dilutions greater than 12 CH. Remember here that a series of dilutions that makes the molecule of the active ingredient disappear does not mean that we have created a vacuum. Over successive dilutions, these molecules have simply been replaced by other water molecules. Of course, there remains a vacuum between the atoms and between the electrons and the atomic nuclei. But neither more nor less than before any dilution. It is therefore difficult here too to see how the dilution of the active ingredient would have changed anything in the properties of matter or vacuum. Or what information could have appeared and been maintained following these dilutions. Conclusion: The *characteristic action* of homeopathic dilutions being null, these cannot be associated with any quantum effect. They are located outside the *quantum domain*, outside the *classical domain*, in a domain foreign to physics.

Box 9. *Fluctuation of vacuum*

⚠ The fluctuation of the vacuum is a typically quantum phenomenon which also corresponds, via the *Heisenberg temporal inequality*, to a *characteristic action* of the order of $\hbar$. To make a virtual electron-positron pair emerge from the vacuum, for example, whose specific energy ΔE is around 1 MeV, it is necessary to *"borrow from the vacuum"* a quantity of energy ΔE in a time Δt extremely short, less than $\hbar/\Delta E$, which means, in this case, a time less than 6×10^{-22}s. And this virtual electron-positron pair can then disappear as quickly as it appeared by returning its 1 MeV energy to vacuum. The *characteristic action* of the vacuum fluctuation, the product of the energy involved ($\Delta E = 1.6\times10^{-13}$ J) by the duration ($\Delta t = \times10^{-22}$s), is equal to 10^{-34} J-s and shows that it is part of the *quantum domain* and that it is a typically quantum phenomenon. In a classical world where $\hbar$ would be zero, there would be no vacuum fluctuation.

The reader unaccustomed to the concepts of quantum physics might think from reading the above that the concepts of dilution and succussion in homeopathy seem much more sensible after all than these absurd borrowings of quantum energy from the vacuum!

This reader would not be completely wrong. Some concepts of quantum physics are indeed very strange. And it is precisely on this strangeness, alas, that homeopaths bet to mystify the layman. But unlike homeopathy, which is based on a few dogmas that have never been questioned, physical theories are systematically subjected to harsh tests by quantitatively rigorous and precise experimental verifications. To give you an idea of the incredible precision of these theoretical predictions and their experimental verification, Richard Feynman [3] — one of the founders of quantum electrodynamics — gives the following example: From this fluctuation of the vacuum and the diagrams which now bear his name, he was able to predict theoretically in 1948 that the Landé *g* factor which intervenes in the calculation of the magnetic moment of the electron should be equal to

$$g_{\text{the}} = -2.002\ 319\ 304\ 92 \pm 0.000\ 000\ 000\ 40$$

while the most recent experimental values give:

$$g_{\text{exp}} = -2.002\ 319\ 304\ 371\ 8 \pm 0.000\ 000\ 000\ 0075.$$

The discrepancy between the theoretically predicted value and that obtained experimentally is approximately one part in 4 billion. It's like measuring the distance of 3,936 km

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[j] On May 23, 1994, to clearly show that there was nothing left of the active ingredient beyond 12 CH, the author *"homeopathically committed suicide"* in public, by swallowing a thousand homeopathic granules *Arsenica* 30 CH. He is still doing wonderfully well today, twenty-eight years later… In 1995, he also made a commitment to the *Québec Skeptics* to give a prize of $500,000 to anyone who could experimentally differentiate between two different homeopathic products having a degree of dilution greater than 12 CH. No homeopath or homeopathic "laboratory" has attempted to meet this challenge during the five years this prize has been offered...

between New York and Los Angeles with the accuracy of one millimeter! It is on this kind of precise match between theoretical predictions and experimental verifications that the confidence we now have in quantum theory has been built. Notwithstanding the strangeness of some of its concepts…

1.7 Homeopathic succussion

To ensure proper homogenization, Hahnemann [4] shook the liquid containing the active ingredient at each dilution step.

> *« For homœopathic purposes, this dilution is performed by well shaking a drop of the medicine with a hundred drops of a non-medicinal fluid; from the bottle so shaken, a drop is taken and shaken up in the same manner with another hundred drops of unmedicinal fluid, and so on. »*

He believed in doing so, not only to homogenize each dilution, but to increase the potency of the active ingredient.

> *« Medicinal substances are not dead masses in the ordinary sense of the term, on the contrary, their true essential nature is only dynamically spiritual — pure force, which may be increased in potency by that most wonderful process of trituration (and succussion) according to the homœopathic method, almost to an infinite degree. »*

Hahnemann's speech here borders on delirium. What does this affirmation mean concretely, saying that the *"true essential nature"* of matter would be *"dynamically spiritual — a pure force which may be increased in potency by the process of trituration and succussion"*? It is, however, on this kind of delirium that homeopaths rely today to find "energizing" virtues in homeopathic triturations and succussions which, according to them, would amplify the healing power of their products.

To give an appearance of scientificity to the case, they are now trying to link these succussions to quantum effects such as *entanglement*. The intimate contact that these succussions would produce would ensure that the active ingredient and the water molecules would remain in permanent contact, via the quantum amplitude that describes them, even after the active ingredient had completely disappeared. after dilutions. Some like Milgrom [11], go even further, claiming that this *quantum entanglement* extends to include in a big whole, at the same time the therapist, the patient and the granule! (See Box 10 on this subject.) Which would explain, among other things, according to them, why homeopathy cannot lend itself to statistical studies on the therapeutic efficacy of its products. Because it would not necessarily be the product itself which would act, but rather this new quantum trinity *therapist-patient-granule* which would now act as an inextricable whole and which would condition the result of the treatment. Phew!

Box 10. *Quantum entanglement*

⚠ When calcium (Ca) atoms are excited using a krypton fluoride (KrF) laser, a cascade of *entangled* UV photon pairs is produced, i.e., each photon pair is described by a single quantum wave function Ψ where each photon has a 50% probability of being polarized in an **H** plane, or in a **V** plane, perpendicular to the first. If one of the photons is polarized in a plane, the other is necessarily polarized in the same plane.

The wave function Ψ describing the two photons forms a unique *non localized* system[k] as if the two photons formed a single particle, even if they are very far apart. If we make a measurement on one of the two photons and we see, for example, that it has an **H** polarization, then we can be sure that the other also has the same **H** polarization.

So far, nothing fancy.

The classical explanation is that, as soon as they are emitted, the photons already have an **H** or **V** polarization. If we measure the polarization of one of the two photons, and we see that it is **V** polarized, then, of course, the other must be **V** polarized.

It's full of common sense. But that is not what quantum theory says.

The quantum explanation is that when emitted, the photons do not "know" their polarization. A bit like the photons that we send onto a glass slide do not "know" in advance whether they will be reflected or transmitted.

Initially, their polarization is *indeterminate*. But the two photons form a single system described by the quantum wave Ψ, whatever the dimensions of the system!

If we detect one of the two photons and we see that it is **V**-polarized, say, then the other "learns" instantaneously that it is also **V**-polarized. Even if the distance between the two photons were such that " information" would have been transmitted faster than the speed of light.

This quantum interpretation was presented by Schrödinger in 1935. Einstein found it "unreasonable" because it shocked his conception of *local realism*. Making a measurement on a particle in a given place could not instantly influence, according to him, the state of another particle elsewhere. He proposed that particles must have "hidden variables" that determine their state at the very moment of their emission.

It took 45 years to be able to settle the question with a decisive experiment: that of Alain Aspect who experimentally demonstrated in 1982-1984 the violation of *Bell's inequalities* confirming that the quantum interpretation was correct.

This quantum interpretation in no way violates the relativistic principle that the transmission of information (which necessarily involves the transmission of energy, in physics) cannot travel faster than light. Because even when the state of one of the particles has been determined, the state of the other *entangled* particle remains just as probabilistic. Only a measurement on this other particle will make it possible to determine its state. There is therefore no *"instantaneous communication"* here, in the physical sense of the term.

But what is important to note here is that this phenomenon of *quantum entanglement* can only occur if the characteristic action of the particles involved is of the order of $\hbar$. In the case of KrF laser emission, the two entangled photons each have an energy E of 5 eV (or 8×10^{-19} J) and are located in the near ultraviolet spectrum with a pulsation ω of 7.6×10^{15} Hz. Their characteristic action is therefore equal to $2E/\omega$, i.e.,

$$(2\times8\times10^{-19}\,\text{J})/(7.6\times10^{15}\,\text{Hz}) = 2.1\times10^{-34}\ \text{J-s},$$

which is equal to $2\hbar$.

If the characteristic action of a system of two entangled particles is equal to $2\hbar$, one can easily generalize for a system with N particles where the characteristic action would be equal to $N\hbar$. We immediately see the difficulty of

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[k] To characterize this essential aspect of the quantum world, Lévy-Leblond [10] proposed the term *"implexity"*, in reference to the etymological meaning of the Latin *implicare*.

obtaining a system where the number N of entangled particles could be high: the *characteristic action* would become very large compared to $\hbar$ and would be outside of the *quantum domain*. The *entanglement* of the quantum wave describing these N particles would eventually destroy the *entanglement*.

When we see, for example, certain authors, Ho [7], speak of zones of molecular coherence and quantum entanglement having a radius of 100 nm, involving a billion molecules, themselves composed of tens of protons, neutrons, electrons, etc., one can imagine the gigantic characteristic action involved which would then be billions of times greater than $\hbar$. Which would once again take us completely out of the *quantum domain*. And what to say now when the entanglement would involve at the same time the therapist, the patient and the homeopathic granule, thus putting billions of billions of times more particles in play?... — See Milgrom, [11]. We would probably be then in a *psychedelic domain…*

1.8 The characteristic action of homeopathic succussion

To find out if we can expect some quantum effect from homeopathic succussion, the recipe is simple: evaluate the *characteristic action* of a succussion and compare it to $\hbar$. This assessment is presented in Box 11.

Box 11. *Calculation of the* characteristic action *of homeopathic succussion*

⚠ To find out the parameters that would allow us to evaluate this *characteristic action*, we asked Mr. Luc Delem, responsible for homeopathic preparations at *Laboratoires Homéodel*, in Quebec City. At *Homéodel*, each dilution is made with a quantity of 0.1 mL from a previous dilution, diluted in 10 mL of water. This new dilution is then shaken 100 times, with an amplitude L of 3 cm, at the frequency f of 18 shakes/second.

The evaluation of a *characteristic action* requires a certain physical sense in order to properly determine the quantities characterizing a system. If we assume here that all of the 10 mL of water contributes to the homeopathic properties of succussion, the characteristic mass M involved would then be equal to 10 g. In the case of a periodic movement — such as succussion — the pulsation ω appears more natural than the frequency f for evaluating the characteristic action. The relation between these two quantities is: $\omega = 2\pi f$.

Thus, the *action A characteristic* of a homeopathic succussion of n shakes will be:

$$A = nML^2\omega.$$

By expressing these last three quantities in the *International System of Units* and multiplying the whole with n = 100, we obtain:

$$A = (100)(0.01\ \text{kg})(0.03\ \text{m})^2(2\pi \times 18/\text{s}) = 0.1\ \text{J-s}$$

We note that this *characteristic action* is equal to $10^{33}\hbar$! In Box 3, it was shown that the characteristic action of a ping-pong ball launched at 1 m/s against a concrete wall one meter thick was equal to $10^{31}\hbar$. The *characteristic action* of a homeopathic succussion being 100 times greater, this means that the probability of one day seeing a quantum effect arise in homeopathy is even lower than that of seeing one day a ping-pong ball go through a concrete wall 100 meters thick…

1.9 Conclusion of Section 1

The *characteristic action* of a homeopathic succussion being very large compared to $\hbar$, this places us squarely outside the *quantum domain*, very far in the *classical domain.* Homeopathic succussions therefore have *characteristic actions* completely foreign to quantum physics. If the presumed effects of these succussions one day find a physical explanation, it is surely not from quantum physics that it will come.

1.10 Some advice to Dr. René-Philippe Halm…

The *characteristic actions* found in homeopathy completely exclude it from the quantum domain. In other words: quantum physics cannot be used to explain how homeopathy supposedly works.

To Dr. René-Philippe Halm [5]— whom I quoted at the beginning of the text — I would like to give the following advice:

If someone invokes quantum physics to explain any homeopathic effect, ask him what is the *characteristic action* of this effect.

If your interlocutor seems to ignore the meaning of what is a *characteristic action* in physics, you are dealing with an amateur who knows nothing about quantum physics. Don't waste your time listening to his nonsense. Above all, avoid disturbing Professor Lévy-Leblond with this!

If your interlocutor gives you a quantitative estimate (expressed in J-s) of this *characteristic action*, that is already good. Now ask how this *characteristic action* compares to Planck's constant $\hbar = 1.05 \times 10^{-34}$ J-s.

If this *characteristic action* is of the order of $\hbar$, it can be interesting. I am convinced that Professor Lévy-Leblond — who told you precisely in his answer to be *" interested in these pseudoscientific drifts and quite ready to respond to other requests from you in this field "* [5] — might want to take a look and give you an expert opinion on the relevance of the invoked quantum effect.

If this characteristic action is not of the order of $\hbar$ (either because it is too large or because it is too small compared to $\hbar$), you are dealing with an impostor. The effect he invokes is surely not explained by quantum physics. Don't waste your time (and even less that of Professor Lévy-Leblond) listening to his nonsense...

There is another category of impostors who are perfectly aware that their claims do not fall within the quantum domain as defined by Planck's constant, but who claim to have developed outside this domain an "extension" of quantum theory they call *Weak Quantum Theory (WQT)* — Weingärtner [19]. This quantum theory is weak indeed! It appropriates typically quantum effects to apply them without reason to the classical domain, which allows it to say anything. Know that this *WQT* is not physics.

But in some cases, the imposture is so obvious that you could recognize it yourself, dear Dr. Halm, without the help of Professor Lévy-Leblond. We saw at the beginning that Planck's constant $\hbar$ was equal to 1.05×10^{-34} joule-second and that one *joule-second* has the dimension of an *action* in physics. However, if one day you come across a text in which the author expresses Planck's constant in " joule " — which is a unit of *energy* — rather than in " joule-second " — a unit of *action* — you would be entitled to wonder if this person makes the distinction between an *energy* and an *action* in physics. It can be a typo, of course, anyone can make a mistake. But if this author is careful to add that :

> [l] *" Planck's constant defines the minimum energy that a system is likely to exchange with the outside. In the universe, no action can take place if it involves an energy lower than the value of Planck's constant, i.e., 6.22.10-34 Joules."* Marc Henry [6]

So there's no doubt that this person doesn't understand anything about Planck's constant, which is nevertheless the *abc… h* of quantum physics. That's okay, not everyone has to know quantum physics. But when this person then presents himself as a Professor of Chemistry at the University of Strasbourg and a specialist in quantum physics of complex materials, then you have the right to doubt his competence. If, moreover, this Professor, relying on his ignorance of physics, then undertakes to support homeopathy with other nonsense like this:

> [m] *"As soon as we take into account the inescapable duality matter/vibration, we can put the healing information on the vibration (the quantum field) as soon as there is no more active matter. Water plays a crucial role here in conveying coded information on what are called 'domains of coherence'".* Marc Henry [6]

There, you can be sure of dealing with an impostor.

This obscurantism then spread, at the speed of the shadows, from the University of Strasbourg to the University of Rouen. As evidenced by the thesis entitled *"Quantum hypotheses of the mechanism of action of high homeopathic dilutions"* presented by Mathieu Palluel [12] at the University of Rouen for the state diploma of doctor of pharmacy. A doctoral thesis is normally a serious document. However, what do we learn on page 188 of this thesis? That Planck's constant (unnormalized) would be equal to 6.622×10^{-34} joule. Not *joule-second* as it should be, but just *joule*. Typo again? Perhaps, except that the author repeats this typo five more times in the following pages[n]. And we end up understanding on page 189 that it was not at all a careless error on his part since he repeats word for word the absurdity that Henry [6] served us previously, namely that *" Planck's constant defines the minimum energy that a system is likely to exchange with the outside. (...) "*. That none of the four members of Mr. Palluel's thesis jury pointed out these absurdities speaks for itself about their incompetence in quantum physics and their inability to judge a thesis that claims to be based on this theory. It also says a lot about the value of a doctoral degree in pharmacy awarded by the University of Rouen. As well as on the inability of the chemistry department of the University of Strasbourg to judge the competence of its professors to teach quantum physics. Poor students...

1.11 Maintaining the illusion of scientific legitimacy

Throughout the 19th century, homeopathy was able to prosper away from our ignorance of the reality of atoms. Several were already questioning his claims about the properties of these extreme dilutions and these energizing succussions — as evidenced by the writings of Hahnemann [4] who, in return, treated them as ignorant… But we still had no scientific evidence for or against these hypotheses, for lack of knowing the value of Avogadro's number, the key to knowing the size of atoms. After all, if this Avogadro's number had a value greater than 10^{60} molecules/mole, there would still have been a few atoms of the active ingredient, even after a dilution of 30 CH, and it could have happened that Hahnemann's hypothesis had some basis.

But when in 1908, Jean Perrin was able to experimentally establish the value of Avogadro's number at 6.022×10^{23} molecules/mole allowing at the same time to finally determine the size of atoms, the homeopathic theory collapsed. Hahnemann's hypothesis that matter could subdivide indefinitely and that some of the active ingredient always remained after all these extreme dilutions had just been refuted. A simple calculation made it possible to conclude that for dilutions greater than 12 CH, there were no longer any molecules of the active ingredient. (See Box 8.) This was definitive proof that higher dilutions could not have any physical effect.

Normally therefore, from 1908, we should have sent homeopathy to the cemetery of hypotheses refuted by the facts. But that was without counting on the mercantile interests of an industry that had become very lucrative over time. We can understand the resistance of homeopaths at the time, faced with a scientific discovery that made both their doctrine and their business obsolete.

However, if no one is supposed to ignore the law, even less those of nature. What would have been noble and honest (I'm dreaming a bit here!) would have been that, following this great discovery by Perrin, homeopaths convened — perhaps not as early as 1908 (Perrin having published his discovery in 1909), but shortly afterwards, around 1910, let's say, to give them time to draw the necessary conclusions — convene, I say, a *World Congress of Homeopathy*. First, to apologize for having (perhaps unwittingly) deceived thousands of people for more than a century about the proclaimed virtues of homeopathy. But also to officially announce to the whole world that the homeopathic doctrine had just been scientifically refuted, that it could not work given the absence of molecules of the active ingredient above 12 CH and that consequently all homeopathic medicines would therefore be withdrawn from drugstores, homeopathic laboratories would cease to produce them and homeopaths would undertake to advise their patients against using them. At the end of the congress, the *International Association of Homeopaths* would have scuttled itself. It would have been noble, honest and beautiful. Something to restore your confidence in human nature.

But that's not what happened. Human nature being what it is, homeopaths continued their practice. Homeopathy has survived until today by clinging pathetically to the latest advances in science. Not to try to find a scientific basis for homeopathy. It would have been lost anyway. But to at least give an appearance of scientificity.

To make believe in quantum effects that would endorse homeopathy is very easy. Few people know quantum physics. It is therefore very easy in these circumstances for homeopaths to say anything and thus maintain in the public the illusion of scientific legitimacy.

This memorable year 1908 when Perrin measured the number of Avogadro allowing to finally know the dimension of the atoms will therefore have marked the history of homeopathy. This is the year when homeopaths — at least those who persisted in prescribing, manufacturing or selling their empty granules — all officially became charlatans…

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[l] Free translation of the original text in French.

[m] Free translation of the original text in French.

[n] Palluel's ignorance of the most elementary notions of physics is still apparent on page 188 of his doctoral thesis when he teaches us that *momentum* is measured in *m/s* instead of in *kg•m/s*...

2. Homeopathic granules made amnesic

2.1 How homeopathic procedures erase part of molecular information

After the shock caused by the discovery of Perrin in 1908 implying that dilutions above 12 CH no longer contained any molecule of the active ingredient, homeopaths then invented the following thing: despite the absence of any active molecule, they began to claim — still without proof of course — that the homeopathic granules nevertheless contained a *"healing message"* which was transmitted to the patient. Asked to explain a little more what they meant by that and how it was possible, they embellished it by adding this fable on the *" memory of water "*. (See Larivée [8]) No details, however, on the nature of this mysterious message, nor on the information it would contain, or on the mechanism for recording this information, either in the structure of the water molecule or either in the *" coherence "* of the liquid, even less on how this *message* could pass from water to the granule, then from the granule to the patient, etc. But this imprecision was perhaps intentional. After the shock undergone in 1908 by the discovery of Perrin which destroyed the myth on the infinitesimal character of the matter, the homeopaths sought perhaps to move away from any risk of verification a little too tight on the validity of the homeopathy and the reality of this famous *message*. By taking great care to wrap it in an esoteric vagueness, perhaps they thought they were protected from scientific curiosity for a long time.

But no luck. After the shock of 1908, another awaited them in 1948 when Claude Shannon [17] laid the foundations of *information theory* linking the concept of *information* to that of *entropy* in thermodynamics. It has been known since the 19th century that increasing the temperature of a substance increases the *" disorder "* in this substance, which decreases the internal energy convertible into *work* (in the physical sense of the term). This measure of *"disorder"* has been called *"entropy"*. It is Ludwig Boltzmann, at the end of the 19th century, who established the famous relation $S = k \ln \Omega$ which makes the bridge between the *entropy S* and the *disorder* " ln Ω " [o], through the intermediary of the constant *k* which now bears his name. A relationship which we will use a little further to apply it to homeopathy.

What Shannon demonstrated in 1948 is that *information* is the opposite of *disorder*, the negative of this *" entropy "* that we already knew in thermodynamics. For this reason, *information* is now synonymous with *negentropy*. And *information* has therefore become a measurable physical quantity considered today as one of the important constituents of the Universe, in the same way as *energy* or *mass*. In astrophysics, we thus measure the *nuclear, electromagnetic* or *gravitational information* contained in the laws of nature [p]. In telecommunication and informatics, engineers work every day with this physical quantity to design their systems. In genetics, we measure the information contained in DNA. The notion of *bit* or *byte* to measure information, or that of *baud* to measure the speed of transmission of information are now familiar to anyone who has ever bought a computer or has ever connected to the web.

Curiously, homeopathy has remained on the sidelines of this information revolution that began more than 70 years ago, despite claiming to write a message in the memory [q] of water, a message that would be transmitted to the patient through the homeopathic granule. So many concepts which should however, be measured in bits and bauds. Unless this message is of a nature other than physical. Mystical, perhaps? Or esoteric? This is what we will see in the next sections by confronting homeopathy with this new physics of information. But first, let's look at an effect that homeopaths attribute to succussion.

2.2 Homeopathic energization

Homeopaths make a big deal of what they call the *"energization"* or *"energizing effect"* of homeopathic succussions that somehow *"imprints"* the *"homeopathic message"* onto the solvent molecules, *"message"* that would remain even after the active ingredient is gone. Hahnemann [4], as we saw in the first part, thought that the active ingredient did not disappear following extreme dilutions, but claimed that homeopathic succussions released *" pure, dynamically spiritual forces "*.

For a physicist, this language is pure gibberish. Some of Hahnemann's contemporaries were not shy about questioning this kind of assertion by opposing it with a quantitative argument. But nothing helped. He treated his detractors rather disdainfully as "arithmeticians". As evidenced by the following quotation, where Hahnemann speaks of the energy " released " by the friction of steel on a stone, which he compares to that " released " by succussion.

> *" (Steel contains)*, he says, *an inexhaustible store of energy which is not calculable by the cyphers of any of those arithmeticians who seek to limit nature and render her contemptible, by applying their multiplication table to the phenomena of her illimitable forces."*(Hahnemann [4]).

Defying Hahnemann, let's have fun playing *arithmeticians* by evaluating the *characteristic energy* of such homeopathic succussions; to see how it compares to the ionization energy of atoms, for example, or the thermal energy of intermolecular collisions. We will then draw the appropriate conclusions. (See Box 12.)

Box 12. *Calculation of the* characteristic energy *of a homeopathic succussion*

⚠ The *energy* E_{succ} *characteristic* of a homeopathic succussion of *n* shakes is obtained by the relation:

$$E_{\text{succ}} = nML^2\omega^2.$$

where $n = 100$ (if we take the data provided by Homéodel appearing in Box 11) and where $M = 10$ g is the shaken mass, $L = 3$ cm the amplitude of the shakes and $\omega = 2\pi \times 18/\text{s}$ the pulsation of the shake. Which give :

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[o] More precisely, this " disorder " is defined as the logarithm of the number Ω of accessible states of all the molecules of the substance. (Boltzmann was so proud of this relationship $S = k \ln \Omega$ that he asked for it to be inscribed on his grave!)

[p] The reader interested in knowing more about the entropy-information duo in astrophysics can consult the beautiful book by Hubert Reeves [15] — *L'heure de s'enivrer. L'univers a-t-il un sens ?*— where he will find a bright and accessible presentation of these two concepts.

[q] Do not confuse here what homeopaths call *"water memory"* with what is called *"molecular information"*. The first is a fuzzy, unmeasurable concept that does not correspond to any known physical property of water. While the second is defined as the negative of entropy, a quantity measurable in J/°K and which constitutes a physical property of substances. The concept of entropy has been well known since the beginning of the 19th century, having been used by engineers of the time (such as Sadi Carnot) to optimize the efficiency of the first steam engines.

$$E_{\text{succ}} = (100)(0.01\ \text{kg})(0.03\ \text{m})^2(2\pi\times 18/\text{s})^2 = 12\ \text{J}.$$

That's not a lot of energy. To give you an idea, a kW-h of electrical energy costs approximately 7¢ in Quebec and is equal to 3.6×10^6 J. The *characteristic energy* of 100 homeopathic shakes therefore represents approximately three millionths of a kWh or 3×10^{-6} kWh. If we placed our 10 g of solvent in a 500 W microwave oven, it would only take 24 ms (!) to provide the same energy. (So it's high time for homeopathic labs to modernize a bit by doing their homeopathic succussions with a microwave oven that would shake their water molecules at the formidable frequency of 2.4 billion oscillations/second — instead of their lousy 18 shakes/second — and all that in the blink of an eye of 24 ms...)

What happens to this E_{succ} energy of 12 J once supplied to the 10 g of water serving as a solvent? The multiple intermolecular collisions resulting from the thermal agitation will distribute this energy about equally on average between the water molecules, which will be agitated a little more (in translation, in rotation and in vibration). One calorie (or 4.18 J) supplied to 1 g of water increases its temperature by 1°C; 12 J of energy (i.e., about 3 calories) supplied to 10 g of water will therefore increase its temperature by about 0.3°C.

One mole of water weighs 18 g. This means that in 10 g of water, the number of molecules is about half Avogadro's number, or 3×10^{23} molecules. If we distribute between these 3×10^{23} molecules, our energy E_{succ} of 12 J coming from our shakes, we obtain an average energy per molecule:

$$E_{\text{succ/mol}} = 4\times10^{-23}\ \text{J/molecule}.$$

The electronvolt (eV) which is worth 1.6×10^{-19} J is a more practical unit of energy to express the energies involved at the molecular and atomic level. We will use it from now on to rewrite $E_{\text{succ/mol}}$ as:

$$E_{\text{succ/mol}} = 2.5\times10^{-4}\ \text{eV/molecule}.$$

A sixth of this energy will be used by the water molecule to increase its speed of translation along the 3 degrees of freedom relative to the 3 dimensions of space. The remaining 5/6 will serve to excite the energy of rotation and oscillation of the three atoms of the H_2O molecule. In all, the energy $E_{\text{succ/mol}}$ will be redistributed within the molecule approximately equally between its 18 degrees of freedom. Each degree of freedom receiving an energy $E_{\text{succ/mol/deg-lib}}$ equal to

$$\begin{aligned} E_{\text{succ/mol/deg-lib}} &= (1/18)(2.5\times10^{-4})\ \text{eV/deg-lib} \\ &= 1.4\times10^{-5}\ \text{eV/deg-lib}. \end{aligned}$$

It is at this last level that we will find distributed the original energy E_{succ} of 12 J coming from homeopathic succussion. We can compare this energy $E_{\text{succ/mol/deg-lib}}$ coming from homeopathic succussion with the thermal energy per molecule $E_{\text{therm/mol}}$ already present in water at 20°C (or 293°K):

$$E_{\text{therm/mol}} = \tfrac{1}{2} f kT$$

where f is the number of degrees of freedom of the molecule (18 in the case of the H_2O molecule) and where $k = 8.6\times10^{-5}$ eV/°K is the Boltzmann constant. That is :

$$\begin{aligned} E_{\text{therm/mol}} &= \tfrac{1}{2}(18)(8.6\times10^{-5}\ \text{eV/°K})(293\text{°K}) \\ &= 0.2\ \text{eV/molecule}. \end{aligned}$$

The $E_{\text{succ/mol/deg-lib}}$ energy is therefore 14,000 (!) times less than the thermal energy:

$$E_{\text{succ/mol/deg-lib}} = (7\times10^{-5})\ E_{\text{therm/mol}}.$$

If we now compare this energy $E_{\text{succ/mol/deg-lib}}$ with the $E_{\text{ion-H}}$ energy of 13.6 eV that must be supplied to a hydrogen atom to ionize it (i.e., to tear away its electron), we have

$$E_{\text{succ/mol/deg-lib}} = (10^{-6})\ E_{\text{ion-H}}$$

i.e., one million (!) times less than the ionization energy of hydrogen.

The excitation energy $E_{\text{excit-atom}}$ of atoms is of the order of eV. That of excitation of molecules, $E_{\text{excit-molecule}}$, is of the order of 0.1 eV. The energy $E_{\text{succ/mol/deg-lib}}$ from succussion is therefore 70,000 times lower than the excitation energy of atoms and 7,000 times lower than that of molecules.

What can we conclude from the calculation in Box 12?

That homeopathic *"energization"* provides

- at each degree of freedom of the water molecule, 14,000 times less energy than the thermal energy already present and therefore practically does not affect the intensity of collisions between molecules;
- 7,000 times less energy than that required on average to excite a molecule,
- 70,000 times less energy than that required on average to excite an atom,
- and 1,000,000 times less energy than that required to ionize a hydrogen atom.

The *"energization"* from homeopathic succussion is therefore at least 7,000 times too weak, in terms of energy, to *"imprint*" any *"message"* whatsoever in the form of excitation (and even less ionization) of atoms and molecules present.

2.3 Homeopathic **succussions** *destroy* **information**

Shannon's relationship between *information* and *entropy* will allow us to measure the effectiveness of homeopathic processes to inscribe information in matter and to test, at the same time, the physical reality of this homeopathic message.

We saw in the previous section that homeopathic succussion had the effect of increasing the temperature of the solvent by 0.3°C. This is not much, of course, but — it is the principle that counts here — by increasing the temperature, we at the same time increase the entropy of the solvent. And who says increase in entropy of a system, says at the same time decrease in the information present in this system. (See Box 13 for the calculation of this information loss.)

Box 13. *Calculation of the information loss resulting from* succussion

⚠ If the temperature of a substance (solid, liquid or gas) is increased by a quantity ΔT, the entropy of this substance is increased by a quantity ΔS according to the relationship (Sears, [16]): [r]

$$\Delta S = mc_p \ln\left(1 + \frac{\Delta T}{T}\right)$$

where m is the mass of this substance; c_p its specific heat at constant pressure; T the initial temperature (in degrees Kelvin) and where $\ln(x)$ is the natural logarithm function. (Scientific calculators have an "$\ln x$" or " LN " key to calculate this function.) In the case of homeopathic succussion carried out according to the data in Box 11, we would have :

a mass	$m = 0.01$ kg,
specific heat at constant pressure	$c_p = 4.18\times10^3$ J/(kg · °K),
an initial temperature	$T = 20$°C (or 293°K)
a temperature increase	$\Delta T = 0.3$°K.

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[r] Notice the similarity between this relationship and the Boltzmann equation $S = k\ln\Omega$. This is no coincidence since this relationship derives from the Boltzmann equation.

Which would give, after a first dilution to 1 CH, an increase in entropy $\Delta S_{1\text{CH}}$:

$$\Delta S_{1\text{CH}} = (0.01)[4.18 \times 10^3] \cdot \ln\left(1 + \frac{0.3}{293}\right)$$

$$\Delta S_{1\text{CH}} = 0.04\ \text{J/°K}.$$

This increase $\Delta S_{1\text{CH}}$ of entropy is accompanied by a loss $\Delta I_{1\text{CH}}$ of *molecular information* (expressed in bits) according to the relationship

$$\Delta I_{1\text{CH}} = -\frac{\Delta S_{1\text{CH}}}{k \ln 2} = -\frac{0.04\ \text{J/°K}}{(1.4 \times 10^{-23}\text{J/°K}) \times 0.69}$$

$$= -4 \times 10^{21}\text{bits} = -5 \times 10^{20}\text{bytes},$$

where $k = 1.4 \times 10^{-23}$J/°K, is the Boltzmann constant.

This loss of molecular information comes from the fact that by increasing the temperature, one increases the uncertainty on the speed distribution of the molecules as well as on the number of states accessible by each molecule.

If this succussion is repeated after each dilution of one CH, the entropy will increase accordingly. At 30 CH, this information $\Delta I_{1\text{CH}}$will be destroyed 30 times:

$$\Delta I_{30\text{CH}} = 30\Delta I_{1\text{CH}} = (30)(-5 \times 10^{20}\text{bytes})$$

$$\approx -1.5 \times 10^{22}\text{bytes}.$$

In computer science, we measure the storage capacity of information in bytes which group together 8 bits. For example, my computer's hard disk has a capacity of 913 GB (913 gigabytes or $9.13{\times}10^{11}$ bytes). They are manufactured today with a capacity greater than 1 TB (1 terabyte or 10^{12} bytes). Which means that the loss of information resulting from the homeopathic succussion after a dilution to 30 CH, amounts to erasing the hard disk of at least 15 billion computers...

Thus, not only is the energy from homeopathic succussions too weak to *"imprint"* any *"information"* whatsoever on the molecules of the solvent, but these succussions have exactly the opposite effect to the claims of homeopaths: instead of *" transmitting or printing a message "*, they rather erase part of the molecular information already present in the solvent! And this destruction is massive. The equivalent of erasing five times the hard disk contents of ALL computers on Earth.

2.3 Homeopathic **dilutions** *also destroy* **information**

Box 8 showed how to obtain a homeopathic dilution of 1 CH by taking 1 cm^3 of a solute (containing the active ingredient) which was then diluted in 99 cm^3 of water. In doing so, we increased the *entropy* of our solute and thereby destroyed *molecular information*. Why ? Because dilution increases our uncertainty about the position of each of the solute molecules. Thus a molecule of the solute which one could locate with certainty at the start as being inside a certain volume of 1 cm^3 is found, after dilution, inside a volume 100 times larger. If you had been asked to locate this molecule after dilution, you would have had only one chance in 100 of locating it in a certain volume of 1 cm^3. The dilution had therefore just made you lose information on the position of this molecule as well as on all the other molecules of the solute. How much information has been lost this way? The answer can be found in Box 14.

Box 14. *Calculation of the information loss resulting from* dilution

⚠ The dilution of a solute (containing the active ingredient) leads to an increase ΔS in the entropy of the solute, according to the relationship (UCDavis [18]): [s]

$$\Delta S = \alpha N_A k \ln\left(1 + \frac{\Delta V}{V}\right)$$

where α is the number of moles of the solute, N_A the Avogadro's number, k the Boltzmann constant, V the volume initially occupied by the solute and ΔV the increase in volume occupied by the solute once diluted in the water.

According to the data in Box 11, where α= (0.1 g)/(18 g) = 0.006 mole, V = 0.1 cm^3 and ΔV = 9.9 cm^3, the increase in entropy after a first dilution of 1 CH would be :

$$\Delta S_{1\text{CH}} = (0{,}006)(6 \times 10^{23})(1{,}4 \times 10^{-23}) \ln\left(1 + \frac{9{,}9}{0{,}1}\right)$$

$$= 0{,}2\ \text{J/°K}.$$

This increase $\Delta S_{1\text{CH}}$ of entropy is accompanied by a loss $\Delta I_{1\text{CH}}$ of information (expressed in bits) according to the relation

$$\Delta I_{1\text{CH}} = -\frac{\Delta S_{1\text{CH}}}{k \ln 2} = -\frac{0.2\ \text{J/°K}}{(1.4 \times 10^{-23}\text{J/°K}) \times 0.69}$$

$$= -2 \times 10^{22}\text{bits} \approx -3 \times 10^{21}\text{bytes}.$$

The loss of information resulting from a dilution of 1 CH therefore amounts to erasing the equivalent of the hard disk of at least 3 billion computers.

With each dilution of an additional CH, the entropy increases, but 100 times slower than at the previous dilution since the number of moles of the active ingredient is 100 times less at each stage. This means that even after a series of 30 successive homeopathic dilutions, the final entropy will hardly have increased by more than 1% compared to the increase in entropy resulting from the first dilution. In fact, this entropy will even have stopped increasing from 12 CH since there will already not be a single molecule of the active ingredient to be diluted left there. The cumulative loss of information $\Delta I_{>12\text{CH}}$ suffered, beyond 12 CH will therefore be:

$$\Delta I_{>12\text{CH}} = (1{,}01)(-3 \times 10^{21}\text{bytes})$$

$$\Delta I_{>12\text{CH}} \approx \Delta I_{1\text{CH}} = -3 \times 10^{21}\text{bytes}$$

The bulk of the loss of information therefore occurred from the first dilution.

To illustrate the loss of information resulting from dilution, imagine that you draw a black line on a white sheet with a graphite pencil. By depositing carbon atoms on the sheet, you have just written *molecular information* on it. This information comes from the fact that the carbon atoms of your pencil stroke are not scattered randomly, but concentrated in specific places on the sheet, even forming a certain alignment. The *meaning* of this pencil line is irrelevant as far as *information* is concerned. The important thing here is to see that the distribution of carbon atoms is not random, but has a particular configuration. There is little chance of getting this configuration by throwing a pinch of carbon powder in the air. If you now take an eraser and erase your pencil line, you disperse the carbon atoms. These spread randomly on

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[s] Same remark as in Box 13: The resemblance between this relation and the Boltzmann equation $S = k \ln \Omega$ is not the result of chance…

the sheet (and even next to it). You have thus just increased the *"disorder"* (or the entropy) of your pencil line, as if you had "diluted" it. And you have thereby erased the *molecular information* that was present on your sheet of paper.

The loss of information resulting from a 30 CH homeopathic dilution is 5 times less than that resulting from succussion. But it's still the equivalent of erasing the hard drives of nearly 3 billion computers. That is practically ALL the computers on Earth...

2.4 Conclusion of Section 2

Nothing in the homeopathic processes of succussion or dilution goes in the direction of a local reduction of the entropy of water or solute, necessary for the inscription of a *message* in matter. On the contrary, as we have just seen, these two processes rather have the effect of increasing the entropy of the solute and therefore of massively erasing the *molecular information* already present. We are therefore faced with the following paradox: to write a *message*, homeopaths use a process that has the effect of... erasing *information*. It is as if you decided to write on a sheet of paper using an eraser rather than a pencil. Not sure this is the smartest way to write a message...

Moreover, as no homeopath can give an operational definition of this homeopathic message, so that one can measure — in bits or in J/°K — the information that it would contain, this one is thus excluded by the very fact of the physical domain. It will no doubt be found somewhere else in a magical domain. But certainly not in a homeopathic granule.

If the year 1908 — when Perrin determined the size of atoms — was a landmark year in the history of homeopathy, that of 1948 — when Shannon established the link between *information* and *entropy* — will have been just as important.

It was from that year, in fact, that homeopaths — at least those who continued to claim the physical reality of these homeopathic messages — all officially became impostors...

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