Homeopathic treatments based on nanotechnology?

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According to the National Center for Complementary and Alternative Medicine of the National Institutes of Health, USA, 'Homeopathy is a controversial area of alternative medicine involving highly diluted preparations and its concepts are not consistent with well-known laws of science.' German physician Samuel Hahnemann first proposed this alternate form of medicine in 1796 (Figure 1). During his experiments, he prepared medicines from a wide variety of natural products. In homeopathy, a solution that is very dilute can be described as a more potent state, and more dilute substances are considered to be stronger and deeper-acting remedies. The end-product is often so diluted that it is indistinguishable from the dilutant (pure water, sugar or alcohol). Three logarithmic potency scales are in regular use in homeopathy. Hahnemann created the centesimal or C scale, diluting a substance by a factor of 100 at each stage[1]. A 2C dilution requires a substance to be diluted to one part in 100, and then some of that solution diluted by a further factor of 100. This works out to one part of the original substance in 10,000 parts of the solution. A 6C dilution repeats this process six times, ending up with the original material diluted by a factor of $10^{-6} = 10^{-12}$. The main difficulty in arriving at a rational explanation originates from the fact that homeopathic medicines are used in extreme dilutions, including dilution factors exceeding Avogadro number (6.023×10^{23}) by several orders of magnitude, in which one would not expect any measurable remnant of the starting material to be present. In clinical practice, homeopathic potencies of 30C and 200C having dilution factors of 10^{60} and 10^{400} respectively, far beyond the Avogadro number of molecules in one mole, are routinely used[2]. However, except in a few developing countries like India, homeopathic treatment is not well accepted in the Western countries. The laws of chemistry state that there is a limit to the extent to which a solution can be diluted without losing the original substance completely. Owing to this fact, homeopathy has been disputed right from the beginning. Critics even say that it is not worthwhile to continue the scientific study of homeopathy. Many hypotheses have been postulated to justify and elucidate the mechanisms of action of homeopathic medicines. Although some such as the theory of water memory[3,4], formation of clathrates[5] and epitaxy[6] are conjectural in nature, others such as those based on the quantum physical aspects of the solutions[7] have not been sufficiently tested, either due to complexity in validating the hypothesis or due to irreproducible results. Thus, most of the modern scientific community continue to believe that homeopathy at best provides a placebo effect due to the lack of proper and credible hypotheses to identify any physical reason for its medical activity.

In a recent development, researchers from the Indian Institute of Technology (IIT)-Bombay, have discovered that nanotechnology is the very basis of homeopathic treatments[8]. They have established the origin of homeopathic medicine by carrying out experiments with homeopathic pills made of naturally occurring metals such as gold, silver, copper, platinum, tin, zinc and iron[8]. They prepared highly diluted solutions and examined them under a powerful electron microscope to find nanoparticles of the original metal. These researchers had found similar nanoparticles in the complementary medicinal substances, i.e. ayurvedic bhasmas a few years ago. Using market samples of metal-derived medicines from reputed manufacturers, they demonstrated by transmission electron microscopy, electron diffraction and chemical analysis by inductively coupled plasma-atomic emission spectroscopy, the presence of physical entities in these extreme dilutions, in the form of nanoparticles of the starting metals and their aggregates.

The researchers gave an explanation for the mechanism behind homeopathy based on their experimental findings. Their hypothesis is that the original metals formed nanobubbles and floated on the surface of the highly diluted mixtures. This is how they retained their original potency. The particles of the starting material instantaneously get adsorbed onto the surface of these bubbles and cavitations. This phenomenon could be similar to the mechanism of formation of Pickering emulsions[9–11], wherein the emulsified phase, viz. air bubbles or liquid droplets are stabilized by a layer of particles. This nanoparticle–nanobubble complex rises to the surface and can be within a monolayer once the total metal concentrations are well below 1 ppm. Chikramane *et al.*[8] have shown that the original molecules in nanogram quantities are present in their most potent state contrary to the arithmetic.

With the introduction of nanotechnology, has the recent development in homeopathic treatments opened up the possibility of providing strong scientific

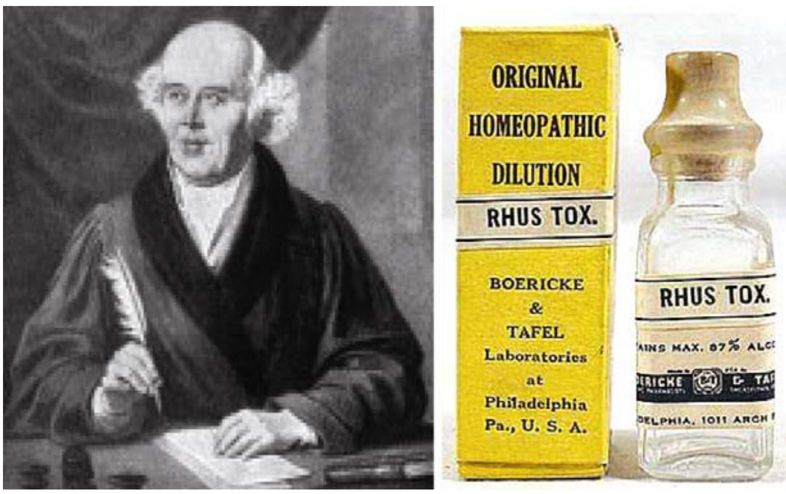

Figure 1. Samuel Hahnemann and the original homeopathic dilution.

explanation to other age-old medicinal practices too? It is up to the National Center for Complementary and Alternative Medicine to answer such an appropriate query. The scientific world is of the opinion that further research has to be carried out to replicate the work done at IIT-Bombay. Only then, the proposed hypothesis of Bellare and his group based on nanotechnology can attain the status of an accepted theory.

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Revisiting the source–sink paradigm in sugarcane

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Extensive research has been directed towards the basic understanding of accumulation of photoassimilates in defined and undefined storage organs in plants. Biophysiological study pertaining to carbon source (leaf)–sink (specialized storage organs, culm parenchyma tissue in sugarcane) communication and its relationship has been better addressed in C_3 over C_4 crops. Nevertheless, sugarcane (*Saccharum* spp. hybrids), a C_4 crop is the best reference crop where the source–sink relationship study has been largely concentrated owing to its ability to accumulate a highly economical product, i.e. sucrose in culm. At the global level, > 70% sucrose comes from sugarcane[1]. Several authors have opined that accumulation of sucrose in sugarcane is principally regulated at the level of sink (cane stalk/culm). Furthermore, futile cycle of degradation–synthesis of sucrose occurring in the culm is also one factor which controls and regulates sucrose concentration; hence all these cellular activities account for variable accumulation of sucrose in the cane stalk. A better understanding of sucrose synthesis and accumulation in sugarcane and its modulation through exogenous or endogenous means leading to higher sucrose productivity would be a boon for sugarcane farmers, millers and associated industries.

The regulatory enzymes, viz. the three invertases, soluble acid (SAI), cell wall-bound (CWAI), neutral (NI); sucrose synthase (SS) and sucrose phosphate synthase (SPS) play an important role in sucrose metabolism. The hydrolysis of sucrose in tissue-free space (apoplast/apparent free space) seems obligatory and rate limiting for sucrose uptake and its storage, which play a central role in spatial and temporal regulation of sucrose accumulation in sugarcane[2]. Continued research on sugarcane has indicated that attributes like delayed leaf senescence, increased sucrose loading rates in source tissues, high photosynthetic activity (electron transport rate) and higher activity of CWAI are found to be associated with the high total sugar phenotype of a sugarcane line having the ability to accumulate a high level of sucrose in the culm[3]. The maximum level of accumulation of partitioned carbon into sucrose is 0.7 M in the sugarcane culm. Normally, the observed sucrose content on dry matter (SCd) basis is 350–400 mg/g; however, the capacity of some lines to accumulate 500–560 mg/g sucrose (SCd) has also been reported[4]. Physio-biochemical processes like rate of photosynthesis, partitioning of carbon pools other than culm storage (respiratory demand of carbon and demand for water-insoluble compounds), loading and unloading of sucrose in the leaf and culm, three-phasic metabolic activity of sucrose in parenchymatous cells (apparent free space, metabolic space and vacuolar storage space), and developmental constraints such as duration and timing of maturation (temperature, drought-dependent maturation and use of ripeners) may accentuate the ceiling of apparent sucrose concentration in the culm. Thus, the physiological threshold of sucrose in the culm may be seen in the context of feedback regulation by biosensors like hexoses, as well as energetic limitations imposed by continuous cleavage and synthesis within the storage pool[5].

In many countries, including India, improvements in sugarcane have been primarily in cane yield rather than sucrose content, which is one of the major constraints in improving sucrose productivity. In view of the limited area, growing domestic demand for white sugar and necessity of extra ethanol production for blending, it is imperative to augment sucrose productivity per se. There is need for targeted breeding with the objective of increasing the concentration of sucrose in the culm. In this regard Lakshmanan *et al.*[6] and Snyman *et al.*[7] stressed upon extensive R&D in the development and utilization of new molecular techniques for better understanding of the fate of sucrose in the culm and the cellular mechanism that regulates sucrose accumulation. Extensive research in this direction has yielded deposition of more than 3 lakh ESTs sequences from more than 40 libraries in public domain (SUCEST project from Brazil), 1515 genomic[8,9] and 342 EST-based SSR