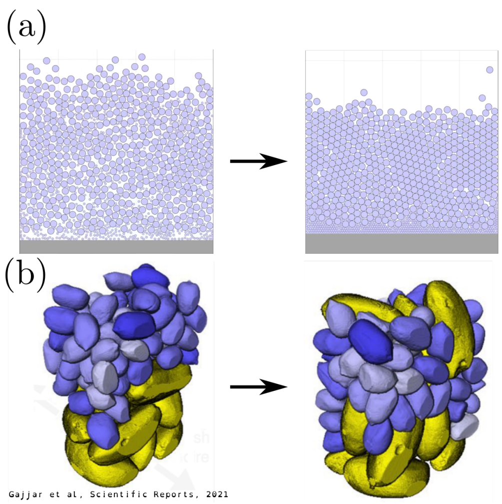

(a) a shaker simulation with a binary mixture of two-dimensional circlular particles. The simulation models the particles using a spring-dashpot based force commonly used in modelling granular matter [1]. Particle size ratio, rather than mass, is the most important factor in segragation when the shaker amplitude and frequency of vibration are suitable. Source code is available at the code-repository. (b) Full 3-D experimental data taken from an actual mixture of peanuts and Brazil-nuts, the more complex geometry plays an as yet not fully understood role, leading to some Brazil-nuts rising from- and some remaining at the bottom [2].

Big Nuts Rise, Sometimes

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The Brazil-nut effect, is the phenomenon of large-sized "particles" rising to the top of a pile composed of large and small particles, when the mixture is vibrated. It gets its name from the observation of this effect in bags of mixed nuts, particularly Brazil-nuts mixed with e.g peanuts. This is despite gravity. That is even though a Brazil-nut is heavier than a peanut, they still rise to the top. Along with being generally intriguing, the effect has uses in sorting real granular materials, and conversely needs to began avoided in certain chemical and medical applications where uniform mixing is required. So why does it happen?

Keywords: Brazil-nut, Granular-materials

Code-repository: Video:

Scientific discussion of the Brazil-nut effect, more correctly segregation in granular matter, appears to have begun in the 50s. At first closely related to industrial practices. With investigations into segragation of granular materials on vibration [3, 4]. Granular materials refer to materials composed of discrete elements, also called particles or granuals, which are roughly macroscopic (visible to the human eye). Where when distinct particles interact this results in a loss of energy, e.g by colliding. For example sand, rocks, and ballbearings all fit the picture. The loss of energy is usually understood by considering collisions between individual particles. Meaning on collision of two particles some kinetic energy is transfered to the environment, by e.g heat or sound, leaving the particles moving with reduced velocity. Parallels can be drawn with basic maths problems on conservation of momentum and elastic/inelastic collisions.

The Brazil-nut effect, as named, was examined computationally by Rosato et al in 1986-87 [5, 6]. Their simulation involved two-dimensional circular particles. With two experiments one with a single large particle and one with particles split in equal proportion between a smaller and larger radius, with a ratio of $2:1$. They did also vary size and mass ratios as well in these two settings. The particles were subjected to gravity, and simulated using an energy minimising monte-carlo process. That means one step in the simulation involved (1) calculating the energy of the system (the particles under gravity) where an overlap between two particles results in an infinite energy; (2) for one particle, generating at random a trial move, a displacement; (3) if that trial move reduced the system's energy, the move was always accepted; (4) if the move increased energy, it was accepted with a given probability dependent on "temperature" (5) The same process is tried once for every particle, once per time step. With this process, a high temperature means more moves that increase energy would be excepted. A very low temperature leads to almost perfect energy minimising behaviour. To simulate shaking, each particle was lifted by a certain height. Once lifted the monte-carlo process was left to settle. This defined one cycle, or "shake".

Higher shaking amplitude, defined by the displacement height each cycle, was strongly correlated with a decreased segragation time with the single large particle. Higher size ratio was also correlated with a decrease in segragation time, and a marked decrease in overall scatter (randomness) in the large particles upward trajectory. The updward rise being a linear trajectory over time. Why it occurs is explained by the creation of "voids" beneath large particles. On shaking gaps underneath large particles are filled, most probably, by smaller ones, blocking the large particles descent. Since for a large particle to move down, many smaller ones must move out of its way, which is unlikely. This results in net upward movement. For the binary mixture the same conclusion can be drawn, with the same dependence on shaking amplitude of the time to segragation.

Particular to these results were the dependence on local geometry giving the results independence of the particles' density ratio. Although specifically invoking 2D spherical objects, the simulation and the effect apply in 3D and with particles of complex shape. Complex particle geometry likely plays a role in the process as well.

Recently Gajjar et al have succeeded in full detail 3-D imaging of the Brazil-nut effect, with actual Brazil-nuts [2]. Two results are apparent, firstly some of the Brazil-nuts segragate by moving to the top of the mixture but some do not, secondly the risen-brazil nuts all appear to change from a slightly non-horizontal orientation (with their direction of largest length aligned withthe floor) to an increasingly vertical one during upward movement, and finally to a roughly horizontal resting place at the top. The experiment raises the important questions as to why and how complex particle geomtry effects segragation.

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