we can display the same information using what are called footprint or radial plots. Figure 1 a–d shows the footprint plots for India, USA, South Korea and Japan. Figure 1 a shows that for India there is an imbalance, with the polygon departing considerably from the circle of radius 1. The Government sector is doing far more than is expected from the world average and the university and industry sectors and the university–industry cooperation leaves much to be desired. In Figure 1 b and c, the footprints for USA and South Korea show a fine balance with the polygon closely corresponding to a circle of radius 1. Figure 1 d reveals that Japan has been able to achieve a remarkably fine balance within the university and Government sectors compared to the world norm, and a healthy imbalance with the industrial sector leading through cooperation with one or both of the other two to produce basic research output far in excess of the world norm.

Balaram’s fear that 'a large fraction of work in our network of national laboratories is academic in nature', is clearly brought out from this study. However, considering the fact that India is doing far too little research overall for its size, the logical step is to increase significantly the amount and quality of research done by the university sector, without disturbing the good work done by the Government sector.


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SCIENTIFIC CORRESPONDENCE

Shock waves can enhance bacterial transformation with plasmid DNA

Shock waves appear in nature whenever the different elements in a fluid approach one another with a velocity larger than the local speed of sound. Shock waves are strong perturbations in aerodynamics that propagate at supersonic speeds independent of the wave amplitude. Such disturbances occur in steady transonic or supersonic fluid during explosions, lightening strokes and contact surfaces in laboratory devices. The typical thickness of the shock front in air is \( \sim 10^{-7} \) m, very small compared to other characteristic lengths in fluid flow. Physically, the occurrence of shock waves is always characterized in a fluid flow by instantaneous changes in pressure, velocity and temperature.

On the other hand, shock waves can be generated in a controlled fashion in the laboratory and the nearly instantaneous changes in the fluid velocity and the pressure produced by shock waves can be used for innovative applications in various fields such as medicine, biological sciences and industry. In the present study, we report a novel shock-wave-assisted bacterial cell transformation technique.

An underwater electric discharge device has been designed, fabricated and successfully used for creating spherical micro-shock waves in the Shock Waves Laboratory at the Indian Institute of Science, Bangalore. Figure 1 shows the schematic representation of an underwater shock-wave generator. Spherical micro-shock waves (few millimetres radius) are generated in water, by instantaneously depositing electrical energy (100 J) between two stainless steel electrodes (1 mm apart) for about 0.35 \( \mu \)s. Peak overpressures up to 100 MPa can be generated for about 10 \( \mu \)s. The water between the electrodes is instantaneously vaporized, creating a tiny vapour bubble. This bubble grows in size and subsequently bursts creating the spherical micro-shock wave. The high voltage applied between the electrodes can be varied to generate shock waves of requisite strength. A high-precision mechanical traverse system is used to hold the eppendorf tubes containing bacterial cells with naked plasmid DNA above the
electrodes. The distance between the bottom of the tube and electrodes can be accurately adjusted (least count 0.01 mm) and monitored using a digital encoder. In most of the current experiments, the distance between the test tube and the electrodes was maintained at ~3 mm and the corresponding pressure measured (PVDF Needle Hydrophone, Ms Muller, Germany) inside the test tube was ~130 bar.

To examine the feasibility of using shock waves in bacterial cell transformation, we used *Escherichia coli* (DH5α) competent cells. The fresh overnight-grown cultures of *E. coli* (DH5α) were inoculated to 100 ml LB and allowed to grow at 37°C for 3–4 h till OD600 reached 0.4–0.5. Then the culture was cooled in ice (for 15 min) and centrifuged at 3000 rpm for 7 min at 4°C. The pellet was dissolved in 10 ml of transformation-storage buffer (TSB, PEG4000-10%, DMSO 5%, MgCl2 10 mM, MgSO4 10 mM, Glycerol 10% v/v, LB 6.1 pH) and centrifuged at 3000 rpm for 7 min at 4°C. The resulting pellet was resuspended in 5 ml of TSB. The resuspended cells were stored in 100 μl aliquots at -70°C after freezing in liquid N2 and used for transformation.

The transformation was done using 10 ng of naked plasmid DNA (pBluescript II containing *uplI* and *gas* genes, Clontech, USA). About 50–100 μl competent cells were mixed with plasmid DNA and exposed to shock waves. After exposure to shock waves, the cells were grown in a medium devoid of antibiotic for 1 h at 37°C, before transferring to an antibiotic (kanamycin 50 μg/ml) selection.

The efficiency of transformation was compared with the KCM method of bacterial transformation, which was found to be efficient under normal laboratory conditions. For the KCM method, competent cells (50–100 μl) were mixed with plasmid DNA (10 ng) and KCM buffer (5 × buffer – 500 mM KCl, 150 mM CaCl2, 250 mM MgCl2). The cells were then incubated in ice for 20 min before keeping at room temperature for 10 min. After incubation, the cells were grown and selected as mentioned above. The isolated colonies were counted to express the transformation efficiency as CFU/μg of plasmid DNA.

We have successfully demonstrated the usefulness of shock waves in bacterial cell transformation. The spherical micro-

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