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Early Warning Signals

Natural systems are dynamic. Trees bloom in spring and shed leaves in autumn. A forest composed of such trees changes character over seasons, years, decades. A region containing such forests, rivers, desserts, and other ecosystems reflects these changes. Even the whole earth is showing possibly irreversible signatures of climate change.

Some of these changes are simply due to the natural variability of dynamical systems - a pendulum swings due to gravity, the changing position of the sun causes seasons, the monsoon rains come and go every year. But external factors such as the human interactions with these systems, for example, construction of a dam or a factory, or reforestation of an area, also affect the progression of these changes. Some of these changes due to external factors can occur quite suddenly instead of gradually - something like the difference between going over a cliff instead of rolling down a slope! These sudden changes may be irreversible and are often called “tipping points.” They may prove to be catastrophic, for example, in the context of ecosystems or other complex systems.

The physical exhibit on ecosystems and tipping points provided a illuminating example of such a phenomenon. Here the position of a light ball (a table tennis ball) indicated the state of a system, for example, say the amount of vegetation. We could think of valley on the right to correspond to a forest landscape (henceforth called forest valley) while the valley on the left to correspond to a desert landscape (to be called desert valley).

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The blowers played the role of external factors such as cutting down trees or re-forestation. Two different types of systems were illustrated by two different "tracks" on which the ball moved.

• In one of them with a tall peak, the ball stayed in the valley which corresponded to large amount of vegetation, even in the presence of external factors. This showed the types of systems that do not show the "tipping point" behaviour.

• In another type of system with a short peak, the ball could "tip over" to the desert valley even with a small external push (from the blowers). This type of system is thus capable of the tipping point behaviour. Note that since the depth of the desert valley was deep, the ball would never revert back to the forest valley, showing irreversibility of this transition. (Of course we can pick up the ball and move it to the forest valley - that may correspond to building a canal from Ganga to Rajasthan!)

This exhibit was created by a team from Indian Institute of Science, Bangalore and it won the first prize in the intercollegiate competition for MPE exhibits, organized by ICTS-TIFR. The detailed report which describes the mathematical aspects of the problems is available on the ICTS webpage for this exhibition, to be soon linked from http://www.icts.res.in/program/MPE2013