very powerful optimizing process of evolution by natural selection[3]. But whereas most of these models calculate quantities (such as energy gain) that are presumed to be correlated to survival or reproductive success, Ishii and Higashi[1] set out to calculate survival itself. To do this, they have formulated a remarkably elaborate model. It goes like this.

Given the length of an understorey tree's trunk and the angle to the vertical at which it is tilted, simple trigonometry gives the height of the crown above the ground. An assumption about the amount of light that is blocked out by taller trees allows the intensity of the light falling on the leaves to be calculated. The quantity of leaves can be estimated from the size of the trunk, and a well-known relationship makes it possible to calculate the rate of photosynthesis from the light intensity.

Assume that if there were no need to allow for its weight-supporting function, the radius of the trunk would be one per cent of its length. Now consider the problem of weight support — taking account of the angle of the tree to the vertical, as well as its height — and calculate how much additional wood is needed in the lower parts of the trunk. From the total volume of wood estimate the metabolic rate of the tree, and subtract this from the photosynthetic rate to obtain the rate at which energy and materials become available for growth.

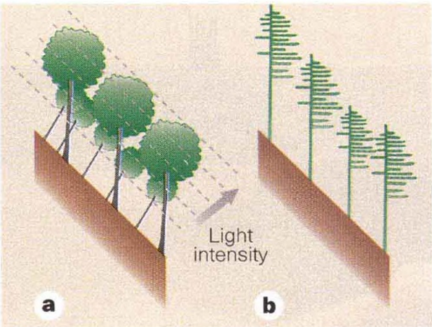


Figure 1 a, **Ishii and Higashi[1] have studied why understorey trees that grow on slopes often incline their trunks downwards. They conclude that there is an optimal angle of growth for maximal survival, and that trees at an angle can get brighter illumination for the leaves by shortening the distance from the canopy surface. Lines of equal light intensity are shown, running parallel to the ground.** b, **The same effect is achieved by trees that have more branches on the downhill side.**

Assume that the lower this rate is, as a fraction of the rate of photosynthesis, the more likely the tree is to die. Calculate the probability of survival from seedling to mature tree by integrating over time, taking account of the rate of growth and the mortality at every stage. Finally, for each angle of slope, calculate this probability of survival for a range of trunk inclinations.

Ishii and Higashi used this procedure to show that, as expected, for any given angle of slope there is an angle of inclination of the trunk that maximizes survival. With environmental and physiological parameters that they select as being plausible for shade-sensitive understorey trees, the authors predict that the optimal angle to the vertical is 0° on level ground, about 10° on a 20° slope, and about 40° on a 50° slope. For shade-tolerant trees, the effect is less marked as light intensity has less effect on their photosynthesis. In the forest that they studied, Ishii and Higashi found the predicted relationship between slope and trunk inclination for one understorey species, *Rhododendron tashiroi*, but there was no significant relationship for another species that was more tolerant of shade.

Surprisingly, it is not clear whether the authors suppose that trees tend to grow towards the light. They find that *Rhododendron* trunk inclination on steep slopes has high variance, and argue that this is consistent with their prediction that, on steep slopes, a range of angles around the optimum will give almost equal survival. This suggests that they envisage seedlings growing indiscriminately at a number of different angles, with only the appropriately angled trees surviving to maturity. ▶

Earthquakes

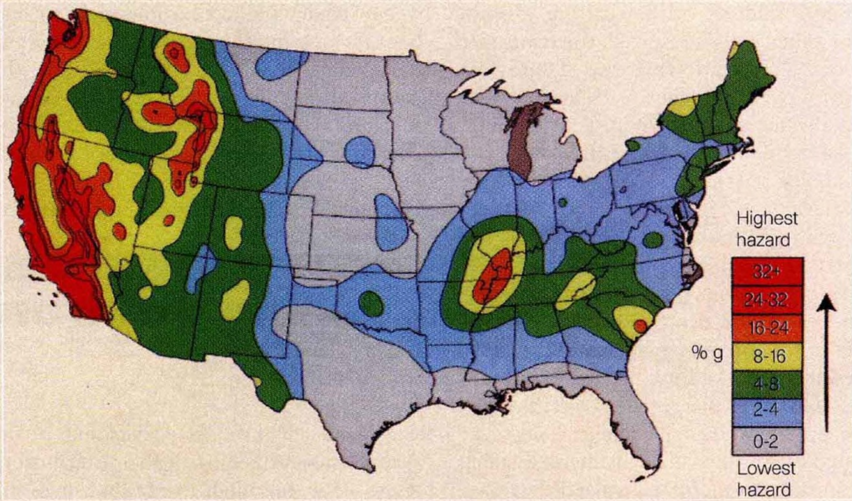
Shaking in the USA

A new set of maps, released by the US Geological Survey, show the latest estimates of earthquake shaking hazards in the United States. Along with the well-known hazards in California, they reveal an increased awareness of the threat of earthquakes in the Pacific Northwest (associated with the Cascadia subduction zone), the central United States (stemming, for example, from the New Madrid fault zone), and regions affected by the Yellowstone hot spot (Wyoming, Idaho and Montana).

The colours on the simplified map shown here represent the level of horizontal shaking that has a 1-in-10 chance of being exceeded in a 50-year period. The potential shaking is represented as a percentage of *g* — gravitational acceleration at the Earth's surface. (So a vertical acceleration of 100 would be sufficient to throw objects into the air.)

The national maps have been produced since 1948, and are used in the design of buildings, highways, utilities and bridges to help to produce structures that will withstand the amount of shaking predicted to be likely for a particular region. The latest versions have been generated by using geological slip rates from an unprecedented number of faults (nearly 500), and can be viewed at http://geohazards.cr.usgs.gov/eq/.

A related development is the publication of a special issue of *Seismological Research Letters* (68, January/February 1997), which presents the methods and data behind the quantification of ground shaking from earthquakes — a major aspect of estimating seismic hazard. The 12 papers describe the science behind seismic hazard assessment in a form that will be of use to public officials as well as seismic engineers.



The estimation of expected ground motion at a particular site depends not only on the magnitude of the potential earthquake and the distance of the site from the epicentre, but also on the type of faulting (orientation of the rupture plane) and conditions at the site concerned (for instance whether it consists of hard rock or unconsolidated sediment). The estimates are also calculated for a range of frequencies, because the sensitivity of a building or other structure to shaking at a given frequency will depend on its size and style of construction.

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