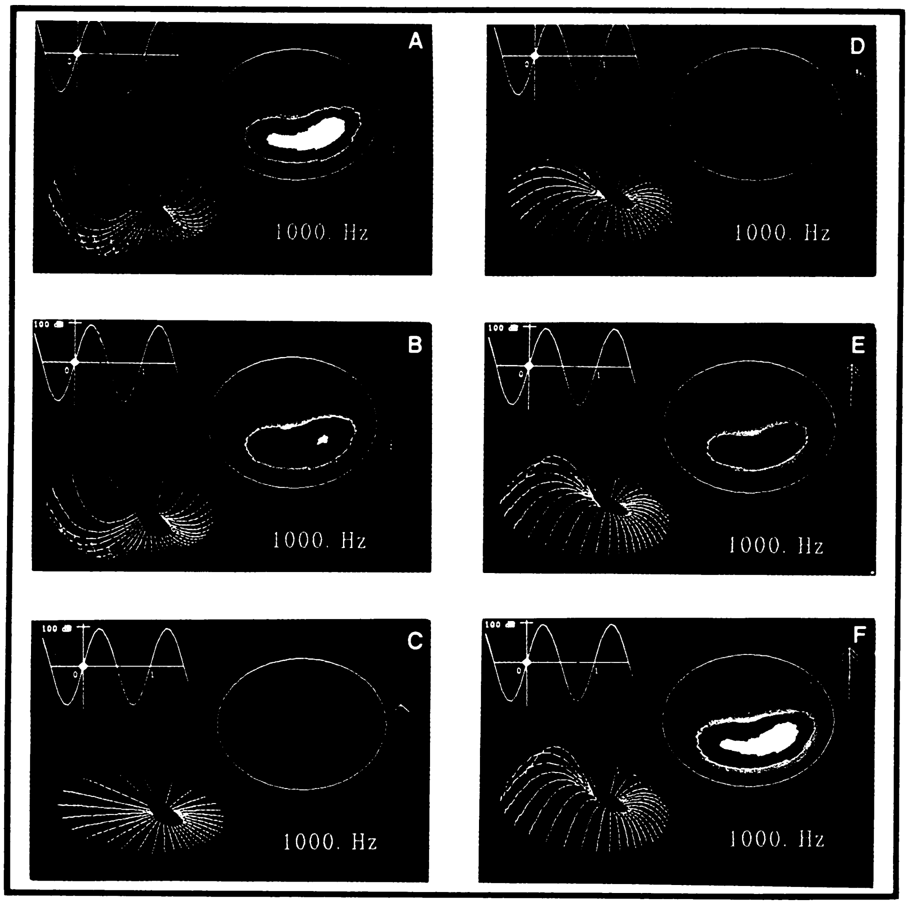
Catching a vivid earful of sound



Holmes & Rabbitt/RPI

This sequence reveals, at six instants in time, how a cat's eardrum responds when a 1,000-hertz sound wave impinges on it. Various colors shown in each oval represent deflection levels, from zero (black) to a maximum (yellow). The arrows can be used to deduce the direction in which the malleus, a tiny bone attached to the eardrum, rotates in response to the eardrum motions.

A cat's eardrum responds to sound waves by vibrating in complicated ways. Now a new mathematical model, closely tied to an eardrum's actual physiological structure, has been developed. It reproduces practically all of this motion's essential features.

"Because of the strong anatomical basis of our model," says mathematician Mark H. Holmes of the Rensselaer Polytechnic Institute in Troy, N.Y., "it is relatively easy to give a detailed description of how the system functions." This model, for example, makes it possible to study — without using animals — what happens when an eardrum ruptures.

A mammal's eardrum is made up of a large number of radial and circumferential fibers (represented in the illustrated sequence as a web of yellow and green lines in the lower left-hand corner of each frame). This stiff, fibrous network is sandwiched between two layers of cells. The entire assembly is sculpted into the shape of a distorted cone.

The model developed by Holmes and mechanical engineer Richard D. Rabbitt accounts for both the eardrum's geometry and the behavior of the fibers as embedded in a cellular matrix. "This has never been done before," says Holmes. Their equations also include the eardrum's connection to the malleus, the first in a chain of tiny bones in the middle ear that transmit sound into the inner ear, and the eardrum's interaction with air in the outer ear.

This mathematical model matches earlier experimental results, which showed that the eardrum doesn't behave like a stiff plate. Instead, the membrane's stiffness isn't uniform, and individual fibers stretch and relax. Because the malleus isn't centered, the radial fibers also have different lengths. When the malleus moves, these fibers try to pull the bone back into place. A tiny muscle attached to the malleus, once thought to be important for protecting the ear from loud noises, now appears to play a greater role in keeping the eardrum tight so that it responds properly to vibrations.

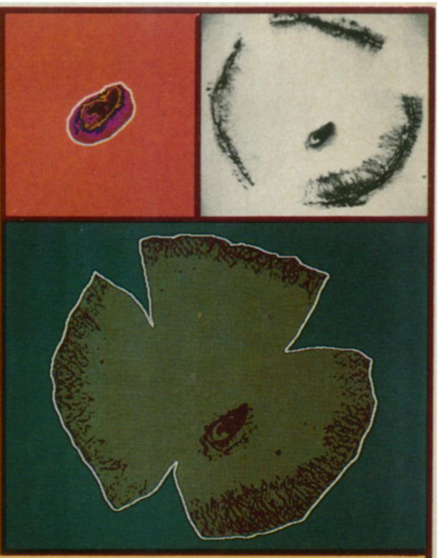
The researchers put together a movie that vividly demonstrates eardrum behavior in a cat and its dependence on the sound's frequency. Moreover, simply by changing the geometry and the characteristics of the fibrous gridwork, this model can be applied to many different animals.

The eardrum model is one step in the development of a complete model for the entire hearing process — how a sound signal is transmitted from the outer ear to the brain. "It's a very complicated process," says Holmes. "Our approach has been to concentrate on the individual components and then to couple them together into a whole-organ model, which we hope to begin soon."

Eventually, a computer model could replace at least some kinds of animal experiments, says Holmes, particularly for studying the effects of loud noises. "It's important to know how much sound and what sounds will cause damage," he says.

— *I. Peterson*

Looking into the eye



David Chandler/Duke Univ. Eye Center

Techniques used to analyze images from "eyes in the sky" can be used to study real eyes, Duke University researchers in Durham, N.C., have found. Using an image analyzer originally developed to study data from earth-scanning satellites, they have devised a system capable of measuring blood vessel growth in the cornea, the normally clear covering over the front of the eye.

At upper right is a rat cornea into which blood vessels have grown as a result of a chemically induced injury. The lower image shows a computer-enhanced view of the cornea. At upper left, the damaged area is outlined; the image analyzer quantifies the amount of damage by determining the exact amount and degree of shading. The system, says Gordon Klintworth of Duke, can be used to study how vessels grow into a damaged cornea. In addition, it can measure the relative strengths of molecules called angiogenesis factors, which promote blood vessel formation, and anti-angiogenesis factors, which inhibit it.

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