EPA

Noise can be hazardous to our health

"Calling noise a nuisance is like calling smog an inconvenience. Noise must be considered a hazard to the health of people everywhere."

William H. Stewart, former U.S. Surgeon General

By JANET RALOFF

Second of two articles

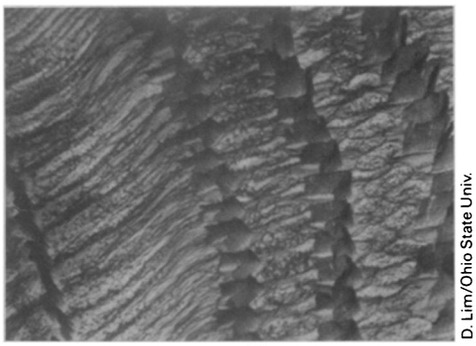
It's not unusual for fans of rock music to leave a particularly raucous concert with a ringing in their ears — clinically known as tinnitis — or even with temporary deafness. These symptoms connote minor damage to the ear's fragile cochlea. But research is beginning to show that noise can affect far more than hearing — including blood pressure, body chemistry, susceptibility to disease, even our ability to acquire knowledge. And according to the Environmental Protection Agency, nearly *half* of all Americans are regularly exposed to levels of noise that interfere with such important natural activities as speaking, listening, sleeping or performing tasks. EPA's rule of thumb is that whenever you need to raise your voice to be heard, the background noise is probably too loud "and should be avoided."

But we don't avoid such sounds. For many of us, it has become virtually impossible to do so. The 24-hour din of street noise in many urban neighborhoods (see table) approaches or exceeds the legal limit to which workers can be exposed without hearing protection (SN: 5/22/82, p. 348). And there's willful abuse of one's own ears: Children play with cap pistols, firecrackers and motorized model airplanes. America's love affair with thunderous vehicles — "hot rods," motorcycles, speed boats and snowmobiles — is a doc-

Sound Levels (decibels)

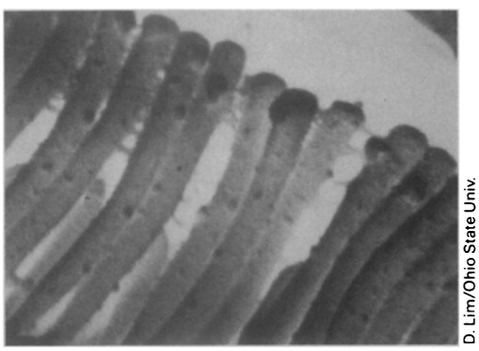
Harmful to hearing	140	Jet engine (25 m distance)
	130	Jet takeoff (100 m away) Threshold of pain
	120	Propeller aircraft
Risk hearing loss	110	Live rock band
	100	Jackhammer/Pneumatic chipper
	90	Heavy-duty truck Los Angeles, 3rd floor apartment next to freeway Average street traffic
Very noisy	80	Harlem, 2nd floor apartment
Urban	70	Private car Boston row house on major avenue Business office Watts — 8 mi. from touch down at major airport
	60	Conversational speech or old residential area in L.A.
Suburban & small town	50	San Diego — wooded residential area
	40	California tomato field Soft music from radio
	30	Quiet whisper
	20	Quiet urban dwelling
	10	Rustle of leaf
	0	Threshold of hearing

Because the decibel scale is a logarithmic measure of sound intensity, values don't add in the usual way: a 60 dB sound played atop another 60 dB sound corresponds to 63 dB noise. And a 10 dB difference means one sound is 10 times louder than the other, so that the ratio between 140 dB and 0 dB is roughly 100 trillion to 1. Readings for cities (above) represent levels actually measured by EPA and expressed as a day-night average.



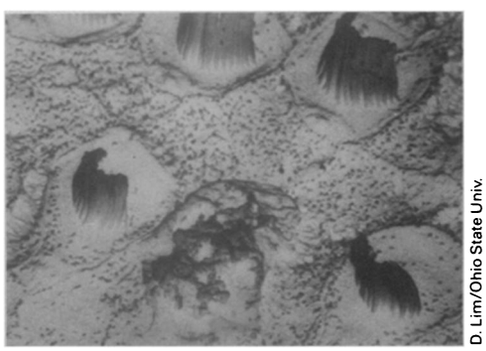
D. Lim/Ohio State Univ.

Healthy guinea pig organ of Corti shows three wavy rows of outer hair cells (right) and parallel row of inner hair cells (left).



D. Lim/Ohio State Univ.

Stereocilia from noise-exposed animal exhibit earliest changes – development of vesicles that will eventually rupture.



D. Lim/Ohio State Univ.

Degenerated outer hair cell shown among normals. Damage occurred from 14-hour exposure to 117 dB noise at 1000-2000 Hz.

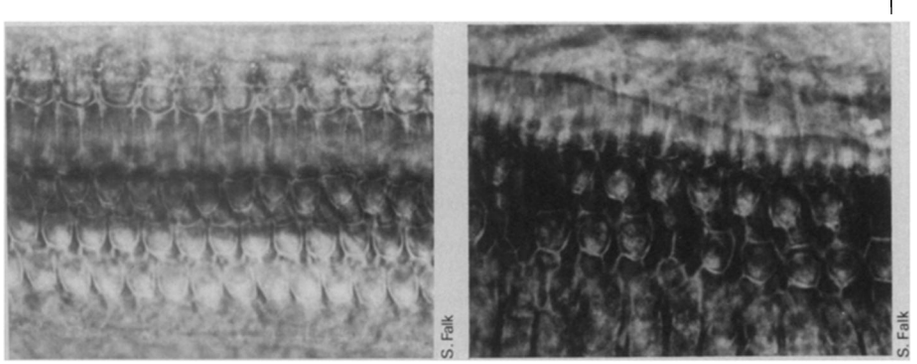
Picturing the Effects of Noise

"We have an idea of what noise does to the ear," David Lipscomb says. "There's a pretty clear cause-effect relationship." And these photomicrographs of the cochlea's tiny structures graphically document noise trauma to the inner ear.

Hair cells transmit the mechanical energy of sound waves into those neural impulses that the brain interprets as sound. Loud noise can damage or destroy hair cells as these scanning electron micrographs illustrate.

Hair cells come in two varieties: a single row of inner cells and a triple row of outer ones. "Outer cells degenerate before inner cells," notes Clifton Springs, N.Y.-otolaryngologist Stephen Falk. The most subtle change wrought by noise is a development of vesicles, or blister-like protrusions along the walls of the hair cells' stereocilia. Continued assault by noise will lead to a rupturing of the vesicles and damage. In addition, the "cuticular plate" — base tissue supporting the stereocilia — may soften, followed by a swelling and ultimate degeneration of hair cells.

But sensory hair cells are not the only structures at risk. Adjacent inner-ear cells, such as Dieter's cells and Hensen's cells, may undergo vacuolation — development of degenerative empty spaces in cells. Even nerve fibers synapsing at the hair cells' roots may die. In the final phase of noise-induced cochlear damage, the organ of Corti — of which hair cells and supporting cells are a part — is completely denuded and covered by a layer of scar tissue.



S. Falk

S. Falk

Organ of Corti tissue showing three geometric rows of outer hair cells. Normal cells in photo at left; noise-damaged cells in photo at right.

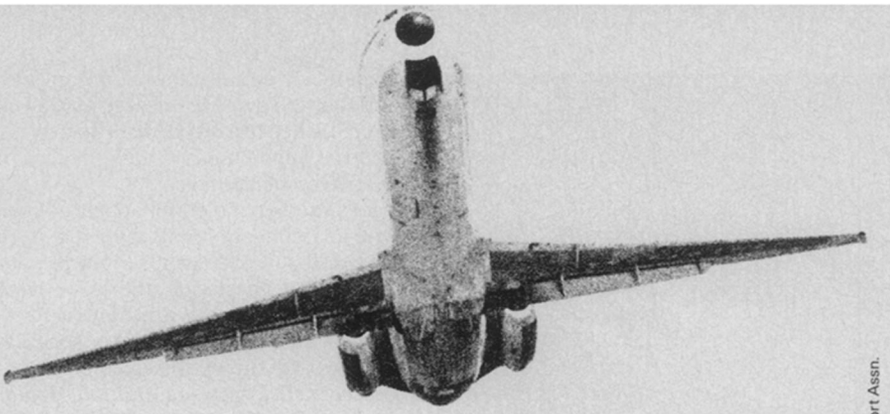
umented sociological phenomenon. Recreational use of firearms is growing. And many of the nation's youth have "turned on" to a literally deafening immersion in *loud* rock and roll. The combined assault of these intentional and inadvertent sources of noise is having an impact on the health and emotional well-being of our society.

Take hearing. The human auditory system evolved to handle sound frequencies and levels necessary for survival in the natural world — a far tamer environment than the nearly ubiquitous noise to which our ears are now exposed. Federal statistics indicate that as many as 20 to 25 million Americans — about one in 10 — are exposed to noises of sufficient duration and intensity to cause a permanent hearing loss. But "[t]he idea that hearing loss is solely the result of industrial noise is dangerously erroneous," notes the EPA in a 1978 report, "Noise: A Health Problem." In fact, the agency has collected data suggesting that at least 10 million people encounter damaging levels of noise outside the work environment.

According to the President's Council on Environmental Quality, at least 13.5 million people are exposed to vehicular noise with an equivalent sound level (L_{eq}) of 75 decibels (dB) or more—a level the agency considers sufficient to cause risk of permanent damage to hearing. This source of noise will grow over the next decade, not only as the number of autos traveling the nation's roadways increases, but also as the formerly popular V-8 engines are replaced within this fleet by an increasing proportion of much noisier diesel engines and four-cylinder gasoline engines.

More problematic are exposures within the home from passing rapid-transit trains and low-flying aircraft. In New York City alone, an estimated half-million people are assaulted by rail rapid-transit noise at levels of between 85 dB and 100 dB. Homes situated near airports or along airport-runway takeoff and landing corridors may also be subjected to noise in the 70dB to 85 dB range.

In fact, it's because aircraft noise in residential settings can be so loud that many research programs have focused on it in attempts to gauge the body's response to uncontrollable high-decibel exposures.



Air Transport Assn.

Such research has pointed toward a wide range of nonauditory effects in human populations — most notably high blood pressure (see connecting story).

But what has environmental noise researchers most concerned is an apparent need of much of today's youth to shroud themselves behind a sound screen of deafeningly loud rock music. More than a decade ago, David Lipscomb, director of the University of Tennessee's Noise Study Laboratory, recorded sound levels in a youth-oriented Knoxville dance establishment that consistently peaked at 122 dB. Since then, rock music halls have anything but lost their deserved reputation as purveyors of excessively loud sound.

Parents, unwilling to share the youthful craze for loud music, have frequently encouraged their children to use earphones when listening at home. But Lipscomb points out that very efficient stereo-and-headphone sets have been demonstrated capable of delivering 136 dB_A (the A-weighted dB scale has been filtered to account for the frequency senstivity of the human ear), when turned all the way up, and peak sound levels in the 150 dB range.

"That's close to what you'd experience if you were riding inside the cell of a jet engine at maximum takeoff power," he told SCIENCE NEWS. "I'm not downgrading earphones, because for both privacy of listening and avoiding the disturbance of others, earphones are good. But," he said, "I am against the careless use of earphones," including portable earphone listening systems, like the Sony Walkman.

Merely mentioning these portable, personal listening devices is enough to propel consulting audiologist Maurice Miller onto the nearest soapbox. Miller, who studies such systems as used by consumers on the streets of New York City, says he has routinely encountered users listening at 102 to 127 dB. Like Lipscomb, his disdain is not for the technology but its abuse, particularly by youth.

And there are signs such abuse is taking its toll. Lipscomb's audiological surveys of high school students and incoming freshmen have demonstrated what he terms "an awesome trend toward loss of high-frequency hearing acuity" — probably owing in large part to noise exposures. Of 2,769 college freshmen he tested one year,

Aircraft noise — a 'silent killer?'

For an individual, few noise exposures are as difficult (and prohibitively costly) to control as those from low-flying aircraft. Seldom deviating much from established air corridors, this thunder showers select segments of affected communities with an irritating roar and what now appears to be a panorama of nonauditory health effects.

Consider the disturbing findings reported in the September-October AMERICAN SCIENTIST by Sheldon Cohen of the University of Oregon and by David Krantz of the Uniformed Services University School of Medicine in Bethesda, Md., together with Gary Evans and Daniel Stokols of the University of California-Irvine. The team has been studying children who attend schools along the Los Angeles International Airport air corridor. When they began their study, children in the noisier schools were in some cases subjected to one overflight every 2.5 minutes throughout the school day and peak classroom sound levels of 95 dB_A.

After controlling for hearing loss and potentially confounding economic and social variables, they found that noise-affected children — relative to their peers in quieter classrooms — had significantly higher blood pressure and greater difficulty in solving puzzles and math problems. "There was very little evidence that children adapted to the noise stressor over time," the psychologists say, since the effects remained stable over a one-year period. The results have led them to advocate that schools attempt to reduce sound levels as much as is affordable.

A Dutch study by Paul Knipschild at the University of Amsterdam's Coronel Laboratory offers an even more troubling picture of noise effects. Knipschild studied patient visits over the course of a week to 19 family physicians serving the region about Amsterdam's Schiphol Airport. Doctors logged in each patient by diagnosis, age, sex and address. The latter were then correlated with day-night equivalent-sound-level ($L_{eq/dn}$) exposure readings for their area. Knipschild's findings, reported at the Third International Congress on Noise as a Public Health Problem in Freiburg, Germany (and published in April 1980 by the American Speech-Language-Hearing Association), showed significant differences between regions with "little" aircraft noise ($L_{eq/dn}$=50 to 60 dB_A), "much" noise ($L_{eq/dn}$=60-65 dB_A), and "very much" noise ($L_{eq/dn}$=65-75 dB_A). As shown in the table below, inhabitants of successively noisier areas sought medical help more frequently for all types of problems.

Of particular interest are data noting that the incidence of high blood pressure (hypertension) in the area with the highest noise was 72 percent above that in the area with the least airport noise. A drug survey Knipschild reported at the same time provided a provocative corollary. In it he noted that over a six-year period following the opening of a new airport runway, sales of anti-hypertensive drugs doubled among residents exposed to runway noise. Prior to the runway's installation, this region had experienced virtually no airport noise. As a control, another quiet area was studied for the same period. Prescription sales records showed no increase there for anti-hypertensives.

"We conclude that aircraft noise is a risk factor to hypertension," Knipschild says. "People who develop hypertension run an increased risk of becoming atherosclerotic. Some may die from a cerebrovascular accident or a heart attack." Before such an attack, hypertensive victims frequently experience a symptomless period, which is why the disease is so often called the "silent killer." Says Knipschild, "If you agree with the conclusion that aircraft noise is a risk factor to hypertension, you will perhaps also agree with the paradox that aircraft noise is a silent killer."

Aircraft noise, $L_{eq(dn)}$ in dB(A)	<60	60-65	>65
Population at risk	14625	4050	3650
Contact rate[1] (per 1,000 persons)	57.1	79.7	93.4
Contact for:			
Psychological problems	6.5	11.3	17.5
Psychosomatic problems[2]	11.2	15.4	16.9
Cardiovascular disease	4.6	6.0	8.2
With hypertension	2.5	3.1	4.3

[1] rate is based on number of patient contacts per week per 1,000 people in the area

[2] low back pain, spastic colon, stomach complaints, allergic diseases, tinnitis, dizziness and headache

Knipschild/ASHA

The Police/A&M Records

Rock bands can generate sounds in excess of 110 dB.

33 percent registered a 15 dB or greater hearing loss in the high-frequency range. When 1,410 members of the next year's freshman class were tested, 60.7 percent showed similar high-frequency losses. Lipscomb says most hearing impairments "were not serious." But the results do suggest, he says, "this generation of young persons will encounter much more serious hearing problems in their middle years than the present group of 50-to-60-year-olds." Perhaps more important, he suspects the affinity of youth for loud music is not the only factor responsible for this trend toward early hearing impairment. After all, he suggests, loud noise from many sources is becoming an increasingly pervasive element of our environment.

"The progressive increase in noise from industrial, traffic and home sources — both machine and human generated—has reached offensive proportions in the United States," observe Jack Westmont of the University of Wisconsin and James Walters of EPA's noise office in the October 1981 ENVIRONMENTAL HEALTH PERSPECTIVES. And the result, they say, is an unhealthy sensory overload for our ears and body.

Research on a remote Sudanese tribe, first discovered in 1956, tends to support their contention. Living in a relatively noise-free Stone Age culture, even the Mabaans' elders exhibit near-perfect hearing. That's important, because it had always been assumed that hearing loss was a natural part of aging. But Lipscomb notes that the hearing of 80-year-old tribesmen "was better than that of the average 30-year-old American." Such observations have led him and others to question whether presbycusis—the clinical term for age-related hearing loss—might not be a degenerative function of age so much as a lifetime's exposure to environmental noise.

What's more, Lipscomb reported that extensive examination of the tribe revealed an "inordinately" low incidence of upper-respiratory defects, cardiovascular disease and intestinal disorders. "Although the results of the Mabaan investigations must necessarily be interpreted with caution," he says "there is strong evidence that the aging processes as well as the occurrence of internal disorders might be at least augmented by the presence of high environmental noise."

That statement no doubt appeared controversial when he first reported it in CLINICAL PEDIATRICS in 1972, but it is far less so today. Scores of studies — using both laboratory animals and human populations — shore up Lipscomb's speculation. The 1981 National Academy of Sciences report, *Effects on Human Health from Long-Term Exposures to Noise,* for example, refers to research that has been published in foreign journals linking excessive noise levels in industry with increased neurologic and gastrointestinal disturbances among workers. And the EPA's report, "Noise: A Health Problem," says that "cases of ulcers in certain noisy industries have been found to be up to five times as numerous as what normally would be expected." That report also noted that studies since the 1930s have chronicled in workers exposed to loud noise the types of digestive changes that were thought to lead to ulcers. Recently, Hans Döring and German colleagues at the University of Freiburg explored whether sound had to be mediated by the ear before it could play a role in gastrointestinal disorders. They reported in 1978 that contractile proteins of smooth intestinal muscle could be altered by the direct interaction of sound upon the tissue.

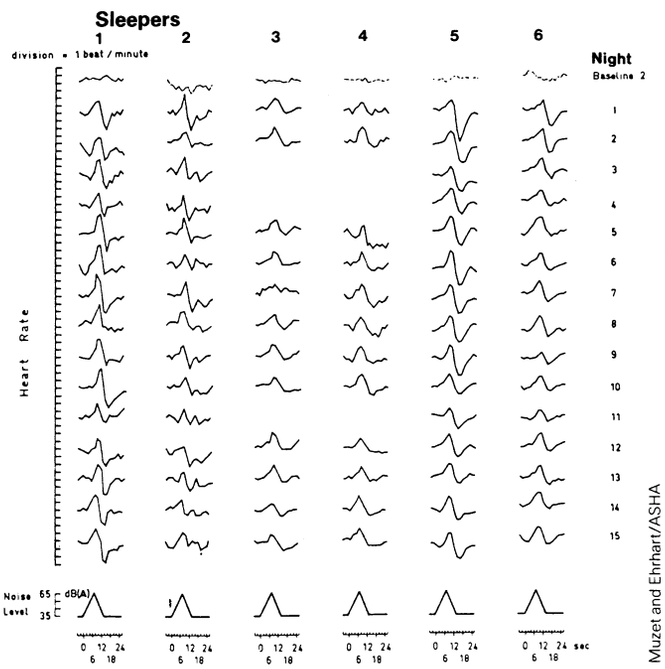
While the methodology used in many of these studies has been questioned, the noise research community is nonetheless coming around to accepting the idea that loud sounds are responsible for more than hearing problems.

Noise is a recognized stressor, meaning the body views it as a warning signal. Although most noise we encounter does not signal danger, our bodies still react to each loud sound as if it were a threat or warning. The EPA sums it up, saying: "The body shifts gears. Blood pressure rises, heart rate and breathing speed up, muscles tense, hormones are released into the bloodstream, and perspiration appears." If the sounds are sudden, unexpected or difficult to recognize, they don't even have to be especially loud to call out these responses.

What's probably most important is that though we can intellectually tune out noise, physiologically, our bodies never adapt. That's why these changes continue to occur even during sleep, as Alain Muzet and Jean Ehrhart demonstrated graphically in research at the Centre d'Etudes Bioclimatiques du CNRS in Strasbourg, France.

Three men and three women (aged 19 to 24 years) were allowed to adapt to sleeping in their laboratory. After three quiet nights, Muzet and Ehrhart bombarded their sleepers for the next 15 nights with a barrage of traffic sounds. Played over loudspeakers at a rate of 30 per hour, the noises randomly exhibited peak intensities of 45, 55 or 65 dB_A. Heart rate, finger-pulse amplitude and pulse-wave velocity were measured throughout the night, and each sleeper filled out a questionnaire upon waking.

After the first two to seven nights, the subjects no longer reported having been disturbed by noise during their sleep. However, their bodies failed to habituate: As a sample log of their heart rate shows, loud noise temporarily spiked heart rate as much as four fold — and effects measured the fifteenth night were identical to those logged the first night. "Such a result raises the question of what are the long-term effects on the cardiovascular system of low-intensity (and perhaps even unnoticed) noises that occur during sleep," the researchers conclude.



Muzet and Ehrhart/ASHA

Baseline (broken lines, top row) establishes normal sleeping heart rate. Below it are examples of spike in heart rate for each of six subjects responding to traffic noise. Sleeping heart rate was as affected the fifteenth night as it was the first.

Wolfgang Ehrenstein and Wolf Müller-Limmroth have looked at another aspect of noise-sleep interaction at the Technical University of Munich in Germany. Monitoring humans exposed to noise throughout the different stages of sleep — i.e. delta-sleep, the rapid-eye-movement phase, etc. — they concluded that sleep was "resistant even to extreme noise exposure" — as measured by the time spent in each sleep phase. A perplexing observation they were unable to explain involved qualitative changes in the sleep of six subjects exposed to eight consecutive nights of loud noise. "After the first night of noise exposure, the moods were negatively affected [for] ten minutes after awakening. With succeeding noise exposure during bedtime," the German team reported, "this negative effect spread more and more to the late morning hours and to the early afternoon, thus indicating an increasing deterioration of sleep quality."

Robert Wilkinson and colleagues with the Medical Research Council in Cambridge, England, reported finding that the performance of certain specific tests could be negatively affected after a night of noise-disturbed sleep. Daytime noise, however, has an even more profound impact on task performance, particularly the storage and selective recall of information and the processing of speech.

"[N]oise of sufficient intensity probably discourages conversation, it probably reduces the content of verbal communication, it probably degrades the fidelity of verbal exchanges, and it probably requires frequent repetition of messages," says John Mills of the Medical University of South Carolina. Not surprisingly, he says this "can lead to irritation, confusion and fatigue on the part of the talker and the listener." When adults are put in such situations, they usually give up attempts at conversing after only a few minutes. How much more dangerous is it, Mills asks, to put children in such a setting when it's largely through verbal communication that they can expect to acquire language skills and the seeds of knowledge?

However, as serious as this noise-induced inhibition of speech may be, it's the link between noise and hypertension (high blood pressure) that garners the lion's share of attention among those studying nonauditory effects of noise. More than 40 studies, many of them involving industrial workers, have shown a link between high levels of noise and cardiovascular changes. One of the most respected of those studies was conducted by H. Ising and H.-U. Melchert at West Germany's federal Institute for Water-, Soil- and Air-Hygiene in Berlin. They found that on days when brewery workers deliberately wore no hearing protectors, their diastolic and systolic blood pressures and urinary excretion or norepinephrine metabolites were elevated — relative to when those same workers wore hearing protection.

Yet to be truly cataloged are the broad-band changes in blood chemistry caused by noise-induced stress and a dose-response index correlating noise exposure to cardiovascular changes. E. A. Peterson and colleagues at the University of Miami have been looking into attempting just that. Beginning with rhesus monkeys (SN: 3/28/81, p. 198) and now using crab-eating macaques, Peterson has exposed his primates to noise of the type, duration and hourly regimen that human workers might encounter. Although most researchers consider Peterson's work the most promising U.S. inquiry into the cardiovascular effects of noise, his research may come to a halt on October 1.

To date, Peterson has been funded through EPA's noise office, which has come under the Reagan budget ax — a victim of the President's regulatory-reform program. As of September 30, 1982, it and the programs it has funded will cease. Noise is a local problem, the new administration has said, and as such should be funded and administered by state and local authorities.

However, notes Jeff Goldstein, who just left EPA's noise office, "The states' big problem will be to get priority funding for noise programs. Even if they do I doubt very much if a state would conduct noise-effects research. It just wouldn't pay them to do it." If so, many of the unanswered questions regarding harm posed by noise will remain unanswered a good while longer. □

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THE ESSENTIAL GUIDE TO PRESCRIPTION DRUGS — James W. Long. Though copious information is available to the health professions, only a small portion of it reaches the public. This book, written by a physician, is meant to be a source of basic information about the most commonly used drugs. A patient complies with a doctor's instructions far better when sufficiently informed to recognize anticipated drug effects and to know when to consult the doctor about the drug therapy. Har-Row, 3rd ed., 1982, 935 p., $32.95, paper, $9.95.

THE MATHEMATICAL EXPERIENCE — Philip J. Davis and Reuben Hersh, introduction by Gian-Carlo Rota. Not a mathematics book, but a book about mathematics which is intended to explain to the general reader what mathematicians do. The emphasis is on the substance of mathematics, its history, its philosophy and how mathematical knowledge is gained. In some areas specialized material is directed to the professional who uses or produces mathematics. "At such places the [general] reader should judiciously and lightheartedly push on." Originally published in hardback by Birkhauser Boston in 1981. HM, 1982, 440 p., illus., paper $9.95.

A PICTORIAL GUIDE TO FOSSILS — Gerard R. Case. An illustrated presentation of past life forms that inhabited the earth millions of years ago. Many typical forms of fossils are presented as well as "index" or guide fossils, together with newly discovered specimens rarely seen outside scientific journals. Many specimens have been photographed from several perspectives to give the reader a multidimensional view of the fossils. Van Nos Reinhold, 1982, 514 p., illus., $29.95.

2081: A Hopeful View of the Human Future — Gerard K. O'Neill. Discusses the lessons that can be learned from earlier attempts at predicting the future, describes the five developments that the author believes will determine the course of the next 100 years, views the world of 2081 and explores the most exciting developments of a century from now. Originally published in hardback in 1981. S&S, 1982, 284 p., illus., paper, $6.25.

WEATHER AND ENGERY — Bruce Schwoegler and Michael McClintock. Looks at the enormous amount of energy present in meteorological phenomena of all kinds. Explains how the weather system works and explores the connections between weather and weather-related sources of energy that are potentially useful. McGraw, 1982, 230 p., illus., $22.50.