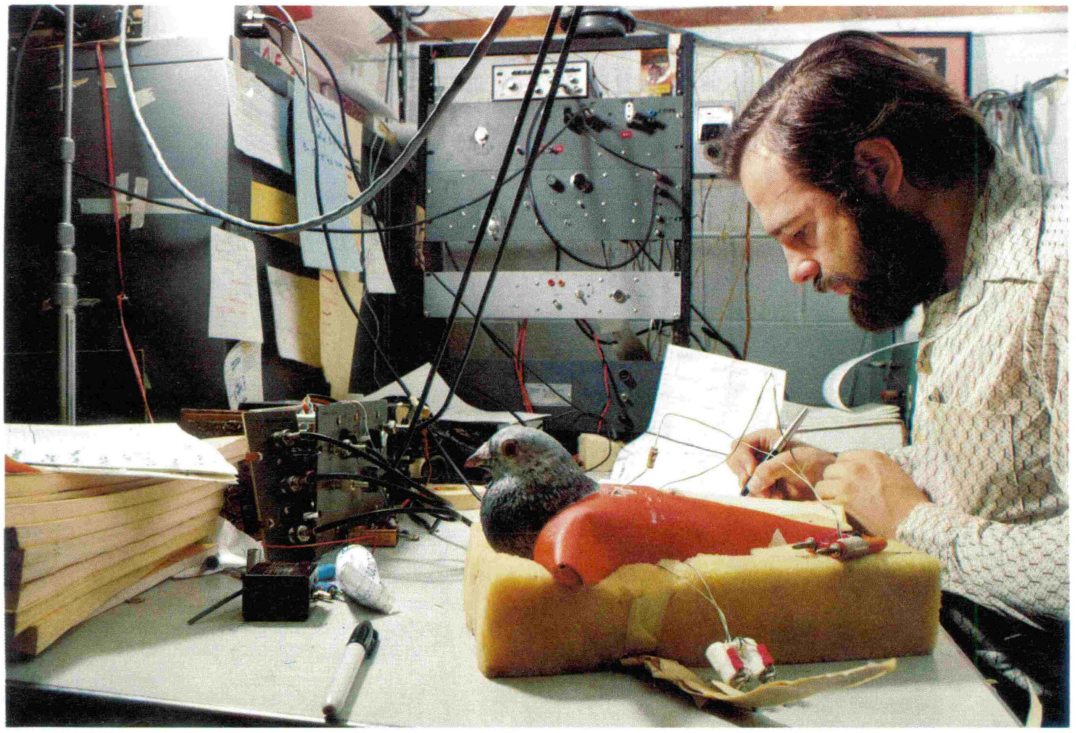
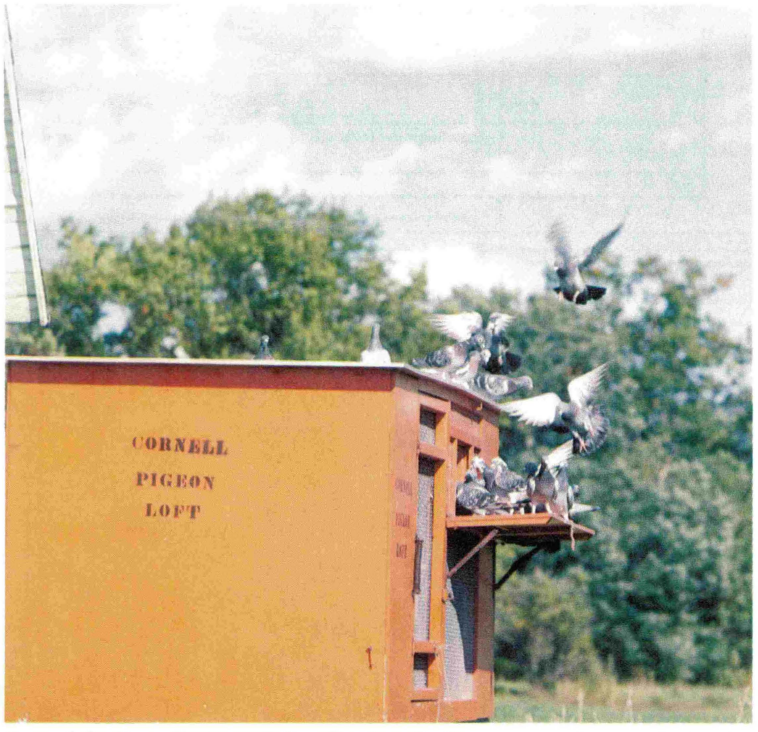
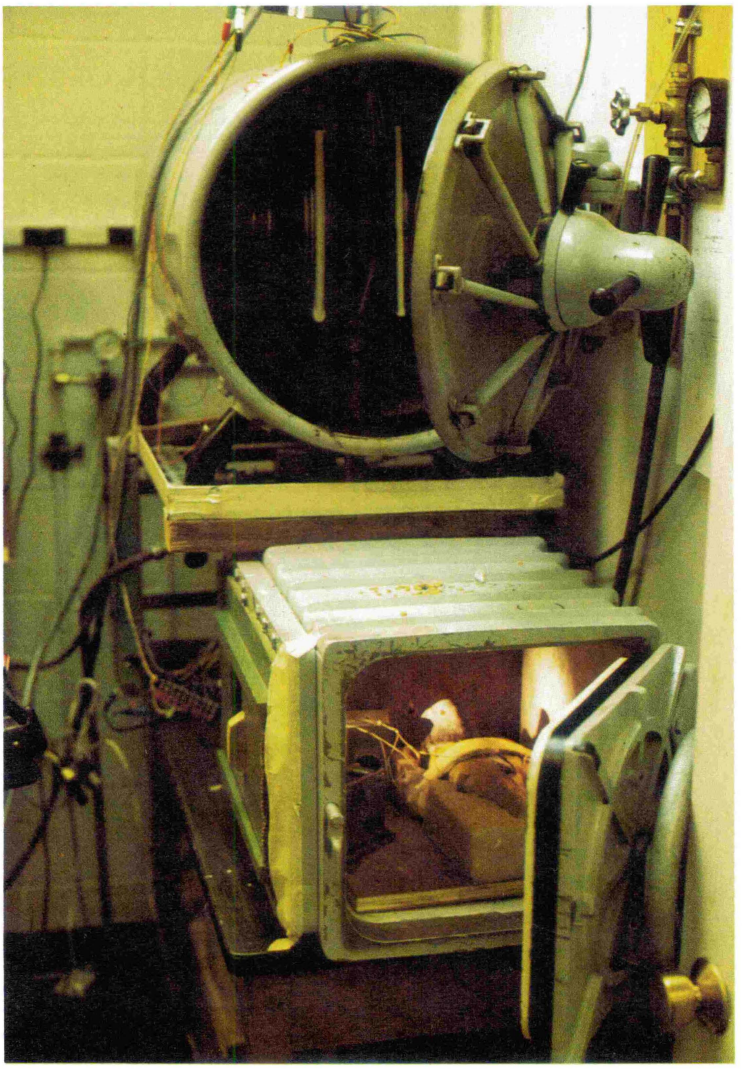


Photos by Dr. Quine

Dr. Quine, surrounded by laboratory paraphernalia, at Cornell.



One of the Cornell pigeon lofts, showing the homers crowding on the landing board.



Pigeon in infrasound testing chamber with door open.

Can Pigeons "Hear" Their Way Home?

by Tanner S. Chrisler and Douglas B. Quine

Julius Caesar used Homing Pigeons to carry messages from the remote corners of Europe to home, in Rome. That was two thousand years ago. Ever since that time, thoughtful people have wondered at these amazing birds, and in the present century, this wonder has manifested itself in some honest scientific study, trying to learn just **how** they do it. What "super-human powers" do the pigeons possess that enable them to take off in unfamiliar territory, make a few circles, and fly home with remarkable speed?

Scientists in Germany, England, Italy, Switzerland and the United States were probing at this question. Then in 1967, Dr. William T. Keeton in the Avian Orientation Research Project, at Cornell University, Ithaca, New York, turned his attention to the question. For many years Cornell had the reputation of having one of the world's leading centers of research in animal behavior – everything from honeybees to monkeys. Keeton was a "natural" – not only because of his boyhood interest as a pigeon fancier, but – because of his broad, multidisciplinary background in many areas of science, besides biology. In addition to his formidable reputation as one of the most popular professors at Cornell and his recognition in the scientific world, Keeton had the ability to get the funds he needed to do the work at hand. This was vital to sustain a program on pigeons that would take many years to show some results.

As most readers already know, birds are basically visual (eye-brained) animals. They use their eyes to find food, to detect danger, and to receive certain mating stimuli. So the research under Keeton's direction started by exploring how the pigeons use their eyes to find the signals for orientation and navigation. The first ten years of his project were involved mostly with visual stimuli, but a few other "powers" entered the picture along the way.

Using pigeons from the established strains of Racing Homers in America, Keeton's team learned that these birds primarily use the sun to navigate. They have some kind of uncanny internal timeclock that tells them where the sun **should** be in the sky at any moment in the day at home. When they are released at a place where the sun is not where it **should** be, they seem to know how to relate this to where the sun **would** be at home, compare the two, and head toward home.

So much for ideal conditions, on a clear day with sunlight. Gradually, the Cornell people stripped away one visual cue after another. What happens on overcast days? What happens at night? (The researchers **did** train enough pigeons to home at night to complete that experiment.) What happens when the pigeons are wearing foggy contact lenses, that obscure any image beyond a few yards? They still come home. How? The pigeons can discern the polarity of light in the sky and probably still tell where the sun is, despite the overcast. Perhaps they can tie this with an ability to perceive light in the ultraviolet range and spot the position of the sun – through the clouds.

Later research showed that the pigeons are extremely sensitive to barometric pressure, extraterrestrial gravity (pull of the moon), and the magnetic north pole on earth. Still, it seemed that the explanation of the pigeon's homing ability was incomplete. After each discovery, a thorough attempt was made to strip-away the birds' ability to utilize the previously explored senses, and a significant number could still find home, almost as though they were without any handicap. They must have some other senses. A laboratory in Italy had run some convincing experiments that lead to the conclusion that pigeons use their sense of smell to find home. But, try as they may, the Cornell researchers could not replicate these experiments. This may have been due to the difference in climate or the difference in the birds used, but Cornell finally dropped

its olfactory explorations on homing pigeons. This left the sense of hearing, and they rolled up their sleeves. Are you ready?

To understand hearing, it is helpful to know a little about sound. The easiest way to think of sound is like the waves that are formed when you drop a rock in a pond. A big rock makes a high wave with a long distance between the top of one wave and the top of the next. A small rock makes a small wave with less distance between the top of one wave and the next. In sound we call the height of the wave amplitude (or loudness). The length between one peak and the next is called wavelength. This is used also to describe the rate of speed that the waves hit the shore, and it is called frequency (or pitch). In sound pitch is measured in cycles per second (waves per second). In recent years, cycles per second has been renamed Hertz (Hz) in honor of the German physicist (not the car rental company). So much for the technical jargon.

Most people can hear low-pitched sounds from about 20 to 30 Hz up to high-pitched sounds of about 12,000 Hz, depending on age and other factors. However, at the extreme ends of this spectrum, the sounds must be rather loud to be audible. (For example, the fundamental pitches from a piano range from about 28 Hz to 4186 Hz.) But what about pigeons' hearing? Earlier tests had shown that pigeons were about as sensitive as humans between 200 Hz and 10,000 Hz. Nobody had investigated the pigeons' ability to hear low-pitched sounds – really low-pitched sounds, below the range of human hearing, which are know as "INFRA-SOUNDS". Dr. Melvin Kreithen and Marilyn Yodlowski (an undergraduate student) tried the pigeons more than an octave below the range of human hearing – at 10 Hz. The pigeons could hear it – not with high sensitivity – but with much greater ability than humans. They went down another octave to 5 Hz. Again the pigeons responded. This was a most impressive discovery – especially, as a part of an undergraduate project.

After this, Douglas Quine (a graduate student of Keeton) began a detailed study of the homing pigeons' hearing ability at extremely low frequencies. He went down to 2.5 Hz – even to 1 Hz – and he found that the pigeons could not only hear these sounds, but they were more than 200 times more sensitive in this range than humans. Quine and Kreithen went to 0.5 Hz (one cycle every two seconds). Quine eventually went down to 0.05 Hz (one cycle every twenty seconds), and the pigeons could still hear it! It is difficult for humans to believe.

In tests to demonstrate the pigeons' ability to sense a change in pitch, Quine found that – between 1 Hz and 10 Hz – the pigeons could discriminate between very slight differences in pitch, a small fraction of a Hertz apart. Remarkable! This was not just a breakthrough in **pigeon** research. It was a breakthrough with any kind of animal. Pigeons can hear INFRA-SOUND – a whole "new" spectrum – far below the threshold of human hearing. And they can not only hear down there, but they can detect very slight differences in pitch down there. This is fantastic!

To understand how the pigeons may use this ability to find their way home, let us consider for a moment the sound of a train whistle. If you are outdoors and a train whistle blows (say 260 Hz, or a wavelength of 4 feet), you can not only hear it, but you can tell what direction it is coming from. Even though this soundwave is rather long, it hits one ear in a slightly different way than it hits the other ear. Your brain interprets this difference and tells you which direction the whistle came from. However, if you hear a very distant thunderstorm, you may not be able to tell where the sound is coming from. This is because the air has filtered out all but the very lowest pitches. These sounds have such long waves that there is no measurable difference between the way the waves strike one ear and the way they strike the other. Sounds of such low pitch are non-directional to humans, because we can not tell the direction of their source. But we have reasons to believe than homing pigeons **can** – not when they are standing still, but – when they are released to fly home. As you know, they do not usually take off for home right away; they fly out in a wide circle, which they may repeat several times, before setting their course.

For ages people have watched this maneuver and thought to themselves, "The pigeons are getting their bearings." We ask, "What bearings? How?" Perhaps they are LISTENING while they fly around. They may be detecting infrasounds which have traveled tremendous distances, because of their very long wavelengths. What infrasounds? From where?

Let's take some educated guesses about what the origins of these infrasounds might be. Maybe ocean waves hitting the shore, 200 miles away. Maybe thunder in an electrical storm, 500 miles away. Maybe the Rocky Mountains grunting, 2,000 miles away. All of these natural forces are known to science as generators of enormous long wavelength energy, that can be detected by delicate instruments. For example, a volcano in the South

Pacific (Krakatoa), generating enormous vibrations in the infrasound range, was detected in America by an infrasound microphone (that's what a seismograph is). It is quite possible that every time the Concorde (a supersonic jet transport) leaves Kennedy Airport on Long Island and breaks through the sound barrier — maybe 400 miles from Cornell — the pigeons can hear the sonic boom, which has infrasound components. If the pigeons were flying in a pre-course circle, getting their bearings, they might be able to tell the direction the boom was coming from. What makes the difference between the infrasound while standing still and hearing it while flying? Something called the Doppler effect. The what? Glad you asked.

Have you ever heard a train go by with the whistle blowing? It sounds like this, "Wheeee-ooooh", as it passes. You hear the pitch change. On the approach the pitch is higher. At the instant it passes, the pitch seems to drop. If you were the engineer on the train, you'd hear the same pitch the whole time the whistle was blowing, but to the listener outside the train, the pitch seems to drop noticeably. That is the Doppler effect. As the distance between the source and the listener decreases, the length of the waves is "compressed", and the pitch seems higher. As the distance between the source and the listener increases, the length of the waves is "expanded", and the pitch seems lower.

Now, suppose you were a pigeon, flying in a circle, and the train was outside the circle **standing still**. You'd get the same Doppler effect. When you were flying toward the whistle, the pitch would sound higher. When you were flying away from the whistle, the pitch would seem to drop. Observing the size of the circle that pigeons fly, before heading for home, and the speed of their flight, it is reasonable to believe that the pigeons may be able to tell the directions the **infrasounds** are coming from. When they are standing still, they can hear the infrasound, but they can't tell where it is coming from. But if they are flying in different directions — toward the source and away from it — they could hear the pitch change, and in this way they could determine the direction it is coming from.

Think about that for a moment. Here is a bird that has a brain that weight less than one-fourth of an ounce, and it can demonstrate senses of perception that are more sophisticated than those of man — with a brain 200-times that size!

So what does all this new business about infrasound mean in terms of the pigeons' homing ability? It means that they have

some constantly available reference points that make a previously unfamiliar release area less strange than one might have assumed – at least, as far as the infrasound environment goes. Take a pigeon from Ithaca, New York, put it in a container with no windows, take it to Georgia, and release it. First, he flies out in a broad circle, and he listens. He may soon discover that he is closer to the Atlantic Ocean than he was at Ithaca, even though he cannot see the ocean or feel the seabreeze. He will also have a different angle on the Rocky Mountains. Without having a verbal understanding of "east" or "west", he may be able to place these familiar sounds in a mental map. He may shape this map with other infrasounds – perhaps the Gulf of Mexico, which is close to Georgia but far from New York. In other words, he may compare the infrasound "picture" of the release site to the one he is used to at home. And using his ability to hear infrasounds and tell which directions they are coming from, he will know to keep the Rocky Mountains on his left, the Atlantic Ocean on his right, and the Gulf of Mexico behind him. So he heads for home, continually comparing the infrasound "picture" along the way to the infrasound "picture" he is familiar with at home. As it gets more and more familiar, he knows he is going in the right direction. When the infrasound "picture" is the same as the one he knows as home, he knows he is near. It could be nighttime. He could be wearing foggy contact lenses. He could have an electromagnet around his neck, knocking out his internal magnetic compass. But give this pigeon access to the infrasound, coursing through the air, and he can navigate without eyesight or compass.

THAT, faithful reader, is the breakthrough – the discovery – the hard-to-believe extra sense – the "secret power" of the homing pigeon! Infrasound sensitivity! Small wonder that, before now, men though it was some "superhuman power". It is.

Of course, on a clear day, pigeons will use the sun. On cloudy days, they may still be able to use the sun, magnetic north, barometric pressure, and the moon. But as you take away the more easily utilized signals, they seem to have one more means to find home. Take away everything else, and they will fly up and down the invisible waves of infrasound. And they will still find home.

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This article is an adaptation of four presentations at the American Pigeon Fanciers' Council, in 1973, 1974, 1977 and 1978, at St. Louis, by W.T. Keeton, M.L. Kreithen and D.B. Quine from Cornell University. These were followed by questions from the audience. Some of the questions that listeners asked are presented here with brief answers.

Q. How many pigeons were they working with at Cornell?

A. About 500 breeders – about 2,000 pigeons of all ages during the testing seasons.

Q. What strains of homing pigeons were used?

A. Practically all of the better-known strains that are flown in America. Although the University's budget to purchase experimental animals was limited, many pigeon fanciers donated breeders to the project. Dr. Keeton made sure that the famous strains of Belgian Racing Pigeons were represented. Gordons, Huyskins, van Riels, and Trentons were some of them.

Do the pigeons "hear" infrasound with their ears or some other organ?

A. Apparently, they detect infrasound with their ears. Pigeons with their ears plugged had reduced sensitivity to infrasounds. Deaf pigeons did not seem to detect infrasounds. We do not know what part of the ear is involved with infrasound detection•

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