

EVOLUTION

Cities Are Forcing a New Era of Rapid Evolution

Humans are changing the course of evolution

By Menno Schilthuizen | Scientific American September 2018 Issue



Credit: Armando Veve

IN BRIEF

Species as varied as snails, dandelions and fish are adapting to urban environments in surprisingly novel ways.

In many cases, the speed of evolution is faster than would have occurred in natural settings.

Because cities worldwide present similar evolutionary pressures, species there may become more alike.

Many species will never be able to adapt to what are often extreme conditions, so they still need protections.

“Whoosh!” exclaims my friend Frank, as he thrusts his cupped hands upward, nearly knocking over his drink on the table between us. We are sitting in my backyard in Leiden, the Netherlands. Frank is demonstrating how, once or twice each day, a peregrine falcon swoops upward past his hospital office window with a freshly killed pigeon in its talons, headed for its lair underneath the giant illuminated logo at the top of the building. A few seconds later plucked feathers come drifting down.

Peregrine falcons are one of many bird species that have recently taken up an urban lifestyle. They traditionally hunt medium-sized birds around rocky cliffs, but as humans worldwide have filled the environment with an artificial cliff-scape of churches, chimneys and office buildings, the birds have happily exchanged escarpments for skyscrapers and jays for pigeons. In some parts of Europe and North America the majority of peregrine falcons nest in cities.

Such accidental similarities between urban and natural environments are attracting more fauna and flora to the metropolis. Cave cockroaches are preadapted to live in our dark, dank homes. Beach plants readily sprout along the briny edges of roads that are salted in winter. Raccoons, with their nimble, handlike forepaws, are eminently suited to manipulate garbage and compost bins strewn across the man-made landscape. *Homo sapiens* have established extensive settlements on nearly every continent, and by 2030 more than 600 cities will each be home to greater than one million people. No single species has ever produced new conditions for other species to live in, on such a global scale.

Something even more surprising is going on as well. The city—with its countenance of brick, glass and steel, the racing pulse of its vehicle-filled veins, its luminescent artificial light and the chemicals emanating from its pores—is an extreme yet bountiful environment. Although the conditions can be harsh, they can also provide many benefits, notably all the food and resources that humans accumulate. As in naturally extreme environments, such as deserts, sulfur springs and deep caves, this combination of risk and opportunity is driving the evolution of animals and plants that venture there. As my colleagues worldwide and I are discovering, cities have become pressure cookers of evolution—places that force adaptation to happen quickly and pervasively.

STREET-SMART SNAILS

You can witness urban evolution on a field trip that begins right outside your door. My own small backyard is a good example. I must admit that, for a biologist, my garden is an embarrassment (as Frank keeps reminding me). All kinds of weeds are sprouting between old pavement tiles on the ground. There is a neglected rose bush in one corner and a potted hydrangea in another. That's about it, except for the sprawling hop plants that relentlessly scale the wall looming over my yard.

The hop leaves shroud one of my favorite examples of urban evolution. I carefully peel them away from the wall, showing Frank grove snails nibbling at the dead branches of previous years. The snails, *Cepaea nemoralis*, native to Europe and introduced across North America, can have a variety of shell colors and patterns. The variations are coded in their DNA. My snails are pale yellow, adorned with up to five black spiral bands.

Why yellow? The answer has to do with the heat island effect. Cities tend to be hotter than the countryside around them because the buildings and streets absorb the sun's heat. That absorption, plus added heat generated by the activities of millions of people and their machines, creates a bubble of hot air. In a modest municipality such as Leiden, the air in the city center is on average two to three degrees Celsius warmer than it is in the surrounding area. In big cities such as New York or Tokyo, the difference can be more than 10 degrees C. For snails, which are sometimes forced to spend weeks of summer drought clinging to a wall, the extra heat can become fatal—more so if they have a dark shell, which absorbs the energy. Natural selection is causing grove snail shells in my city and others to become lighter in color. Outside the city perimeter they are more likely to be red or brown.

As Frank and I pass through my garden gate into the alley, we stumble across a second example of urban evolution: dandelions! They are pushing up from cracks in the pavement. Some are in full yellow bloom; others sport a head of fluffy, umbrellalike seeds. Under natural conditions, the seeds, suspended from feathery parachutes, are supposed to drift in the wind and eventually land and germinate far away from their parents and siblings. This system prevents competition. But in the city, the strategy is not likely to work, because the stamp-sized bit of soil where the parent grows is often the only fertile spot around. Seeds that blow far in the

wind will likely land on barren asphalt or concrete. It would be better to have a heavy seed that drops straight down to the soil at the parent's feet. That is exactly what Arathi Seshadri of Colorado State University discovered in 2012. The parachutes of urban dandelion seeds, she found, are more elongated and drop up to twice as fast as the parachutes holding dandelion seeds out in traditional meadows.

Ironically, this adaptation is similar to what a relative of the dandelion, cat's ear (*Hypochaeris radicata*), has undergone in a natural, extreme environment. On tiny islets off the Canadian western coast, cat's ear has evolved seeds that descend faster than those of plants on the mainland. Here the risk of being blown out to sea drove the modification.

BRIGHT LIGHTS, BIG CITY

Continuing our field trip to uncover urban evolution, Frank and I emerge from the alley and cross the main street to reach the river, *Galgenwater* (Gallows' Water). A cluster of houseboats hugs the embankment where Rembrandt's birthplace once stood. As we approach a suspension bridge, we notice spider webs everywhere: between bars on the bridge railings, against the windows of the houseboats. Large circular webs, ranging in size from dessert plates to bicycle wheels, glisten in the sun. The sucked-dry corpses of midges and moths hang from the threads, a reminder of the gallows that once stood here.



DOWNTOWN ADAPTERS: Dandelions in cities are reshaping their seeds so they drop straight down into precious small patches of soil. Bridge spiders, which usually avoid sunlight, are bravely spinning webs under streetlights. Credit: Marcel Van Den Bergh

The bridge spiders (*Larinioides sclopetarius*) themselves are nowhere to be seen. The species is nocturnal, hiding in crevices that block daylight, waiting for night to venture to the web hubs to snare prey. Yet these webs are constructed right below the bridge lights. This now urban spider has thrown tradition to the wind because

the lights attract insects. In the 1990s Austrian arachnologist Astrid Heiling determined that urban bridge spiders are born with a love for artificial light, even though they still avoid sunlight.

Interestingly, an opposite evolution is happening in at least one species of the spiders' prey. For insects, the lure of a lightbulb is often fatal. They get fried by the heat, exhaust themselves circling the lamp when they should be feeding or mating, or end up in a bridge spider's jaws. Many entomologists believe the attraction to light is so hardwired in an insect's brain that it cannot switch off, even in the face of a severe death toll.



SURVIVAL SKILLS: Pigeons, unafraid of the author, must learn to hide from the rising number of urban peregrine falcons that hunt them. Snails that live on city walls are evolving lighter shells to absorb less heat. Credit: Marcel Van Den Bergh

But Swiss entomologist Florian Altermatt was not convinced. He targeted the small ermine moth (*Yponomeuta cagnagella*). He collected hundreds of the caterpillars in the illuminated center of Basel and a similar number in dark forests

outside the city. He reared them all in the lab and gave each moth a little paint mark to denote its urban or rural origin. Then he released more than 1,000 of them in a large dark cage that had a single fluorescent tube at one end. True to form, the rural moths tended to hover near the lamp, but the urban ones were more likely to ignore the light and settle elsewhere in the cage. Apparently, Altermatt concluded, the urban moths had evolved a resistance to artificial light.

RAPID EVOLUTION

The handful of examples of urban Darwinism that Frank and I encountered on our brief stroll represent a ubiquitous process under way in city ecosystems around the globe. In addition to the heat island effect, impervious surfaces and light pollution, urban wildlife faces a panoply of other challenges: noise, chemical pollution and traffic, to name but a few. Urban evolutionary biologists have found many instances of wildlife adapting to such stressors. Some creatures can even overcome the seemingly insurmountable obstacle of heavy toxic pollution. Andrew Whitehead of the University of California, Davis, and his colleagues found that little estuarine fishes on the U.S. East Coast, called mummichogs, have developed tolerance to PCB concentrations up to 8,000 times higher than what is normally lethal for them.

Perhaps even more important than physical and chemical factors are the biological ones. The new city dwellers rub shoulders with a motley crew of foreign species, brought in accidentally or intentionally: ornamental plants, agricultural crops and pests, domesticated pets, and all the insects and weeds that people unwittingly carry in on their clothes and vehicles. Together these organisms form an ecosystem of species that cohabit willy-nilly, without ever having had the opportunity to adapt to one another. This unorthodox mix sets the stage for the mutual evolution of new attack and defense abilities: exotic parakeets might adapt to feed on native city seeds, whereas native city birds could evolve immunities against foreign parasites.

All these challenges and opportunities create a powerful mix in which urban species evolve rapidly. Substantial adaptation often happens in a couple of decades, sometimes only a few years. Mummichogs evolved their PCB tolerance in just a few dozen fish generations; theoretical models show that is about as fast as evolution could take place for them.

Many people doubt evolution can really happen so quickly. After all, Darwin wrote: “We see nothing of these slow changes in progress, until the hand of time has marked the long lapse of ages.” Yet under strong natural selection pressure, evolution can proceed much more rapidly than Darwin thought possible. This is especially true for organisms that can reproduce multiple times in a year.

In a meta-analysis of more than 1,600 case studies, published last year in the *Proceedings of the National Academy of Sciences USA*, a group of researchers led by Marina Alberti of the University of Washington found a clear signal that urbanization does speed up evolution, in some cases as much as double the rate. One of the strongest drivers of greater speed was the introduction of exotic species into an environment.

Given that rapid urban evolution is happening all around us, does that mean everything is fine? Will all species simply adapt to the human-altered habitats that will increasingly dominate Earth in our current geologic epoch, the Anthropocene? Sadly, no. Only certain species will be able to colonize, survive and thrive in cities. For each success story, there may be a dozen cases of urban extinction: species that simply could not adapt and therefore disappear. Many, many species will continue to need the reserves, protected areas, laws and other safeguards that allow pristine habitats to survive in the citified future.

Nevertheless, urban ecosystems expanding around the world do represent an exciting new phase in the history of life on Earth. Never before has an extreme habitat had such a global presence. Cities everywhere share a suite of common features that flora and fauna will adapt to in similar ways. Perhaps spare-time naturalists can help the full-timers track the extent and pace of change. Many urban species, such as city pigeons, white clover and dandelions, are prevalent across the planet; a global community of citizen scientists could effectively monitor how they are changing. (Indeed, the evolution of yellow-shelled grove snails was revealed by volunteers using the smartphone app SnailSnap, which has yielded data on more than 12,000 snails in Dutch cities.)

It may turn out that all those intrepid creatures adapting in parallel to comparable cityscape conditions could become more alike, coming up with the same solutions for the many pressures. Global homogenization could be the characteristic that actually sets urban evolution apart from “natural” evolution and become the hallmark of human influence on other species. Because such a situation is unprecedented ecologically, we can only guess what the future will hold.

This article was originally published with the title "Darwin in the City"

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FROM OUR ARCHIVES

Urban Monkeys. Sheo Dan Singh; July 1969.

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