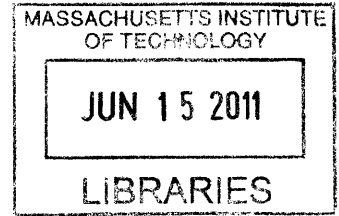


Metromorphosis:  
Evolution on the Urban Island

by

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B.A. Zoology  
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Submitted to the Program in Writing and Humanistic Studies  
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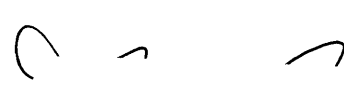
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ABSTRACT

Cities are very much alive. Like islands, they provide a natural testing ground for evolution. With more than half of the world's population living in urban areas now, the influence cities have on the planet's life is enormous. But can they produce species?

Foxes are learning to take advantage of human handouts in London, blackbirds are adjusting their physiology to relax around humans, and two forms of mosquito are diverging in the London tube system. Cities are hotbeds of evolutionary change, and regardless of whether or not new forms of life are destined to arise, they may help shed light on the origin of species.

Thesis Supervisor: Thomas Levenson  
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## Part I: Archipelagos

Leaning forward, I watch Boston fall away. The plane is doing most of the work, but my shoulders strain against gravity as I peer out the too-small window. It is night, and the city is defined by its glow. At first I can see individual cars, their shapes and colors, illuminated by streetlights. Soon, cars are consumed by their headlights. Roads become glittering streams. The city itself becomes a brilliant web. We climb higher. Other cities and towns come into view, smaller but no less bright. Higher and higher. All at once, it's clear: the cities and towns of the eastern seaboard have formed a luminescent archipelago in a sea of darkness.

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Islands are the curio shops of evolution, choc-a-block full of oddities, exceptions, and one-of-a-kind creatures. New Zealand was once dominated by birds of tremendous sizes: eleven species of moa, completely wingless giants (lacking even the vestigial wings of emus or ostriches), the largest of which could reach twelve feet in height. These were in turn hunted by Haast's eagle, the largest eagle ever known. The avian megafauna of New Zealand was wiped out some time ago, perhaps due to the arrival of man, but the islands are still marked by feathered freaks: the nearly blind, nocturnal kiwi, which lays the largest egg relative to body weight of any bird; the kakapo, a critically endangered, chubby, lime-green flightless parrot of which there are less than 150 left.

New Zealand isn't even *that* weird, as islands go. On nearby Australia, pouch-bearing mammals – marsupials – reign. Off the southeastern coast of Africa, Madagascar hosts all 100 or so species of living lemur, primitive primates. The islands of Santa Catalina, off of California, are home to a rattlesnake sans rattle, alongside six distinct subspecies of aptly named island fox, an offshoot of the common gray fox. On Komodo there be dragons. A tiny coral island, Aldabra, in the Indian Ocean is home to its own giant tortoise, distinct from those famous reptiles of the Galapagos. Speaking of which, the Galapagos are also home to marine iguanas, flying (rather, *swimming*) in the face of usual iguana habits by spending their time submerged in the surf and feeding off algae.

If you're like me, the Galapagos Islands are inseparable from their most famous visitor, Charles Darwin. Indeed, Darwin's time on the Galapagos Islands in 1835 is often credited as the catalyst for his famous idea: evolution via natural selection. Darwin visited the Galapagos aboard the *HMS Beagle*, toward the tail-end of a surveying trip that lasted from December 1831 until October 1836. Of all the many species Darwin collected, described, and observed during his time on the islands, it is his eponymous finches that are most famous. Darwin first collected these smallish, sooty-colored birds without bothering to label their islands of origin. Upon Darwin's return, his ornithologist friend John Gould pointed out that the birds, which Darwin had assumed to be unrelated orioles, wrens, and grosbeaks, were actually all finches. In 1837, four months after the *Beagle's* return, Gould gave a report at a Zoological Society meeting, revealing that Darwin's finches comprised a group of 12 new, closely-related species. Soon after, in private, Gould upped the number of finch species to 13, and further identified three new species of mockingbird from Darwin's Galapagos collections. These *had* been tagged with location. Isn't it odd, Gould noted, that these three different species all come from different islands?

In his ornithological notes written during the *Beagle's* journey Darwin had already wondered at the fact that distinct-but-related birds could be found filling similar ecological roles on closely neighboring islands. There seemed to be a connection between the relationships among species and their location in geography. The mockingbirds fed neatly into this growing idea. (Had he the foresight or fortune to label his finches with location, he would have found them similarly thought-provoking.)

This all led him to wonder if the theological sense of creation as a divine act was wrong; if perhaps species arose from one another in space and time. In other words, it led him toward his idea on the origin of species. "If there is the slightest foundation for these remarks," he wrote, "the Zoology of archipelagoes will be well worth examining, for such facts would undermine the stability of species."

In the twenty years after his return from the voyage of the *Beagle*, Darwin worked on his idea. Only Darwin's big idea wasn't to be unique for very long. His comment about archipelagos was portentous, as it was another archipelago which would lead fellow naturalist Alfred Russell Wallace to the same conclusions.

In his opus of island-hopping, *The Song of the Dodo*, nature writer David Quammen calls Wallace "the greatest field biologist of the nineteenth century." Wallace spent eight years in the Malay Archipelago, modern Indonesia, beginning in 1854, fully 18 years after Darwin had returned from the Galapagos. While Darwin nurtured his idea, Wallace was out collecting more than 125,000 specimens, more than a thousand of which would turn out to be new to science. More importantly, he was collecting evidence for his own ideas about evolution. The Malay Archipelago served as his Galapagos, and it catalyzed a manuscript that he sent to Darwin in 1858. Darwin found in that manuscript, for all intents and purposes, the doppelganger of his own idea.

Two archipelagos, on opposite sides of the Pacific, had brought two men, of wildly different temperament and history, to the same conclusion: evolution via natural selection.

Evolution as a larger concept didn't belong to either man: others had proposed that species could change over time. French zoologist Jean-Baptiste Lamarck is now most famous for taking a big swing for the fences and whiffing with his theory of inheritance of acquired characteristics. In short, he proposed that a stubby-necked giraffe in the distant past might stretch its neck a bit while reaching for the extra-delicious leaves at the top of a tree, and then pass a slightly elongated neck on to its offspring, and so on down the generations, with giraffes' necks stretching ever upward until we end with the faintly ridiculous proportions of modern-day giraffes.

Darwin and Wallace had a different take. Let's return to our hypothetical giraffes. Imagine that their neck length varies from individual to individual, with some giraffes having longer necks than others. Second, imagine that this innate variation can be passed from parents to offspring. If we assume the highest leaves are truly more delicious and nutritious, then having a longer neck will give a giraffe access to a boost in nutrition. This boost in nutrition translates to a boost in baby production (simply: not starving lets you have more kids). Longer-necked giraffes will send more babies into the next generation, and these babies will tend to have longer necks like their parents. On the whole, giraffes get a bit more ridiculous.

In this example, natural selection is 'selecting' for giraffes with longer necks, as they are better-suited for their current environment. What's more, Darwin and Wallace argued, is that the long-term pressure from selective forces, given enough time, could account for new

species -- for the dizzying diversity of life as we know it. The actual formation of species, however -- that critical moment in our hypothetical when our evolving giraffes would become so ridiculous as to merit distinction as a new species -- is a problem that has plagued Darwin and continues to puzzle scientists to this day.

It's not that biology lacks a species definition – rather, it has a surfeit. There are definitions based on external appearance, on genetic distances, on behavior, and mixtures thereof. And that's just for the intellectual pure, abstracted definition of what a 'species' should be. The actual category of 'species', as used by biologists today, doesn't necessarily adhere to any of these. That said, one definition, called the Biological Species Concept, stands head and shoulders above the rest in terms of usage and familiarity. This is the 'standard' definition offered in most biology textbooks. It was first proposed by Ernst Mayr, renowned taxonomist and one of the 20<sup>th</sup> century's top evolutionary biologists . By his definition, “species are groups of interbreeding populations that are reproductively isolated from other such groups.”

His definition helps to explain why islands – and potentially cities – produce so many interesting new species. Islands are inherently isolating, particularly for terrestrial species. The marine iguanas that populate the Galapagos are likely descended from mainland iguanas that got lucky and rode a raft of vegetation out to the islands some time long, long ago. Fundamentally, isolation facilitates speciation through mutation.

Whenever DNA is copied, there can be mistakes. These 'imperfections' are the source of genetic novelty we call mutations. When a population of iguanas is happily interbreeding, then these mutations get mixed around in the collective 'gene pool' of all the individuals. But once some of the iguanas get separated, and are only able to breed with one another, they will begin to accumulate mutations that they are *not* sharing with the larger population. It is only a matter of time before they accumulate so many mutations that they are no longer compatible with their former cohabitants. It may seem like an oversimplification, but the only two prerequisites for speciation are *isolation* and *time*.

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Knowing this, the archipelago of light below my plane takes on new meaning. Each circle of light could be a hotspot for speciation. What's happening to the wildlife that enters our cities? Are these urban pioneers like those seafaring iguanas that would eventually become the salt-sneezing denizens of the Galapagos islands? Have they become isolated, and has enough time passed? Could they reveal what exactly happens when a new species forms, something even Darwin wasn't sure of?

The white marble statue of Darwin stands mute on the matter, preferring to regard the entrance hall of the London Natural History Museum from beneath heavy brows like some deep-thinking emperor. Here, I thought, is the closest thing to a prophet biology has ever had. Hidden in the wings to either side of Darwin are statues of Richard Owen, paleontologist extraordinaire, and T.H. Huxley, Darwin's pugnacious champion. I could not find Wallace.

Everywhere in the museum – in all such museums – there are tags announcing the species to which each specimen belongs. The species is the primary unit of identification for natural history museums and naturalists, for biology as a whole.

I had journeyed to my own island, in this case England, in search of urban speciation. And, more broadly, an understanding of what speciation looks like. The cities of Europe are older than those of America, and they've had more of that crucial component – time – for speciation. Maybe that's why the most compelling research on urban evolution seems to come from Europe.

In London alone, at least three species are in the process of evolving on, above, or below the streets. Each of these species, in turn, represents a larger trend in the the process of urbanization. There are the foxes, *Vulpes vulpes*, a familiar face across most of the northern hemisphere, and they reveal that speciation is far from the only way to succeed as an urban species. There are the blackbirds, *Turdus merula*, which may show how much a species can change without becoming a new species. And finally, there are two mosquitoes, *Culex pipiens pipiens*, and *Culex pipiens molestus*, which show just how messy the search for speciation can get.

## Part II: The Plastics

In today's parlance, 'plastic' usually refers to bottles and surgery, but in the world of ecology it has a slightly different meaning. In this this context, plastic means malleable, flexible. When ecologists discuss the “plasticity” of a species, they're not talking about whether it has had any work done, but how much changeability it shows in response to its environment. The full, two-part term of art is 'phenotypic plasticity' – where 'phenotype' denotes any observable trait of an organism, from activity patterns (behavior), to fur color (morphology) to hormone levels (physiology).

The first three species we will meet are paragons of plasticity, particularly as far as behavior is concerned. The first is remarkable for it's wide-ranging appetite, the second for its skill at dodging traffic, and the third for its size and sheer newness.

On nights in Acton, West London, Monesh watches foxes. He works at the London Guest House, a modest bed and breakfast, equipped with close-circuit television cameras. From the cramped command center behind the front desk, he can see the vacant lot across the street. When people put their rubbish bins out, the foxes come.

The people of London speak with casual ease of their foxes. A red-haired woman in the George and Dragon Pub shares harrowing tales of being “attacked” while walking home at night. Again, it's the garbage, she says: they get angry if they think you're trying to take their food. Everyone, from a professor of history from Cambridge to a frequent-flying businesswoman agree: foxes are ubiquitous.

This is more than just hearsay, of course. The red fox, *Vulpes vulpes*, is one of the most ubiquitous animals on the planet, never mind cities. It has the largest geographic range of any carnivore, from Alaska across America, over the Atlantic into Europe, down into northern Africa and straight on into Asia. It's even been introduced to Australia. Its range of habitats is just as varied, including forests of all sorts, farmland, tundra, and – recently – cities.



But the real hotspot for foxes is the UK, and the hottest spot therein is Bristol, some two hours east of London by car. The foxes here have been the focal point of an extensive research program spanning more than 30 years. Before an outbreak of mange decimated the population, one could, with minimal effort, encounter 20 foxes in an hour on an average night.

Here is a species that has truly earned the title 'urban'. Surely, if urbanization were to put pressure on a species to change, or were to isolate it from its rural kin, these foxes would show it.

These foxes are like old friends to Stephen Harris and his colleague Phil Baker. Harris, in particular, has studied the foxes of Bristol and London for more than 30 years now. They've tracked the movements of hundreds of foxes in and around the cities, gathered public opinion and observation, and become the reigning experts on the matter of urban foxes. The two have, quite literally, written the book on this subject.

Faced with the question of urban speciation among foxes, Phil Baker said via email that this is something he has considered. The evidence for this is, however, "sparse" at best. Wherever the pressures of urban living might be trying to separate and change them from their rural kin, they're able to adjust to this pressure without needing to change their genes very much.

There persists a stereotype of mangy, half-starved foxes living a hardscrabble life on the streets, like some vulpine *Oliver Twist*. People in the UK seem quite certain that their urban foxes are able to eke out a meager survival primarily by raiding dustbins. Yet these foxes are, by all accounts, flourishing. To them, the city doesn't represent the epitome of a hard-knock life. Quite the opposite, in fact.

Anybody who has walked down a city street and stepped on a rotting apple core can attest to the fact that city streets, despite our best efforts, are often littered with food particles. I remember sitting near Faneuil Hall in Boston, tearing into a steak and egg sub while a crowd of house sparrows, starlings, and pigeons gathered 'round, like living vacuums, to suck up all the crumbs. Lucky for the birds, I'm not a very fastidious eater. Bottom line: people like to eat. A lot. And just as cities concentrate human populations, they concentrate food resources. The scientific word for human-made, *anthropogenic*, is scattered through the urban ecology literature like shreds of an orange rind. This abundance of anthropogenic food in cities provides a strong incentive (read: strong selective pressure) for any species willing and able to take advantage of it.

In Bristol, particularly in affluent neighborhoods, residents have taken to *their* foxes. They delight in providing food for the animals each evening. Oftentimes, whole fox families can be found waiting in the backyard for their dinner. In fact, the humans and foxes have grown comfortable enough around one another that some foxes have been known to paw at the back door to remind their human providers that it's dinnertime. Yet even in these well-to-do-neighborhoods, where foxes may set up nightly routes to get all the best free meals, foxes don't subsist primarily on handouts. Nor are they gorging themselves on refuse. Rather, they display a remarkable breadth of diet.

Harris and Baker's work has shown that more than any one food source being particularly important, that foxes are dyed-in-the-fur opportunists. They can get by on fruits and berries, on earthworms and insects, on refuse, rodents, generous homeowners, or –

almost always – some combination thereof. They'll sample any food, provided it's available. Foxes in Bristol actually get 26.9% of their food as insects. In contrast, London foxes eat only 15.4% insects. Furthermore, wild mammals were an almost nonexistent part of the Bristol fox diet (3.5%), but in London they were fully 10%.

It's this opportunism that has allowed foxes to succeed as urban animals, and yet it also ends up buffering them against the effects of urban selective pressures. Foxes in the wild are every bit as opportunistic as foxes in the city. These foxes are not, in fact, all that different from their rural kin – they don't need to be. If a fox's primary advantage in the forest is that it's able to take advantage of whatever food is available, then that same advantage translates handily the streets of Bristol. Case in point: oftentimes 'urban' and 'rural' foxes are actually the same individual.

A subset of the urban fox population, affectionately dubbed 'commuters', spend part of their day in the city, and part of their day in the rural areas around the city. They might spend daytime nestled in a countryside thicket, and trot right into the city each night to take advantage of the anthropogenic smorgasbord. There are even 'reverse-commuters', who shelter in urban areas by day but seek sustenance in the rural surroundings by night. The point is, foxes are creative enough – plastic enough – in their behavior to do whatever works best in a given situation.

This plasticity ends up presenting a twofold obstacle to speciation. First, if a species has high behavioral plasticity that means its genes code for flexibility. If that flexibility already encompasses the sorts of traits necessary for urban living, then there's not much need for change on a genetic level. Yes, an urban fox might rip open a garbage bag instead of hunting voles in a field, but its genes already enable both behaviors.

Second, the foxes' mobility and flexibility also breaks down any isolation that might otherwise happen between urban and rural populations. Those 'commuter' foxes are carrying genes back and forth between the rural and urban fox populations all the time. In ecological terms, there is a high level of gene flow between the two populations – which washes out any differences that may otherwise develop. So, while foxes are certainly consummate urban survivors, they are not likely to develop an urban species anytime soon.

A very similar story is playing out now, in America, where a masked bandit is showing itself every bit as clever as a fox – if not more so. Stanley Gehrt, an urban ecologist and editor of *Urban Carnivores*, found his own island of sorts in the form of the Ned Brown Forest Preserve just outside of Chicago. In this paradise, one can find plenty of food and water and lots of trees to take refuge in.

It's as isolated a patch of habitat as one might find within an urban area. The preserve is bounded on all sides by high-traffic roadways, and beyond that is all developed land. The sounds of planes passing overhead from O'Hare is so loud that researchers in the park have had to yell at one another simply to be heard. Gehrt expected, quite reasonably, that any population of raccoons here must be prime candidates for isolation. In retrospect, he may have underestimated just resourceful raccoons are.

Gehrt had also worked with raccoons in Texas, and there he met an individual that embodied the sort of behavioral plasticity that would make even a Bristol fox jealous. This particular raccoon figured out that he could catch grasshoppers, when none of his peers did, and he got himself good and fat off this crunchy meal. The same individual also developed a particularly troublesome trick for when he was trapped by Gehrt for further study. This raccoon would heave himself at the side of his trap, rolling it over. One time he managed to

roll so far away that, were it not for the fact that he had already been radio-collared, Gehrt never would have found him. (Lucky for the animal, Gehrt says, or the animal would have starved in the trap.)

With this in mind, perhaps it's not so shocking to find that the Ned Brown Forest Preserve raccoons are savvy enough to cross those multi-line highways. When Gehrt's team did genetic work on the Ned Brown raccoons, they found that several alleles – specific forms of genes – which were common in the rural population were also present in these 'urban-locked' raccoons. While they did prove different enough to merit consideration as a distinct population, there was still too much gene flow – too many clever raccoons dogging traffic – to leave any hope of incipient speciation.

Both foxes and raccoons are already well-established as urban species, and what the urban ecologists working with them discover about the urbanization process is almost reconstructed from after-the-fact observations. The third plastic, however, is a relative newcomer, and its arrival in American cities is making quite a fuss. My own first encounter with this species is one of the more vivid memories from my childhood.

I'd like to say it was a dark and stormy night, but it was just dark. I was up in my room, ostensibly asleep – but probably reading – in a big blue two-story house on the Lowell edge of the Lowell-Dracut-Tyngsborough state forest. Up to that point, the forest behind my house – by far the largest tract of green anywhere in the city – had been largely silent at night. That night, I heard something new, distant and wailing.

As I listened, the sounds coalesced into a symphony of yipping, undulating howls. They weren't wolves, I knew that much – a wolf howl, by comparison, is long, low, and comparatively even. Regardless, I was terrified. My parents heard it too, but assumed it was a sound effect from the television.

The sounds would eventually become the familiar signal that our new neighbors, coyotes, were out and about. I saw one, once, hiding behind a neighbor's car on – of all nights – Halloween. It bolted into the forest under the beam of my flashlight. I grew up in those woods, knew them well, but we'd never heard nor seen any coyotes in our forest. It was, by my reckoning, the mid-to-late-90s when the animals appeared in our forest.

It's now apparent that Lowell wasn't the only city experiencing an influx of coyotes. Their range has exploded in the wake of the extermination of gray wolves from most of America by the beginning of the 20<sup>th</sup> century. Ever since, the coyote (*Canis latrans*), originally a species of the American southwest, has been pushing north and east, filling the ecological void left behind by its top predator kin. Today, the coyote is typically the largest predator taking up residence near humans.

Their history shows a pattern similar to many urban species: at first, they stick to wild areas, 'natural' habitats. As populations grow and cities expand, they begin to move into the greener, less-tamed parts of cities – parks, suburbs, the ditches around train tracks. Once the population gets established there, they begin to move into the city proper. For instance, Central Park in NYC is currently host to a population of coyotes, and coyotes are also showing up on Columbia University's campus in Manhattan.

Even in the last few weeks, stories about urban coyotes around Boston have been frequent news fodder. On February 1<sup>st</sup>, a coyote was rescued from the Charles River by the Animal Rescue League of Boston after falling through the ice. On February 11<sup>th</sup>,

environmental police were called in to remove a coyote living under a porch in Dorchester, Massachusetts, eventually euthanizing the animal when it proved too persistent and too injured to present any other options. Yet another was found in Salem, trapped with its back feet wedged between the top slats of a picket fence. There are frequent reports of coyotes preying on pets, and indeed, although the overall proportion is low, small cats and dogs do show up consistently in dietary studies of urban populations.

Worse still are the extremely rare attacks on human beings. In one incident, a coyote attacked a five-year-old girl while she was in her back yard, biting her in the stomach and dragging her away. The animal was chased for 100 feet before dropping the girl, but she died soon afterward from a broken neck. Though children hardly constitute anything approaching a normal part of a coyote's diet, and stories of coyote attacks are probably over-hyped in the news, it's hard to ignore the simple fact that small children are not outside the size range for prey by coyotes.

It's reached the point that at least in one suburb in Rye, NY, people have begun to walk their dogs while carrying large sticks, and police are warning people to keep their children at arm's length at all times. An article in *The New York Times* quotes a mother from the area: "There's the bad-man talk, stranger danger, don't eat so much candy — and now here's the coyote talk."

Whether or not coyotes and people will be able to coexist peacefully in the long-term as urban coyote populations continue to grow remains to be seen. Should we collectively decide that they are unwanted, then the 'selective pressure' on them to avoid cities may overwhelm urban coyote populations.

Yet even as this story unfolds, urban ecologists are watching coyotes change in response to urbanization. In general, urban coyotes show surprisingly high life expectancy, with cars as a chief source of mortality. They also find their home range shrinking. With so much anthropogenic food, and with space in cities at such a premium, it seems that urban coyotes need to cover less ground to find enough food, and, at the same time, are under competitive pressure to keep their ranges as small as they can.

At the same time, in the most developed areas — the core of the city — some coyotes actually show an increase in home range size compared with their rural kin. Scientists speculate that this may be because downtown is actually rather poor habitat. Coyotes do best in the 'in-between' parts of the city. In the full-blown concrete jungle of the city core, they may have trouble finding food, and so the animals that do end up living in these spaces are forced to keep wider territories to find enough food.

These coyotes are adapting to the urban environment by changing their behavior, not necessarily their genes. Urban coyotes, Gehrt says, are spending more time with their parents than usual, sometimes never leaving and setting off on their own. The implication is that surviving in an urban environment may require a greater degree of parental 'training' than the rural lifestyle, and these animals are spending more time with their folks to fully develop the behavioral toolkit to survive in a world of people and cars and concrete. This ability to alter their parenting strategies is yet another form of plasticity.

What all of the plastics we've discussed above have in common is that their genes already allow them to be flexible, to do the sorts of things they need to survive in an urban environment. They adjust their schedules to compliment ours, for example — coyotes in particular more active at night in cities than in rural habitats. British foxes visit houses in sequence to get handouts. Raccoons open trash cans to get at the food inside.

In other words, what these animals are doing is changing their behavior and not their genes. They've retrofitted forest-smarts into street-smarts. As long as their behavioral plasticity is enough to satisfy the needs of urban life, it's unlikely that they will show significant genetic change anytime soon.

So far, we've emphasized plasticity, but these species are also linked by medium size – they're small enough to hide and be generally unobtrusive, to live in what essentially amounts to the spaces between our daily lives. (Although coyotes probably push the upper limit of this.) This medium size is directly connected to the mobility that 'commuter' foxes demonstrate – these animals are also big enough to travel large distances, and in doing so to carry their genes large distances too. The city/rural divide simply doesn't seem to mean as much for them as it might for other, less mobile, species. They're also all relatively recent arrivals to the city, particularly coyotes. Thus, they seem to fail both prerequisites for speciation: they are not very isolated and they have not had very much time to accumulate genetic differences even if they were. However, not every species that's succeeded in the city is a medium-sized mammal with a penchant for plasticity.

### Part III: “Common” Blackbirds

Just 200 years ago the common blackbird, *Turdus merula*, was a forest specialist. They were secretive things, preferring to remain hidden in thick understory, like our hermit thrushes. Over the summer of 2010, I worked at a Boy Scout camp full of hermit thrushes – at any given moment, two of three would be singing from the forest that ringed the Discovery Area. But in the three months I was there, I only laid eyes on two birds, in the midst of what must have been a territory dispute.

The European blackbird is a chubby specimen with uniformly dark plumage, black for males and browner for females. Imagine an American robin dipped in soot – the resemblance is not incidental, robins are of the same genus, *Turdus*. In many places, they are the single most common urban bird. This is an astounding feat for a species that was, until recently, an sylvan specialist. They weren't just *very good* at living in forests, they *required* forests. The first urban pioneers were reported in German cities in 1820, and now they've spread to dozens of cities across Europe. Like our robins, they are now familiar enough to most Europeans as to seem utterly unremarkable. Somehow, the species has gone from deep-forest-dweller to sly city-slicker with astonishing speed. What happened?

Often, the species that urbanize the quickest are those which are preadapted. In the case of foxes, raccoons, and coyotes, it's their behavioral flexibility that suited them for urban habitats. They have no trouble finding food and shelter because they're not picky; a fox will gobble grubs and garbage with equal gusto. But even some specialist species find that cities provide close analogues to the very habitats for which they've specialized. Peregrine falcons, for instance, are obligate cliff-nesters – they won't raise their young anywhere else. These masked, crow-sized raptors were critically endangered as recently as the 1990s, due to the pesticide DDT<sup>2</sup>. Today, most major cities today have resident falcons.

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<sup>2</sup> The birds would ingest DDT through their prey, and the chemical weakened their eggshells, leading the birds to crush their own broods when trying to incubate them. General use of DDT was banned by the EPA in 1972.

Falcons inhabit Boston, New York City, even my hometown of Lowell, Massachusetts. The facades of skyscrapers are sufficiently cliff-like to meet the falcon's habitat requirements, and the abundance of pigeon-prey doesn't hurt either.

The blackbird does not appear so well-prepared. What part of the urban habitat is forest-like? We clear out the thick brush these birds favored, and what little forest we preserve is often heavily maintained. One would expect the transition this species underwent to be particularly difficult, and to result in more fundamental changes than those seen in foxes and other 'plastics'.

Of all the creatures in the urban ecology literature, the urban blackbird is arguably the best studied. What these studies have found about the blackbird shows another dimension to the urbanization process, one largely missing from the story of foxes and their ilk. Blackbirds were not able to make the transition to cities unscathed. For them, infiltrating the urban matrix required an investment, a period of deeper adaptation and adjustment that seems absent from the story of the plastics.

Blackbirds have changed on a morphological, physiological, and genetic basis as part of their urbanization process. Compared to their rural kin, urban blackbirds have an extended breeding season, a tendency toward greater longevity, a reduced propensity to migrate, are more tame, and show a higher breeding density. Furthermore, they are genetically distinct from rural populations, and have lower overall genetic diversity.

There's little doubt that urban blackbirds have changed significantly, at a variety of levels, but the big question surrounding them – and one of the biggest questions in urban ecology – is how much of this change is a result of the sort of plasticity demonstrated by foxes and how much is change on a genetic level. You can think of plasticity as a buffer: high levels of plasticity mean a species' genes, in essence, code for flexibility. As long as the pressures of the urban habitat don't overwhelm this buffer, a species' genome should remain relatively untouched. Unfortunately, trying to tease apart plasticity and genetic change can be very difficult. The blackbird is one of a handful of species for which this work is being done. Consider the boldness (i.e. increased tameness) of urban blackbirds.

We may be inclined, as species used to 'learning' quite a bit about the world, that these birds could have simply become acclimated to city life. They've learned by trial and error, perhaps, that they can get close to people in cities with comparatively little risk (bratty kids who favor punting as their preferred form of pigeon interaction notwithstanding). Perhaps.

But flight distance – how close a blackbird will let you get before fleeing – is modulated, like all behavior, by genetics. Flight distance is a heritable trait that varies across individuals and across species – some species are bolder than others, and some individuals within species are bolder than others. This puts 'boldness' firmly within the grasp of the invisible hand of natural selection. It's possible that this aspect of behavior could be changing on a genetic level, not simply on an individual comfort level. It's the difference between a single brave Spartan and an entire army of innately braver individuals, shaped by centuries of warmongering.

The trick to separating nature and nurture is to eliminate one to observe the effects of the other. In the case of blackbirds, this means hand-rearing. Take eggs from a rural population and an urban population, prepare identical habitats in the lab for each, and then raise them from birth under the exact same conditions. They get the same air, the same perches, the same everything. Then, when these birds grow up, you see if they show any

differences. A 2006 study by Jesko Partecke, Ingrid Schwabl, and Eberhard Gwinner did just that.

They collected urban blackbirds from 10 nests in the center of Munich, Germany and forest blackbirds from 10 nests in a forest in Raisting, Germany. The urban birds were known to live close to humans, to breed on balconies, and were fans of foraging on traffic islands. By contrast, their forest birds led a reclusive lifestyle in a remote forest that saw only sporadic use for recreation. What's more, Partecke observed that these birds "explicitly avoid contact with humans".

The eggs were hatched in captivity, where the young were hand-reared and eventually moved to their own cages. The experimenters took blood samples from all the birds at seasonal intervals to measure the baseline levels of a stress hormone, corticosterone, in the birds' blood. They then stressed the birds by putting each of them in cloth bags and restraining them for an hour, taking blood samples at 5, 10, 30 and 60 minutes.

Ultimately, they compared both the baseline hormone levels of urban and rural blackbirds, as well as the acute responses to the stress of being trapped in a cloth bag. They found that while the baseline stress levels between urban and rural birds were similar, urban birds *did* show a lower acute stress response.

This, write the authors, "is evidence of an intrinsically reduced reactivity" – that is, on a biochemical level, they just don't react as strongly to being handled (or, by extension, stress in general). They are physiologically more even-tempered than their rural peers, having been influenced by the stresses of city life to take the genetic equivalent of a chill-pill.

This movement toward boldness may be one of the few general trends in the urbanization process. Such *trends* are hard to pin down for two reasons: first, research is often lacking, despite the current explosion of work being done and, second, because the effects of urbanization vary wildly across species. That said, the evolutionary logic underlying the development of boldness is awfully convincing.

The one constant feature of all urban habitats is us – people. Many species have been under direct pressure to avoid us in rural situations, where we are more often hunters and competitors than potential food source. But if a species is to survive in the city, it must invariably learn to be around humans. And there are certainly rewards for the bravest individuals. Here in Cambridge, the house sparrow with the most *chutzpah* is much more likely to pilfer a dropped French fry from a bench-bound student on lunch than his more skittish fellows.

Karl Evans, an urban ecologist with the University of Sheffield, has working with blackbirds and urbanization more generally for the better part of the last decade. He is trying to use the animal as a model species to identify larger patterns in how species adapt to urban areas. His 2010 paper, "A conceptual framework for the colonisation [sic] of urban areas", draws upon a huge body of research (well over 200 papers), to create a general model of the urbanization process. It was the first such comprehensive effort. His model includes three phases: (1) arrival (2) adjustment, and (3) spread.

During the arrival phase, Evans argues, species enter a city for the first time. Naturally, the more densely packed individuals are in the surrounding countryside, the more likely a few pioneering sorts are to disperse into the city. Environmental contingencies, such as droughts and increased predation, can also put pressures on a normally rural species to try urban habitats as a potential refuge. The arrival of goshawks in Hamburg, Germany, for

instance, is linked to severe winters and increased persecution. Along the same lines, urban white ibises in Sydney, Australia have increased rapidly in the wake of habitat (that is, wetland) destruction due to drought, dam construction, and agricultural water use.

So what drove blackbirds to enter cities? It may not have been a single specific inciting event. Sometimes, all that's necessary is time. All populations disperse in some form or another, and given enough time with cities and blackbirds existing in close proximity to one another, it's inevitable that a few blackbirds would end up in urban areas. It's what happens next, during the second, adaptation phase, that most interests us.

It's during this phase that the new pressures of the city mold our blackbirds, resulting in the sorts of physiological, behavioral, and genetic changes we see. This is the price the blackbirds must pay, in evolutionary terms, to establish themselves as a viable urban species. Having read so much about how urban blackbirds had changed, I couldn't resist the temptation to try and find some myself. I wanted to lay eyes on one, watch it for a while, see how it compared to *Turdus* species I was familiar with. So, in London, I set out to explore the urban matrix and find myself some blackbirds.

Urban ecologists are fond of the term *urban matrix* to describe the structure of cities: it reflects the patchy distribution of various habitats. Think of a handful of familiar city blocks. For the area around my apartment in Cambridge, this includes several towering dormitories for MIT students; an empty lot; gravel-coated railroad tracks; several small businesses; and at least two well-groomed parks, one of which is simply grass and trees, the other of which is rimmed with dense gardens. The matrix is more apparent with planned cities. Washington, D.C., when seen from above, looks for all the world like an austere gray grid, checkered with green. But even in a ramshackle collection of streets and alleys like Boston, the patchy distribution of habitats is evident. Of particular interest for wildlife are the parks interspersed amidst the concrete.

Boston has its Common, New York has Central Park, and London has the combined greenspace of Kensington Gardens and Hyde Park. Kensington Gardens used to be part of Hyde Park proper until bought up by William III in 1698, but for our purposes they might as well be one and the same. Together, the two halves comprise 625 acres in total, making the whole slightly smaller than Central Park (843 acres) but still roughly six times the size of Vatican City (only 109 acres). When I arrived at the park on a Sunday afternoon, I didn't know how big it was; all I knew was that I had a scant few hours before sundown to track down some urban blackbirds.

The *RSPB Pocket Guide to British Birds* I'd purchased at the Natural History Museum describes my quarry thusly: "One of the most familiar garden birds, with one of the richest and loveliest songs. Often sings from rooftops and aerials." Despite keeping my eyes fixed upwards, I'd seen only crows, magpies, pigeons, and a half-dozen other interesting birds. I checked the population status again. "Common." I couldn't help but feel like it was mocking me.

I entered the park from the western end amid a perpetual half-rain, the sort of weather where it's not so much 'drizzling' as the air itself is simply cold and wet at all times. The artificiality of Hyde Park is transparent. The green is too monotonous, all the same shade, intercut with lanes and pathways. It's winter, so the trees are largely barren, making their eerily even distribution all the more obvious. This is nature by design, carefully groomed to meet expectations. Some guys are playing a pick-up game of football that would be impossible in the dense understory once favored by blackbird. Hyde Park may feel like an



island of green in the larger island of gray that is London, but just because it's a green space doesn't mean it's all suitable habitat – something I was learning first-hand.

Within the park, though, there are even smaller islands – microhabitats – that differ greatly from one another. One, in particular, caught my eye – a dense strip of garden behind the Albert Memorial. With the sun setting, I wander down the narrow paved lane amid dozens of plants I wish I could identify.

It's not birds I lack, birds are everywhere. Every few steps, a European robin (not a true thrush like our robins, but a smallish bird with a red throat and chest) would appear from the underbrush to perch on a the low, wrought-iron fence or an open branch and sing right at me. Every now and then it's a great tit or a blue tit instead, inquisitive. They remind me of the chickadees back home, which in some places have learned to take food right out of human hands. Time wears on.

With the sun nearly gone, and every bird I see reduced to little more than a silhouette, my hopes are all but gone. As I walk through the garden, resigned, I'm startled out of my thoughts by an ungodly racket. I can hear the rasping of magpies, and what sounds like doves doing their best to coo with anger. I also hear rapid, high-pitched alarm calls. Blackbirds!

Rushing to investigate, I find a dense bush, easily taller than me by half, with a pair of magpies and a pair of doves of some kind perched in overhanging branches. I have no idea what's going on in that bush, or what the doves are doing there. The whole thing has the air of watching somebody else's domestic dispute. I keep hearing the blackbird sounds from within the impenetrable brush.

I stand there, squinting against the failing light. Eventually, the magpies lose interest and take off. Soon, the doves grow bored and depart. All goes silent. I wait, wondering if I'm not just hallucinating bird sounds now.

A flutter of sooty wings, a brief call, and a bird appears on the branch. It's chunky physique, long tail, and uniform matte-black coloration are unmistakable. Blackbird! And then, as soon as it appeared, it is gone.

In retrospect, it was acting quite a bit like the secretive hermit thrushes back home; like rural blackbirds probably act today, and as all blackbirds probably acted in the evolutionarily recent past. Of course, this was one bird, observed for an incredibly brief moment – I make no claims of scientific weight here. But what my hunt demonstrates is the subtlety of the effects on urban animals.

The effects of Evans's third phase, distribution, are even more subtle. For the distribution of urban blackbirds, one fact of their genetics is key to Evans's theory: any two populations of urban blackbirds are more similar, genetically, to one another than they are to the corresponding rural population. In other words, if you compared an urban blackbird from London to an urban blackbird from Paris, the London bird – despite being separated by more than 200 miles – will have more in common with the Paris bird than it will with rural blackbirds from just outside London.

This surprising relationship has led Evans to propose that the initial barrier for urbanization among blackbirds is so high that it's only been crossed once, by a single pioneering population, which then budded off and formed all the other urban population. This mirrors the effects one might see of a mainland species sending out a small pioneering population to an offshore archipelago. Once the pioneers got established in the first island, they were then able to island-hop, one-by-one, until they spread across the archipelago. In

the case of the urban blackbird, the urban pioneers hopped from city to city until they had become one of the most common urban birds in Europe.

Admittedly, for other species in the distribution phase, the urbanization process does not mimic the island colonization process so neatly. For some species, like the wood pigeon, it seems that initial barrier for urbanization is lower. As a result, rural wood pigeons are able to cross the rural/urban boundary with some frequency, and urban populations are often more closely related to the nearest rural population than to the nearest rural population.

Still, in the case of the blackbird, which is rapidly becoming something of a master case study in the field of urban ecology, the parallels between island colonization and urbanization are striking. Although these urban blackbirds may not be on the path to becoming a unique species (yet?), they are certainly on something of a unique evolutionary path within the larger blackbird population. They are distinguishable, perhaps not via the naked eye, but certainly with genetic and physiological work – and evolution is the master of genetic work. So are these particular birds becoming a new species? Probably not. Are they evolving? Absolutely. Things are considerably less clear-cut with these birds than with the plastics from before – they are changing in response to urbanization, but aren't changing *enough* to merit consideration as an incipient species. To be fair, the urban blackbirds have only been in the city for about 200 years, and evolutionary time is traditionally considered to operate in units more like thousands of years.

I'm sorry to say that things are not going to get any clearer from here. Our next and final case study is far and away the closest thing to urban speciation that I've found, but it's also an ungodly mess of blurred taxonomic lines and itchy red bites.

## Part V: A Tale of Two Mosquitoes

Deep in the dark beneath London, there lurks a menace so malicious that it will drive service workers back with its bloodsucking assault. It's confined to London's extensive tube network, where thousands of commuters spend dozens of man-hours a week shuffling into and out of trains. Little do they know that the city is waging an expensive war against the menace of *Culex pipiens molestus*, a form of mosquito found nowhere else in London. And it's a war that seems to be working: despite my best efforts to roll up my sleeves and create an enticing target, I was unable to successfully sacrifice my blood for science. This is despite its subspecies name, *molestus*, which denotes its most conspicuous behavior: it is a voracious biter.

The *molestus* form is a relatively recent find in London, having come to public attention in the midst of World War II. As people were driven to take shelter in the tunnels during the Blitz, they were badly bitten by a subterranean insect. Later scientific analysis revealed that this creature was morphologically indistinguishable from an aboveground form of mosquito in London, *Culex pipiens pipiens*. The *pipiens* form, however, doesn't bite people – or any mammals, for that matter. Instead, it feeds exclusively on birds. Genetic work has shown the two forms are extremely closely related, to the point that they are classified as the same genus and species, only distinguished at the troublesome taxonomic level of *subspecies*.

As we've seen, Darwin himself never quite settled on a clear definition of species. Nor have scientists since been able to come up with something universally satisfying. If we don't know for sure what a species is yet, one might ask, how can we go around creating subspecies? Subspecies are a subcategory within species, usually created by factors such as

geographic isolation of two populations – herring gulls found on either side of the Atlantic, for instance, are considered subspecies by some. But some biologists would tell you that subspecies are often a useless category. Karl Evans, in his genetic work on blackbirds, which are divided up into a dizzying array of more than a dozen subspecies across their range, found that essentially none of them match patterns in nature. At least with species, there is some vague consensus about what the acceptable parameters are: reproductive isolation, wildly divergent morphology, *et cetera*. In the case of subspecies, though, it seems like anything goes. Do your blackbirds seem a bit larger on average? Subspecies. This population of gorillas has smaller teeth and shorter skulls? Subspecies. Are your mosquitoes biting people but otherwise look exactly like a species of mosquito that *doesn't* bite people? Subspecies!

Taxonomic tinkering can grow tiresome, especially for biologists working with contentious subjects like *Culex pipiens molestus*. Researcher C.A. Malcolm recalls getting sick of typing *Culex pipiens molestus* every time he needed to mention his subject in a recent paper – something I can empathize with. So he began referring to it as simply *molestus*. This may not seem like a crime to us, but biological convention dictates that stating a name in italicized isolation denotes a species, not subspecies. Sure enough, his paper got an immediate response from another scientist: Oh, when did *molestus* become a full species? Malcolm's response to the entire thing was to throw up his hands in frustration.

Malcolm's frustration is not trivial. In any practical estimation, the two forms might as well be different species. Though they look alike, it's hard to imagine their life stories being any more divergent. It's like Spock and evil Spock: almost impossible to tell apart (except that goatee) yet wildly different in behavior.

We already know that *molestus* bites mammals whereas *pipiens* bites birds, but that's just the beginning. *Molestus*, in keeping with its seedy reputation, can reproduce anywhere there's enough space for mosquitoes to have sex; *pipiens*, on the other hand, requires open spaces to form breeding swarms. Despite their voracious reputation, *molestus* females can lay eggs without first taking a blood meal; *pipiens* cannot. *Molestus* stays active throughout the winter; *pipiens* goes into diapause, the insect equivalent of hibernation. Genetic work comparing the two forms has been used to argue for their consideration as separate species. As with the urban vs. rural blackbirds, all of the underground *molestus* mosquitoes are more closely related to one another than to the corresponding aboveground populations of *pipiens*. What's more, researchers were even able to identify which individual tube line a *molestus* was from via its genetics; the Northern Line and Bakerloo populations are distinct. And here's the kicker: they don't seem willing to interbreed. (It's as though *pipiens* are the Eloi and *molestus* are the Morlocks.) Even if you bring the two into a lab under presumably ideal conditions – some Marvin Gaye? – you can get them to get it on, but the eggs they produce are sterile. Therein lies the problem: successful reproduction is fundamental to a species under the Biological Species Concept. Why, then, aren't these these two forms given full-species status? The find the answer, we need to zoom out a bit, geographically and taxonomically.

You see, *molestus* and *pipiens* are not the only forms of the species *Culex pipiens*, and they're not just found in London, either. They're part of the “*Culex pipiens* complex”, which lumps them with the second species (and mouthful) *Culex quinquefasciatus*. Not to put too fine a point on it, but when biologists refer to a 'species complex,' what they're essentially saying

is: this is a horrible mess and we're not sure what's what. The *Culex pipiens* complex is found around the world, and its members are often the most common mosquitoes in urban habitats. The *molestus* form, recent evidence implies, is a more southern form that favors underground habitats in London because it is warm enough there to support them.

While it's true that the *pipiens* and *molestus* forms aren't interbreeding in London, this reproductive barrier erodes as you travel south and east. By the time you reach Egypt, the two forms are hybridizing freely. As far as the potential isolation – and therefore, potential for speciation – of the London *pipiens* and *molestus* populations goes, we need to look at gene flow once again. It would require quite a journey to get genes from the aboveground *pipiens* to the subterranean *molestus* in London, and thus to break the isolation speciation presumably requires – far more than the fifteen or so feet that separate the tube system from the city's streets. It would take a chain of breeding mosquitoes, like a cross-continent relay race with each individual mosquito carrying the gene just a bit further. That one gene (more specifically, its replicates) may need to travel across more than 2,000 miles and who knows how many generations of mosquito before crossing from *pipiens* to *molestus*, somewhere in Egypt. Then it would need to happen all over again, back up to London, traveling primarily in the *molestus* this time, until it gets bred back in to the London *molestus* population. As for whether or not this is actually happening ... nobody knows yet.

If we pull our gaze back even further, taking in North America now, the story of the *Culex pipiens* complex gets even more, well, complex. The New Jersey Mosquito Biology and Control Center website explains that the *Culex pipiens* complex in North America is represented by four 'members':

1. *Culex pipiens*, found in the north.
2. *Culex quinquefasciatus*, found in the south
3. Hybrids of the above two species, as well as members of either individual species, where their ranges overlap.
4. *Culex pipiens* form *molestus*, whose “distribution is poorly known.”<sup>4</sup>

It's interesting that the four 'members' listed above are not of equivalent taxonomic class. We have two species, a hybrid of the two, and a 'form', which is a rather vague term for a category beneath species. All of this taxonomy can seem abstract at best – it is, ostensibly, the most nit-picky of disciplines. Insect taxonomists may spend hours hunched over microscopes looking at things like siphonal tufts, counting how many branches they have. In the case of these mosquitoes, however, the taxonomy has important real-world repercussions.

These mosquitoes may seem little more than a nuisance; bites are unpleasant, but rank below bee stings as far as insect insults to our health are concerned. But mosquitoes are *vectors* – carriers and transmitters of disease. Malaria, the most famous mosquito-borne disease, killed 708,000 - 1,003,000 people in 2008, according to CDC estimates. These days, in northern latitudes, it's West Nile Virus that gets most of the press. The CDC's stance is fairly alarming: “If mosquitoes are still flying there is still a danger from West Nile Virus.” And as far as biting goes, C.A. Malcolm's independent report on the public health issues posed by mosquitoes warns that we shouldn't let disease transmission overshadow “the significance and extent of biting, which is much more than just an inconvenience to those

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<sup>4</sup> New Jersey Mosquito Biology and Control Center website, “House Mosquitoes of the U.S.A., *Culex pipiens* complex;” Dr. Harry Savage and Dr. Barry Miller, <http://www.rci.rutgers.edu/~insects/sp1.htm>.

being attacked and can lead to psychological and medical problems, in some cases requiring hospitalisation.” That said, of all the threats posed by mosquitoes, West Nile in particular represents an important intersection between taxonomy and public health.

Unlike malaria, which is transmitted from human-to-human, the West Nile virus requires a cross-species transmission. In fact, it requires a cross-class transmission, from birds (class *Aves*) to humans (mammals, class *Mammalia*). Now, remember that *Culex pipiens pipiens* bites birds exclusively, while *Culex pipiens molestus* bites only mammals. For this disease to be successfully transmitted, the same individual mosquito needs to bite an infected bird first and a person second. In the case of London's members of the *Culex pipiens* complex, this would seem impossible – and indeed, it likely is. But in North America, both *Culex quinquefasciatus* and *Culex pipiens* will bite birds and mammals, making them the most important vectors for West Nile virus. What's more, there's evidence that the *Culex pipiens* hybrids between the bird-favoring *pipiens* and the mammal-favoring *molestus* may be the most important vector of West Nile virus. Suddenly, the obtuse taxonomy of what is *pipiens* and what is *molestus* and whether or not they breed becomes a matter of life and death.

When the London Olympic Games happen next year, it will represent a coming-together of taxonomy, epidemiology, urban ecology, engineering, cultures, and, of course, good ol' fashioned sports. And *Culex pipiens* will be involved in all of it. Construction is predicted to cover an area twice the size of Heathrow airport's Terminal 5, potentially creating huge swaths of new mosquito habitat; people will be pouring into the city, bringing with them as many different diseases as they do clothing styles and ethnic cuisines. It's bound to be a great, big, *glorious mess*. And, indeed, that's how I've come to see the *Culex pipiens* complex. Furthermore, like the Olympic Games, it is powerfully symbolic. It is precisely *glorious messes* like this that give birth to species.

## Part VI: Life Will Find a Way

If one thing has become apparent, with the species complex of *Culex pipiens* and with this entire endeavor, it's that nature refuses categorization. Clearly defined boundaries are nearly impossible to find. Even something as seemingly simple as a species blurs under closer examination, much as effects of cities bleed into their surrounding landscapes, or how behavioral and genetic changes can feed into one another.

I left for London hoping to find a handful of interesting case studies that would reveal the evolutionary consequences of cities in three easy steps. What I found was, in many ways, evolutionary mayhem. Foxes are commuting to and from British backyards for handouts, blackbirds are changing on a physiological level to achieve an inner peace around humans, and mosquitoes are forming distinct populations within the tubes of the London Underground. None of these can be said, with any certainty, to be on their own evolutionary track. In a sense, this is the sort of speculation any good scientist is loathe to perform, but the animals I encountered (human and otherwise) paint a compelling case that perhaps speciation isn't the thing to look for. The 'species problem' has been a celebrated conundrum for a long time now, but it tends to distract from the remarkable evolutionary stories that are unfolding without necessarily producing new species.

Dozens of other interesting things are happening. In this age of human-driven ecosystems, as cities expand their territory around the globe, we've entered what some geologists call the anthropocene period – a time wherein human activities have a powerful

effect on the global environment. These effects are made manifest not simply in crises like global warming and the loss of species diversity. There is another story being told within our cities, and it is the same story that led Darwin to conclude that “there is grandeur in this view of life”.

To paraphrase Jeff Goldblum’s character in *Jurassic Park*: life has found a way. Though it’s easy to imagine cities as unnatural, natural selection working overtime in these dramatic environments. The negative impacts of cities on wildlife are well-documented, but there’s another side of them, a wilder side, a side that refuses to be tamed and seems to be growing like a stubborn sidewalk weed. It’s this side that urban ecologists are focused on exploring; cities are a new frontier in biology, and they’re literally in our own backyards.

In this view of cities, we find gigantic natural experiments in ecology, subjecting life to anthropogenic stresses that are otherwise rare in the history of biology. They have the potential to unveil new ways of understanding how evolution works, which, even over a century after Darwin’s death, is still a central issue of biology. Cities may not be producing recognizable species of their own yet, but they are certainly driving evolution in new and interesting directions, and this is what urban ecologists focus on. Urban ecologists recognize that evolution is not necessarily as closely tied to the origin of species as Darwin’s book might lead us to believe. Evolution, after all, is *change*, and as such it will always present moving targets for biologists.

That said, urban species may yet arise – in many ways, it seems inevitable, should cities persist long enough into the future. It may not be soon. The odds of seeing a true ‘urban species’ evolving in the next 500 years are, according to Evans, slim. All the same, we’re already seeing dramatic behavioral changes, subtle physiological shifts, and deep genetic change. The longer scientists study our cities, the more glorious messes they’re likely to uncover. And these glorious messes are like the nebulas out of which stars are born, very likely the first stages of the very thing Darwin alluded to but never pinned down: the origin of species.

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