What Hawaii Tells Us About Evolution

Terence McKenna

Terence's home in Hawaii

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Terence McKenna: The subject of this particular trialogue is Hawaii, what this island tells us about evolution, and how it relates to island ecosystems and their evolutionary process generally. The task falls to me because as chance would have it, in the course of my life I have visited most of the major theaters of evolution that involve island groups considered to be exemplars of the various types of island groups on the planet.

Hawaii, where we are recording this trialogue, is a group of mid-ocean volcanic islands. The only other mid-ocean volcanic island groups in the world are the Azores, the Canaries and the Seychelles. They offer great contrast to Hawaii, particularly the Seychelles, which as a portion of the Madagascar land mass has been above water some 300 million years, perhaps longer than any other place on the planet. There the evolutionary process offers a dramatic contrast to the far more recent evolution in the Hawaiian Islands. The Hawaiian Islands represent a unique case, because of the size of the volcanic calderas and of the vents beneath the Pacific floor that have created them. In fact, these vents and volcanic conduits are the largest on the planet. What we have in Hawaii is a tectonic plate sliding slowly toward southern Russia and Japan that is crossing over a weak place in the Earth's crust, a place where the core magma of the planet lies a considerable percentage closer to the surface than anywhere else on earth. The result of this situation is a series of islands formed in the same spot from which each, after its volcanic birth, is rafted away on the continental plate toward the northwest.

The life in the Hawaiian Islands shows 30-35 million years of endemism using the ordinary rates of gene change that biologists recognize. Nevertheless, geologically speaking, no Hawaiian island is over 12 million years old. The obvious interpretation of these facts is that life arose out here on islands which no longer exist, and as islands rose and fell, the life hopscotched from one island to another. Indeed, the dispersal rates of birds, tree snails and other organisms moving eastward from Kauai across Oahu, Molokai and Maui to the Big Island, Hawaii itself, show that this gradient is still operable. The forests of Hawaii are the most species-poor forests of the major islands. The forests of Hawaii are species-poor because animals are still arriving here from other islands. Nevertheless, because these volcanoes are so huge, Hawaii has a complete range of ecological systems, from sea level to 14,000 feet, virtually the entire range on the planet in which life is able to locate itself. The volcano itself, Mauna Loa, is by volume the world's largest mountain, because it is already a 14,000 foot mountain when it breaks through to sea level, having risen from the Pacific floor, and in this part of the world the Pacific Ocean is 13,000 feet deep. The mountain was enormous before it ever broke water. It now rises 13,000 feet above sea level, and its sister mountain, Mauna Kea, is shorter by only 120 feet.

What has been created out here is a very closed ecosystem far from any continental land mass. The forms of life which arise here arrive on rafted debris or tucked into the feathers of migratory birds, or in some other highly improbable fashion. What we see here is a winnowing of continental species based on extreme improbability. As an example, a very common Sierra Nevada wildflower of no great distinction apparently arrived millions of years ago as a single seed on Maui, and by that crossing has created a mutated race of plants that we know as the Hawaiian silversword, one of the most bizarre endemic plants that the islands have produced.

In terms of islands within islands and the fractal adumbration of nature, it's very evident here. For example, because the island is created by a series of lava flows of varying ages, there is a constant process in which ecosystems become islanded by lava flows. So you have a series of micro-islands of species that develop independently of each other even though they may only be some few miles apart, but separated by a landscape so toxic and desolate that there is very little intermixing of genes. This is thought to have been a formative factor in the evolution of the Hawaiian fruit flies, *Drosophila*, which of course were very useful in early studies of genetics because the chromosomes of the Hawaiian *Drosophila* are 10,000 times larger than the ordinary *Drosophila*, and in the era before electron microscopes you could actually color band these with certain dyes. Using chromosomes of these Hawaiian *Drosophila*, early chromosome studies went forward.

In terms of extrapolating all of this particular natural history data into some sort of general model, I think what life on the islands brings home to us is that the earth itself is an island. I've been saying for many years that one of the most revolutionary, yet totally trivial and predictable, revolutions sure to come in biology is the recognition that models of island isolation or species dispersion across oceans can easily be expanded to the three-dimensional ocean of outer space. Very clearly viruses, prions, gene fragments, molecularly coded information, percolate between the stars as a statistically very low component of the general cosmic dust and debris. Indeed, there have been many attempts to establish this idea, by Fred Hoyle and others. Recently a theory of the cometary origin of life has been put forward. It seems to me perfectly obvious that in time these notions will be embraced; after all, viruses can freeze down to crystalline states that are almost minerals, and as for a dispersion between celestial bodies, it's now generally agreed that a number of meteorites that have been recovered in the Antarctic are in fact fragments of Mars.[1] So the work on island dispersal patterns and the statistical mechanics of this process will eventually, I think, play a role in modeling how life is dispersed throughout the galaxy.

Some of the other islands that I've been fortunate enough to relate to are the Indonesian islands, which are the absolute other end of the spectrum of the class of tropical islands. What we have here in Hawaii, as I said, is mid-ocean islands far from continental floras and faunas, while Indonesia is in fact a submerged continent. As recently as 120,000 years ago, Indonesia, from Sumatra to New Guinea, was a single land mass which paleobiologists refer to as Sundaland. In the process of this shallow continent's subsidence, the sea filled in the low spots, so that today there is a direct correlation between species differentiation on any two Indonesian islands and the depth of the sea between them. These correlations have been shown over and over. One of the great conundrums of 19th century biology was the so-called problem of Wallace's Line. Alfred Russel Wallace, the cocreator with Darwin of the principle of natural selection, believed that between the islands of Bali and Lombok and then going west of Celebes you could draw a line which represented the line of convergence between the Austral-Papuan biogeographical zones and the Asian-Malayan zones.

Statistical studies, Ernst Mayr's principally, have disproven this notion. However, I have collected butterflies and stood in the forests on both sides of Wallace's line in several places, and I completely understand Wallace's observation and in fact wonder about Mayr's conclusion. Wallace concluded that these forests are very different; the bird calls, the butterflies and the flora all seemed different, but what Mayr seemed to show was that there was no distinct line. There was a gradient from Australia to Malaya in one direction and Malaya to Australia in the other direction. Island groups like this, and I haven't mentioned the Galapagos but they are another example, are such obvious laboratories of speciation that when Darwin and Wallace and Henry Walter Bates and other 19th century biologists who were grappling with the so-called species problem set out to do their fieldwork, they could not fail to be impressed by this peculiar theme and variation. They could not understand whose fingers strung the harp until they realized that similar populations separated by catastrophe, such as the arrival of ocean water or a lava flow, then come under very slightly different selection pressures which cause very slightly different physical characteristics to be taken on.

In the Amazon Basin, for example, you can move 2,000 miles and have only about a 15% replacement in butterfly species. In Indonesia you can cross a strait of water 20 miles wide and have a 17% replacement of butterfly species. Darwin and Wallace visited these places, both continental floras and faunas and the island situations, and through careful observation they finally understood what the mechanism of speciation was; and it's a wonderful thing, you know. Take, for example, butterfly diversity; that is a situation where diversity itself confers adaptive advantage. Because butterflies are largely predated upon by

[1] This trialogue was recorded prior to the 1996 discovery of hypothesized evidence of fossil life in a meteor of Martian origin.

birds, it's been shown in numerous studies that birds hunt a target image. They have an image of their prey. If, through the chance recombination of genes, your wing color or wing shape pushes you outside the target spectrum, you will be ignored and survive.

Ralph Abraham: Like us!

TM: And so variety itself becomes a premium in the evolutionary game. Novelty itself then is preserved because novelty confers an adaptive advantage in this situation for birds and butterflies. I think the implications of these things lie close to the surface. Earth is a small island, we are making great changes in its ecological parameters, we are affecting plant and animal populations. By studying how evolution has shaped island groups, we can appreciate our own small cosmic island and perhaps eventually draw politically empowering conclusions from that.

Rupert Sheldrake: What a wonderful overview, Terence. A real delight. There remains a major evolutionary puzzle. Islands have a tremendous role in speciation, as all evolutionists believe, and of which both Darwin and Wallace provided classic examples. In places where there are contacts through island chains the flora can be extremely species-rich, as in the Malaysian-Indonesian archipelago, one of the great creation centers of species in the world. That's the kind of tropical forest I know best, having lived in Malaysia. From what you've said, this evolutionary creativity arises from a combination of isolation on islands, plus mingling of two radically different floras, giving rise to all sorts of new possibilities and combinations.

TM: And the process was pumped by the repetitive comings and goings of the sea, which repeatedly islanded populations and then reunited them.

RS: And presumably also pumped by the ice ages, not only through changes in sea level, but also through the compression of all forms of life toward the tropics, followed by a polewards migration of species at the end of each ice age. All this makes sense for the center of evolutionary creativity in the Malaysian-Indonesian archipelago. The problem is that it doesn't explain that other great center of evolutionary creativity, the Amazon Basin.

TM: The answer is very simple. It has simply been above ground a very long time. In other words, the Malaysian-Austral-Papuan situation is fairly recent; probably the map has looked as it does no more than 7 or 8 million years. The Amazon, on the other hand, has been above water 280-300 million years. So simply being in the tropics, with 3-5 breeding seasons a year for many organisms, and never being inundated by sea water or catastrophe allowed that incredible climaxed speciation on a continental land mass. You're right, it didn't happen as far as we know in Africa, although Africa is so heavily impacted by human beings that any notion of its original natural history is impossible. But that's the short answer, that it was above water a long, long time.

RS: But then we have two methods of prolific evolution. One depends on being around a long time, as in the case of the Amazon. The other depends on isolation, climatic pumping, mixing of gene pools and so on.

TM: What pumped the Amazon situation on a micro level is the meandering of rivers. You see, it's very hard in a climaxed forest situation for any new species to gain a foothold, but because rivers meander and destroy forests and create sandbars and the intermediate zone of uninhabited land, so-called pioneer species can move in there, and that's where the speciation is taking place. Carl Sauer estimated that before the advent of human culture it was the meandering rivers that were the main force for modern plant evolution on this planet. A vast amount of shifting of boundaries goes on, and it's in that shifting boundary zone that mutants, new forms, can get hold. That's why a pioneer plant species will have the following characteristics: it will be an annual and it will be a prolific seeder. It will be herbaceous, not woody. In short, it will be a weed. That's what a weed is, a pioneer species, a tremendously predatory species designed for open land, utterly unable to compete in the forest, but in open land able to take over very well.

RS: Yes, but while isolation, new environments and so on explain one side of evolution, I think there's another side which Darwinism can't explain because it puts too much emphasis on natural selection. J. C. Willis, the great British botanist who worked in Ceylon and knew the Asian flora well, started off as a keen Darwinian but was forced to the conclusion that much evolution took place by divergent mutation, rather than in natural selection. For example, in Ceylon and India there are many species of water plants in the family *Podostemaceae* that live in streams with leaves that float on water, with many different leaf forms. Any attempt to account for a particular leaf form in terms of adaptation to water flow fails because leaves of quite different shape seem to do just as well, and can flourish side by side.

TM: I think you'd have to look at this more closely, at how variety itself somehow confers advantage. I would go through the plants and look for very slight chemical variances in the gene expression, because probably this variety is to confuse some feeder, and it's literally bewildering variety that acts as a defense against predation. The Hawaiian Hāpu'u here is an excellent example. Here we have two tree ferns, two distinct species, distributed in a ratio of 50/50. One has little black stickery stems and the other has a fuzzy brown soft stem. What selective pressure caused stickers to work for one and not to work for the other, when they're standing right next to each other? It seems to me that there must be drift of genes or simply variety for its own sake.

RS: Life is constantly trying out new forms. Unsuccessful novelties are weeded out by natural selection. A few are a wild success, but many novel forms may work equally well, and survive equally well, like the two species of tree ferns in your Hawaiian forest. There may just be lots of equivalent species, where you've got novelty for novelty's sake.

RA: It seems, if I understood you correctly, that what's unique about Hawaii is that the Hawaiian Islands are young, and they're maximally oceanic islands, far from any continents. The process of the population of a new island from a neighboring island is visible even in the present, and then we see a certain pattern repeated over and over again, even in the course of a century. So it seems to me that these different examples you were talking about conflate two different processes more or less projected upon the same screen. One is a purely biogeographical process which could at least be imagined to be operating the same way without any evolution. We have only the same species that were found on Maui suddenly appearing on Hawaii by a process of dispersal. Some species are successful at pioneering and help create an ecology suitable for the second species, and their space-time patterns are developed one upon another, very interesting fractal movies that to begin with would have nothing to do with evolution. On top of that, you have — I'm not sure about the relative time scales of this — then you have an evolutionary process involving speciation either during or after the colonization of a brand new island. Is evolutionary process essential to the population of the new island or isn't it?

TM: I think in the short term it isn't and in the long term it is. Because many forms of life are arising in these islands, it's not home free. New arrivals must contend with this kind of islanding by volcanic flow that I mentioned and other large-scale catastrophic events that have gone on in the Hawaiian Islands. Basically I think that what we see here are genes being mixed and stirred at a faster rate than in most places, and that's without mentioning the vast number of plants and animals introduced by human beings. One of the other unique things about Hawaii that I didn't enumerate is that human beings arrived late and this absence of long-term human impact gives us a clearer picture of what's happening. It's almost as though Hawaii is a speeded-up microcosm of the earth itself; probably 8/10ths of the Big Island is in the pre-Archaeozoic phase — in other words, almost abiotic — and then large areas are covered by lichens, with a fern or two here in the crevasses.

RA: You used the word "pumping," and I like that. There's a sort of forcing or coupling or a codependence between these different processes: physical ones, as for example new lava flows, the meandering of rivers or the appearance of islands, and space-time evolutionary processes.

TM: Really, the ice ages are the pump. They raise and lower sea levels. They create deserts and drop humidity. They force change, and they are probably driven by fluctuations in the dynamics of the sun.

RS: I suppose the thing about Hawaii that puzzles me most is why there haven't been more species and more forms of life in Hawaii. In the rainforest here we see only half a dozen or so species of tree, whereas in Sumatra or in the Amazon there would be hundreds.

TM: Again, the answer is time: 200-300 million years versus 20 million years. That's what it is.

RA: There's so many reasons to fail here. I personally find the environment harsh, lush as it may look to you or other people, and I suppose that one way a new species could fail is through having bad habits. There may be habits that manifest visually to us only in terms of spatial pattern. The colonization of the black lava by the Ohia tree appears in a certain fractal pattern in which there are characteristic frequencies of distances that may have to do with the distance the seeds fly in the wind or something like that. There is a certain spatial pattern which is the necessary one for survival, and other species, although they may look equally strong or stronger in the sense of phyllotaxis, when dispersed in the lava can't make it because their spatial characteristic is wrong. So a change in a species that may not involve DNA could be a change of habit in terms of the spatial distribution. It could just be response to a nutrient because of the change in size and therefore characteristic distance in the space-time patterns. We seem to see that — first we see the lichen, the lichen creates just a minimum of degradation of the surface that makes it possible for the Ohia tree to grab hold. The pattern of lichen is obviously fractal, sort of characteristically fractal, and the lava surface is fractal as well, and "fractal" means that there's a resonance across scales. There may be many kinds of lichen, but only this one grows because its fractal pattern has the right basic form, so that as a matter of fact it's compatible with the bare rock; and then the Ohia tree is compatible with its fractal pattern, apparently on a much larger scale which nevertheless resonates harmoniously as opposed to other species that might be disharmonious.

RS: You are talking about the evolution and development of whole ecosystems. I think what's interesting about this island, the Big Island of Hawaii, is that this forest ecosystem gets established on the slopes of the volcano, but is wiped out again and again through new lava flows. When lava flows are recolonized, an entire ecosystem has to move, not just single species, so it has to be an exceptionally portable ecosystem. Maybe that's why it has to travel light.

TM: Good point.

RA: In this creation myth of the Hawaiian Islands ecosystem that you described, there are islands which have already disappeared and ecosystems have jumped from them onto Kauai and so on; but as I understand it, these islands are rafting along over this more or less stationary hot spot. Those earlier islands were right here where we are sitting today, also very distant from any continental land mass. So is Day One of biology on the Hawaiian Island chain a result of long-distance dispersion?

TM: Yes.

RA: Nothing happened until the right lichen arrived after millions of years?

TM: Well, the lichen, I suspect, can probably be found in air samples above any point on the planet.

RS: So you've got spores as the first colonizers.

TM: Yes, and then the ferns come next, which also propagate by spores. The reason the nonflowering plants conquered the planet, if you think about it, is because the planet was like Hawaii. It was new lava, it was covered with lava flows, and the ferns could take hold. We think of ferns as soft, somehow spoiled plants. Actually, they're the toughest plants there are. When you study biology they teach you about *Psilotum*, related to the ancestors of the ferns. The forest here is full of *Psilotum* plants, and I can point them out to you. They're tough.

RA: But how do they get here? These spores are carried by birds?

TM: Sure, by spores. Mud on the feet of migratory birds could carry millions of spores.

RS: The duck's foot theory. More necessary for the transport of seeds than spores, which are so small and light that they can be carried over long distances in the air.

RA: Well, I think there's a startup problem. I just can't imagine that the frequency of ducks flying is enough to explain the arrival of correct species and in the correct temporal sequence. I mean, they would have to be dumping literally truckloads of different genetic materials on a daily basis on a brand new island in order to have a chance to get started.

TM: No, studies with banded birds show that there's a lot of material moving around. A million years is a long time; a number of improbable things can go on in a million years.

RS: OK, let's accept the duck's foot hypothesis, especially in relation to migratory birds. Birds do migrate from place to place over large distances, including many species in Hawaii, which has migrants from different continents; but which is cause and which is effect? No one knows the evolutionary basis for migration.

TM: No, I don't think it is migratory birds. I think the process is primarily one of novelty, unusual events, catastrophe. The greatest storm of the century, every century.

RA: Birds blown off course.

TM: Birds blown off course. Now, *that* happens. A single big storm veering off course might equal a century of ordinary dispersal.

RS: The question of how migratory birds found Hawaii raises the further question of the original Polynesian people who found it. One possibility is that they were keen observers of migrant birds and noticed that birds set off from their islands in a particular direction and months later came back again. It would therefore be a fairly simple deduction that if you followed the migrant birds you'd reach land sooner or later.

TM: That's right.

RS: In terms of human migration, these islands are now the limit of the westward migration of Europeans. Having gone right across North America, subjugating the natives and trying to eliminate their culture, the whole process has moved here. We can see it happening before our very eyes, and in evolutionary terms it's the opposite of everything we've been talking about so far.

RA: There appears to be a double gradient here with the eastward migration of Asian people balancing the westward migration of European people, and this is actually the interface where the double gradient can produce an increase in novelty and new mutations, and a forward leap, perhaps, of human evolution could begin here.

TM: A standing wave forming here as forces move both east and west.

RS: So can we point to any human creativity in Hawaii which exemplifies the cultural equivalent of the Malaysian Archipelago? Or is it more like a stalemate with roughly half of the islands' population coming from the east and half from the west, with the native Hawaiians trapped in between?

TM: Well, a Pacific Rim culture is hypothesized to be emerging, and Hawaii is central to all of that. It's equidistant from Sydney, Lima, Tokyo and Vancouver.

RS: Have they adopted the slogan, "Hawaii, the Pacific Hub"?

TM: If they haven't, I'm sure they're not far behind. The presence of the world's largest telescopes here make it a center of world science, at least in astronomy. I think the world's first, second and third largest telescopes are on this island, with an identical twin of the largest being built 200 yards away from it.

RS: It's a center for linking humanity with the stars.

TM: We're looking out from the top of Hawaii, chosen paradoxically for being the darkest place on Earth.

RA: From here they'll see the next wave of ducks' feet departing for Biosphere II.