From Fearless Flyers to Alcoholic Apes: A Discussion on Extremes with Professor Robert Dudley

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BSJ

BSJ Interview Team had the distinct honor and pleasure to interview Professor Robert Dudley. Professor Dudley's research interests revolve around animal flight, focused on biomechanics and evolution. Professor Dudley explores how the wings and even hemoglobin in blood have evolved in hummingbird and bumblebee populations to allow these creatures to fly and thrive at high elevations. BSJ Interview Team had the opportunity to learn more about the extreme climates that hummingbirds and bumblebees reside in and the drunken monkey hypothesis, which may lead to insight on another form of extremism, particularly in humans – alcoholism.

BSJ: To get things started, how did you get into your field of research?

Prof. Dudley: Both of my parents were biologists, so I was always interested in biology from an early age. I did a lot of fieldwork in New England and in the Northeast, which is where I am from originally. I spent a lot of time studying marine life and forests. I had a lot of exposure to natural environments, so I was interested in bugs, birds, and plants. As an undergraduate, I majored in zoology. I studied a lot of physics because I was and am very interested in mechanics, which is very relevant in my current field. After taking many biology, physics, and math courses, I decided to do my Ph.D. in biomechanics. I had a very good faculty mentor at Duke University, where I completed my undergraduate degree. He steered me towards the right program, and I did my Ph.D. on the biomechanics of insect flight.

BSJ: You already had a general idea of what fielded you want to research in during your graduate education?

Prof. Dudley: Yes, it was a preordained projector. I had great guidance and advice early on in my career. I realize most people don't have that kind of opportunity, but I knew about the university scene from day one. I joke that if I hadn't done a Ph.D., my parents would have considered me a drop out.

I started working on insect flight. Of course, there are 6 million species of insects. Insects are one of the most diverse, amazing groups on the planet. There are lots of different sizes, shapes, colors, and they're doing many different things. They can have different numbers of wings, which is just incredible diversity. The insect scene is an interesting one.

We also do a lot of work on hummingbirds, which are convergent to insects in terms of feeding on nectar, but, of course, they are a lot smarter. You can also work with them behaviorally, in ways you cannot work with insects. You can manipulate their behavior in the lab. You can always feed a nectar reward in a very predictable manner and have submeter level precision. In terms of flight, we're basically looking at stability. We are very interested in stability, but also maneuverability. How the hummingbirds change direction, how do they fly in turbulence or in rain? Half the work is fieldwork and half the work is lab work. We're interested in the origins of flight, the mechanics of flight, aerodynamics, physiology, and diversification. Why are there so many different kinds of flying things and how has flight enabled that diversification?

The other interesting aspect of it, as you've probably heard of, is a field called "micro air vehicles." Everyone is trying to make drones of different kinds, but now, all of a sudden, there are surges of interest by engineers in animal flight because animals have incredible flight capacity that, today, cannot be engineered. The idea is the basic knowledge that animal flight might let us make better drones. It's technology. It can be both good and bad, and we have seen abundant examples of both. We know the bad examples of drones, but the good ones are protecting rhinos and other big game from poachers. The rangers can't cover 500 kilometers a night around a game reserve in South Africa, but drones can easily survey large areas of land. Or if you're walking home in a sketchy neighborhood at night, maybe you want a drone following you, taking pictures and transmitting them to your friend.

BSJ: How does it translate exactly though? Is it just breaking down the basic components of animal flight?

Prof. Dudley: Well, say you're flying along and you encounter a gust of wind, which throws you sideways. What's the most efficient and useful response? If you have wings in normal flight that suddenly they go asymmetrical for whatever reason, how do you control that asymmetry? And what do you do with the body? Can the body act aerodynamically? There are whole books on this topic of a field, "biomimetic," which is another big emerging field. You probably know Professor Foule, in this department, who made this study about gecko adhesion. People made adhesive tape using simulated gecko toe pads. They have millions. Velcro is the best example, invented in the 50's. That's a macroscopic example, but there are many microscopic things that have come into play, as well.

BSJ: How do you design experiments to learn about the evolution of flight and the nature of flight in extreme conditions? We read your papers on bumblebees and your hummingbirds and we were interested in learning more about the experimental apparatus.

Prof. Dudley: There are many different projects regarding the bumblebee research, specifically the origins of flight. One thing we do is throw insects out of trees. We've made the discovery that many things that don't have wings can still maneuver. If they go upside down, they right themselves and then they target the tree. Controlled aerial behavior precedes the origin of wings, which we know this is true in arthropods. We think it's also true in winged vertebrates.

If you look at bird evolution, we are doing a lot of work with a large group of Chinese paleontologists in Beijing. Early birds had four wings, not two wings, by which I mean they had flight feathers on the hind legs, as well as, on the front legs. They had a long flat tail. The whole body was like an aerial platform. Even though they couldn't sustain their weight if they flapped their wings, if they were falling they could control where they were going. Basically, if they were falling out of a tree, they would not land on their head. That's rule number one. Then, they try to avoid damage to their sensory system by landing on their feet. All these animals have landing reflexes, which is pretty amazing.

We also spent a lot of time in Panama and Peru, climbing trees and then throwing different kinds of objects out of trees to film them and actually see the different kinds of trajectories. For example, we dropped a spider that only lives in trees. If you watch a video of the spider falling in slow motion, you notice that it captures a posture and it wants to go to the tree trunk. It targets tree trunks. We dusted the spider with fingerprint powder to visualize it. It started upside down, but it rights itself by some clever way that I don't really understand. When it starts to fall, the spider appears to be really flat. When it's going down, it changes its body posture and starts to generate lateral lift force. One of the legs will stick out more than the others, so the drag is going to be higher on it. It rotates as it's trying to target the tree trunk. If it overshoots, it does the same thing and loops around until it figures, "Oh I have to do something different." It will curve around and hit the tree trunk. We see this a lot with other things we work with.

BSJ: How does it know where the tree trunk is?

Prof. Dudley: It's visually targeting the vertical whitish greyish tree trunk against the green background. We have done fabric columns experiments with different kinds of colors and grey scale and thrown many insects from a height to see what they target. You can use different colored sheets or grey scale coloration. We do this with ants, which also glide. You throw a hundred ants, and you can see what color they land on. That's how you figure it out. Basically, we've done a lot of research with origins of flight. We want to see how things maneuver in the air if they don't have wings. The question is: what is the advantage of a little bit of a wing? It's a big question in evolution. What is the advantage of having half a wing? The classical argument is that half an eye is useless, therefore eyes did not evolve, but now we know that intermediate conditions have functionality. So that is a set of experiments that try to figure out; what these wingless things can do and how this informs us to the origins of flight for both insects and vertebrates.

In collaboration with these Chinese paleontologists, we have reconstructed most of the ancestral forms: early birds, for example. Now we're trying to make physical models of these birds to measured aerodynamic properties in a wind tunnel, which we have here in the basement of Haas. We have a big wind tunnel. We have high-speed video cameras. We have a flow visualization and quantification system, which is called PIV. We attach physical models to measure the lift and drag of structures. Those are some of the aerodynamic methods. We also have a vertical wind tunnel where we can study, for example, a hovering hummingbird. We pushed air up, and we make it easier for the hummingbird to hover. Or we pull air down and make it harder to hover. We know that the hummingbird is going to hover to try to feed at a feeder that is in a designated place. We can also measure their metabolic rate, while they hover. We use little masks placed on their beaks and you can pull of the respiratory gases from their nose, which is amazing. We can do many kinematic, aerodynamic, and energetic measurements using this equipment.

BSJ: How do you recreate the artifacts into the models that you use to test?

Prof. Dudley: We haven't done any modeling of the early insects because they have almost absent fossil records. But I can show you one other example, which will give you an idea of how the early birds looked like. The earliest bird you may be familiar with is archaeopteryx. All of these are known only from fossils. Some early birds have

flight feathers on the hind legs, as well as on the front legs. You can see even the archaeopteryx has a hint of those homologous structure. So, taking these morphologies, there's some reconstruction involved. By placing the physical model on a force transducer and putting it in a wind tunnel, you can measure the lift and drag that's acting on the model. This is a model of an archaeopteryx. Now it's not a perfect model because you're starting with something like a fossil. You have no idea.

BSJ: What materials are used to create the model?

Prof. Dudley: We have a 3D printer downstairs to make the model specific and precise. The geometry is a little arbitrary because we have no idea what defines the actual contour, shape, fit, or the surface texture of the wings. How would you know, right? You can't. So, this is just a first pass, but you can do it for all those different kinds of morphologies that I showed you and then you can actually change it. You can change tail position. You can adjust tail and lateral movements, forwards or backwards. You can vary many factors. In some fossils, the feathering is clear, but the body dimensions are unknown. This is all just an educated guess. But, at least, it does give you some idea of what they might have been able to do aerodynamically.

We will be publishing a paper soon that details this topic. You can measure several different aerodynamic properties, like a pitch moment coefficient. If the animal is at a certain angle of attack, and if you tilt it upwards, does the tilt induce further tilt or does it induce a restoring torque back down to try to stabilize? If you start to roll, does that accentuate the roll leading to instability, or does the animal, like an airplane, start to roll back? These are some of the questions we try to answer. It appears that the early birds were intrinsically stable, because they had great flat surface area. Then, as the birds began to progressively lose the hind-wings, they got better at flapping. The forewings and front wings became more useful in active control. The paper focuses on this shift from passive stability to active stability in bird evolution.

So, that's some of the lab work, and then there is some fieldwork. If you've read the bumblebee high altitude paper, - that was fun – it involved travel, needless to say. Places like the southwest of the Chinese mountains, which are amazing. This is on all the eastern edge of the Himalayan Uplift - just spectacular parts of the world! It is a famous area for flower diversity. So, if you're interested in alpine flowers, let me show you a book, like the "Flowers of Western China." It's super rich flora with many more species than what can be found in most of California. It's really wet in all of mid-montane elevations, and most of these flowers are actually pollinated by flies and bumblebees. It's amazing, and there are a lot of bumblebees. That's the center of origin for bumblebees and then subsequent diversification. The Himalayan arc from Kashmir, all the way around up into Eastern Tibet into parts of Russia are mountains called Tian Shan. There are also some really big mountain ranges that are north of the plateau, and they make the Rockies look tiny. There,

of course, we don't have lab resources. We caught bees at different elevations, measuring morphological parameters. Then, we got them to fly and filmed them to measure the frequency and amplitude of wing motions. You can do that at different elevations or you can do that at the same elevation with a pressurized box. You can hyper-pressurize or de-pressurize the box using a hand pump and measure the same parameters. The question is whether the high altitude bees are doing something really different from the low altitude bees? Some of these bees are specialists only at high elevation and never go below the Tibetan Plateau. Then, there are others from like 0-2,000 feet. From the museums, we have very good distributional data of which species are found where, and now we can go into the field and actually look at flight performance and figure out how they're doing different things.

We've done some similar work with hummingbirds in the Andes Mountains and Peru, which goes from 0 to 4500 meters. There are over 325 species, mostly in Central and South America. So, the question is "how did they adapt to high altitudes?" This is the big question. High altitude is low oxygen and low air density, so it's a double challenge. It's harder to fly. There's less air density, so it's harder to create force. There's less oxygen, so it's harder to create high power output. But, both the birds and the insects are doing it and they're doing it in very different ways. We had a recent paper showing that high altitude hummingbirds have better hemoglobin. They've done amino acid transitions to engineer themselves better hemoglobin, and they've done that multiple times. So that's kind of amazing. What's not in that paper is what we're finishing now. We're getting different elevations and a bird in a box with a feeder and a perch. Into the hummingbird box, we push in pure N2 that drives oxygen down to make the bird hover.

BSJ: So when you test the hummingbirds, you do it in a box instead of traveling like you did with the bumblebees?

Prof. Dudley: No, that we actually did it in the Andes. We had a team of six people and a very good collaborator in Peru running these experiments. Basically, you go to a location, you camp out, you rent a truck. The roads are these crazy dirt roads, the craziest roads in the world after the Himalayas. The mountains are very steep with little ravines. Liquid nitrogen will last for two weeks in those canisters, so you just take a whole bunch. We rent a truck and it goes down the eastern side. It takes all day. Then you can stop off at different places. What's nice is that you can do it on lowland birds and on highland birds in the same trip. Who has the better resistance to oxygen deprivation? Hovering is the most demanding behavior at high altitude. You reduce oxygen, so it's a really a very clean test. We show that the better hemoglobin that we have identified in the lab also conveys a better resistance to oxygen deprivation in the field. That's a whole molecule to whole animal kind of component.

BSJ: You have been talking about studying many different animals, from bumblebees to hummingbirds. Pertaining to the evolution of flight, would you say these current scenarios are taxa specific?

Prof. Dudley: We've argued for the generality of the "falling out of trees" hypothesis. There are also other hypotheses out there, but gravity is a powerful force. Many organisms live in trees. Why do they jump or go aerial? Predatory escape is the main thing and there is a lot of good evidence for that. The startle reflex is ancestral in animals. If you're startled by a predator and you're in a tree, you can go aerial. That's aerial behavior; you're flying whether you like it or not. Also, interestingly, if you're a little insect, mammal, or reptile, your orientation is arbitrary in a tree. These animals are doing this all the time. If something startles them, they're in the air, but then they could be in any posture. Upside down is probably the worst posture. So, this aerial righting reflex we've done a lot of work on recently is very important to understand.

We did some research on baby birds. Baby partridges, from day one, with the tiniest little wings can right themselves and they progressively get better at it. They switch the method all the way up to day 12 or so.

BSJ: What is the startle response? Is that just like jumping out of the-

Prof Dudley: So if I just shout HOUA!!

BSJ: *(Startled)* Woah!

Prof. Dudley: There we go! We all have this intrinsic reflex, a startle reflex, and we jump, right? It's a jump response! And jumping is, by definition, aerial behavior. I now argue that the origins of flight reside in jumping and startle reflex, origins of aerial behavior. This is all well documented. Anything that lives in a tree is at risk of falling out of a tree by many different scenarios. The wind could knock them out, predators can chase them out, they could be chasing prey or fighting each other. There are many different scenarios. Looking at the squirrels living here, we see them jump, but they miss. They miss their target and land on the ground. It's amazing. We think it's a very general idea, and we published this in 2007, but now we're documenting for lots of different kinds of animals. So that's just kind of another fun thing.

BSJ: How does environmental change impact the type and mechanisms of flight of an organism at higher altitudes?

Prof. Dudley: We know flight at altitude involves at least three changes: less oxygen, less air density, and decreased temperature at higher elevations. Animals have to adapt to all of these things. You don't actually see that many insects above 2,000 meters anywhere in the world because it's too cold for them. But, for something like a hummingbird that's endothermic, it can decouple itself from the environment. If you measure, for example, the energetic cost of hovering, it's relatively independent of air temperature. We measured that about 15 years ago. In a way, they are their own autonomous vehicles. Plants like them as dedicated pollinators because they are smarter and more reliable pollinators compared to the insects. They also do really well in these colder – not super cold, but we call them mid-montane elevations of 1,500 to 2,500 meters.

Hummingbirds are only found in the New World; they're not found in the Old World. In the Andes and Central America, we find what are called "cloud forests," where there's incredible coevolution with the plants on the one hand and the hummingbirds as pollinators on the other. We tried to model climate change and how that would affect the performance of the hummingbirds. The answer is: probably not at all because they're decoupled and very mobile at a good elevational range. The idea of climate change is that you let them migrate to a higher elevation. But, a lot of hummingbirds are already doing that when they migrate up and down slopes. Their range is already 1,000 meters. So, we think they are actually going to do quite well in the context of climate change assuming that the plants do well. That is, the flowers that [the hummingbirds] feed on. Except for humans cutting down their trees, which we know is a major problem throughout South America, is the only type of environmental change that will harm them: it's human induced.

BSJ: So, does the presence of wings serve as a useful adaptation for species radiation? And have there been alterations in flight mechanisms within a species?

Prof. Dudley: The diversity of insects is always attributed to the presence of wings. If we look at the sister taxa, the wingless hexapods, there are probably only 5,000 species. The winged hexapods consist of 6 million species. So, that's part of it. Then you can ask, what about the different kinds of insects that are flying differently? It turns out that most insects are quite small. The average body size is 4 mm. We don't really see them very often but they naturally exist, as mostly flies and beetles. Beetles just dominate this picture; although, no one really sees them. Beetles have diversified and miniaturized, and the key to insect diversity is this miniaturization… 4mm is tiny! Some beetles are 0.2mm in body length. Which is ridiculous, right? So, they've all retained the ability to fly. The origin of wings is really important, but then so is miniaturization.

There is also a phenomenon called metamorphosis: beetles, butterflies, moths and all Hymenoptera have a complete metamorphosis. If you compare incomplete metamorphosis to complete metamorphosis, there is a factor of ten more species with complete metamorphosis. It all started with wings, there is no doubt about that! It's about 3D aerial mobility in all contexts. There are also these water striders. I don't know about here in California, but early in the spring, they fly as they look to colonize new ponds and waters. The individuals produced in the subsequent populations don't have wings because they don't need to fly as they are on the surface. But, as the summer progresses and the ponds start to dry out, then they produce individuals who do have wings. And a bunch of other organisms can do that, too. It's facultative. No individual can decide to be winged or wingless, but populations will produce different fractions of polymorphic individuals, which is amazing! It's as if humans could produce individuals who could not walk because they didn't need to walk. And then they would express legs but under other conditions, they would not. It would be crazy!

BSJ: Is that epigenetically favored?

Prof. Dudley: You know, I just don't know. All I can say is that it takes a lot of money to produce and maintain flight muscles. And there is a lot of lab work showing that if you deallocate from the flight muscles you get increased reproductive output, so there is a strong energetic and selective trade-off. It's hormonally regulated in grasshoppers, but I don't really know much more about that. But, insects are remarkably flexible in this regard and can alter life history strategies. This is all within the same species, and some of them can change from sexual to asexual reproduction. The mother produces individuals, clonally, without fertilization of the eggs, and they can't fly, so they eat and take over everything and then start to mate and end up producing winged forms that can fly off to find the next plant. That's just scary! It's an amazing life history strategy.

BSJ: Related to the size, what role does the weight of an organism play? And also, how does this play a factor at extreme elevations?

Prof. Dudley: Flight is harder for heavier things, as they need to have a disproportionally wide surface area of the wings. The force that the wings produce is a function of surface area. But the vertical force to offset weight is a function of linear dimension cubes. So, area goes up with the square of length and mass goes up with the cube of length. Thus, it's a disadvantageous allometry or scaling. Weight increases faster than surface area, so for things to be really heavy and still fly, they'd need to have disproportionally large wings. The largest flying bird is actually pretty small. Any idea what the largest bird is?

BSJ: Emus?

Prof. Dudley: And can they fly? That's where the threshold is, 32 kilograms. Big birds don't like to fly. They'll try to walk, run away, or hide rather than fly. And you see that: if you scare a blue heron or turkeys out here, they'll just run because it's really costly to fly. That's true for bats as well. Some of the biggest bats are getting close to the upper limits. We're very interested in the biomechanics of limits of flight performance.

To power up for flight, the muscles are obviously very specialized, but how specialized are they and what are the limits? The specialization and limits influence the maximum body size. Insects are tiny because they have a very different respiratory system, a diffusion based respiratory system compared to a ventilatory respiratory system. We have an active respiratory system, while insects have a passive respiratory system, which constrains the upper body size because of diffusional limits. It's very hard to diffuse across distances that are greater than 10 microns, so insects are constrained in that regard. But the upper body size of birds and bats is probably a function of the difficulty of producing lift for a large body mass. This problem is exacerbated at higher elevations because it becomes harder to produce force as air density goes down.

So, not many people know this, but helicopters have an upper altitude limit because it's very costly to fly at higher elevations and also difficult to produce lift. One of the problems with humans climbing Everest is that you can't land a helicopter at the base camp of Everest because there is an upper limit and the helicopters can go to about a 1000 meters below the base camp. The power and lift requirements are just too high. And that's true for animals as well. It just gets harder. On the other hand, some big birds can fly over the passes in the Himalayas from India all the way up to Siberia to breed in the summer. So, there are strategies around it, with relatively longer wings known to be one. These strategies are seen in hummingbirds as well. The high elevation hummingbirds are right at the limit. They can hover, but they don't have much excess capacity on top of that and we've proved that through a bunch of different ways in the field. These high elevation hummingbirds will also try to land on flowers, which we don't usually see at lower elevations. With these birds, if you put a perch there, they'll always perch! They can increase their net rate of energy gain. They'll even try to break the flower off and then land on it to feed while on the ground because it's so costly to fly. That's another sort of twist to the story.

BSJ: How does that translate to species with sexual dimorphism?

Prof. Dudley: It's got to impose on both sexes, a size constraint. But the question of whether things are more dimorphic or less dimorphic at higher elevations… I think they become more monomorphic and similar because the energetic constrains are just so high. There could be a cascade of events onto the broader biology of the organisms at higher elevations.

BSJ: So, going back to the question of weight, evolution of flight would be expected to originate in species with small weight?

Prof. Dudley: Exactly! It's easier to evolve, as they're more agile. The early birds were only about the size of my hand. It's an interesting thing. You would expect to see flight origin in smaller things. Early insects also were only about 1-2 cm at max. For bats, there isn't a fossil record, but they couldn't have been that big.

BSJ: One other interesting aspect we were curious about is that we see such diversity in the means by which adjustments are made at high elevations. Hummingbirds have the hemoglobin adaptation which is more biochemical compared to the bumblebees having a wider wingspan. So, where is this optimization between biochemical and biomechanical?

Prof. Dudley: I would say that with the insects, they couldn't evolve a better respiratory system because there isn't a transport molecule. There is a circulatory system in insects, but it is an open circulatory system, a low pressure and high volume system. We have a high pressure and low volume circulatory system. So, the insect design is just fundamentally different. But they do have this tracheal respiratory system with series of iterated branching tubes that come from the outside and go all the way to the deep tissues. And by making a highly invested tracheal system, you might be able to get more oxygen passively. So, there may be changes in the respiratory system of insects at high altitudes.

BSJ: But even optimizing that wouldn't help?

Prof. Dudley: It wouldn't help that much! But, it might be better at the elevation. So, if you compare a lowland bumblebee to a highland bumblebee, there might be more investment in the respiratory system at higher elevations. It's an obvious prediction but we haven't tested that. It is hard to measure all those branching networks. There are some clever ways you can do so. You can take the thorax of a bumblebee and put it in a polymer solution and then you can apply negative pressure. This drives the air out of the thorax and the gel in. You can track all of these little things. Then, you can use an enzyme to digest all of the biomaterial and you get this nice little 3D cast of the tracheal respiratory system. You can cut the cast into pieces and analyze it or you can just weigh it to figure out how much air was in thorax versus muscle. There are ways for doing this. So what else can they change? There is not much else they can in terms of adaptations.

BSJ: So that is why we see the optimization in wing size?

Prof. Dudley: Well, that could help and we see that in hummingbirds as well. They do what they can. The high elevation environment is a great challenge. There is no doubt about that, so they are changing whatever can be changed. The hemoglobin evolution is a really nice story as it matches other stories of adaptation at high elevations. Humans have adapted to high elevation. The Andeans are very different from the Ethiopians or Tibetans in terms of physiological responses to reduced oxygen. The Tibetans have been in high elevation environment for over 200 generations and are different from the Andeans. There are differences in infant mortality between these groups contributed to the differences in oxygenation in infant tissue, otherwise known as cyanosis where the babies aren't able to get enough oxygen to their tissues and they turn blue, literally. There is a beautiful study outlining how this is obviously a major cause of selection on infant survivorship due to the changes in hemoglobin. This has only occurred in like the last 1000 years! It's really neat stuff.

Prof. Dudley: So you guys aren't going to ask about the most interesting thing in the lab? The Drunken Monkey? So let me walk you through this real quickly. The Drunken Monkey: Why We Drink and Abuse Alcohol. It's been getting a lot of press coverage recently. Let me walk you through it real quick. So, there are a lot of tropical fruits that are sugar rich. Primates are ancestrally fruit eaters and they eat ripe fruit. When fruit is green, there is no sugar in the fruit, but when they're ripe, there is a lot of sugar and the fruit is easier to digest. So you can see here, from day one, fruit flies come in. There are a lot of animals that eat fruit, including our nearest primate ancestors. And they use olfaction. When I use alcohol in the lab, fruit flies access a long distance cue. The tropical rainforest is green, so it is difficult to find ripe fruit. How do you find it? These guys will eat 10% of their body weight a day in ripe fruit. That's all they eat.

Our nearest ancestors are dedicated fruit eaters, so alcohol lets them find fruit. Then the other argument is that psychoactive types of alcohol stimulate feeding. You'll see mark ups on alcohol in restaurants, 300-500% mark up in price more than supermarkets. We do have an association between alcohol and food. So the argument is that it's an ancestral bias that associates alcohol with nutritional reward and it works when you're in a rainforest! Now we forage in a concrete jungle. We have unlimited access. In the rainforest, access is very restricted and concentrations of alcohol are fairly low. So animals consuming fruits with alcohol can't get drunk. Their stomach fills up before they can get drunk. But here, we have decoupled the solid and caloric reward from the liquid ethanol. Most of these come form sugars, right? Think about it, its just amazing all the fermentation products that interest people. The possibility could go wrong when you have unlimited access to high concentrations. Fruits found in the rainforest never have more than 3 or 4% alcohol maximum. Distillation is a chemical process. It's very recent in human history. It turned up about 1000 years ago and then you can create alcohols with 80% concentration. It's like with obesity and diabetes, and sugar. Those things are good when you're calorically challenged. We've evolved that way, but when you have unlimited access, things can go badly.

BSJ: How did you get into this field of research?

Prof. Dudley: Well, I spend a lot of time in the tropics, so I see a lot of monkeys and other animals eating a lot of fruit. So, we put two and two together. There is some website coverage on this topic also.

BSJ: Where do you see this going?

Prof. Dudley: With the alcohol research, we're trying to get measurements that are more accurate. We'll eventually get into what chimpanzees are eating. What's out there, relative to what they are selecting? Do they prefer fruits with alcohol? What is the profile? We have some preliminary data from Panama that suggests that spider monkeys are eating more of individual fruits that have higher alcohol content.

BSJ: Do you think they prefer it or do you think it makes it easier to find?

Prof. Dudley: That's a great question. All of these different fruits are in the same tree. You get the different ripeness condition in the same tree where animals reside. I think it's because alcohol is a great indicator of the presence of sugar. Remember, alcohol derives from fermentation of sugar, so it means more alcohol means more sugars in the fruit. The green fruit has no alcohol, meaning there is no sugar in the fruit. The sugars are all long carbohydrate chains. Without this particular interpretation, we don't have a good explanation for why humans drink alcohol and not vinegar. Why did our brain evolve to associate all of these positive things in human and primate social behavior? This is the first evolutionary approach. So that's the first thing we're looking for, alcohol in fruit.

In terms of hummingbirds and insect flight, we're looking into the link with diversification. We still don't have a good explanation to why there are 6 million species of insects. Part of the answer has to be that they are small. There tend to be more small things than big things. There tend to be many more rodents and few elephants, right? So what's the linkage? That's the general question with diversification and body size and specifically for insects, how do you miniaturize those flying platforms and still maintain all the control and all the super cool things flying animals can do. So these are a set of evolutionary questions.

Then we have a lot of questions regarding how hummingbirds fly. We have two projects I'll tell you about. You see many birds flying along and going through vegetation. How does it know to avoid a collision with a branch? Is it predicting? So, we have hummingbirds and we put them through these "Japanese game shows." If you've seen these game shows, you have situations where someone is standing on a bridge and there are these cut outs coming toward the game participant. The participant has to conform a certain way or else they get knocked into the water. We're doing that with hummingbirds. You have a feeder that delivers a small reward and a small perch, separated by an aperture. It can be a circle or an ellipse or something like that of different sizes, so that they learn quickly that they have to go through to get a reward. We can film this as they go through smaller and smaller apertures. Sometimes the birds will tuck their wings and go through. Sometimes they come up and go sideways. All kinds of crazy behaviors! Then what happens when you have multiple apertures? We're trying to imitate foliage, and that's a very hard problem.

Our other project relates to turbulence, or as some call it, an "air knife." You have pressurized air and it is just a kind of blade that creates a vertical jet of air, a curtain of fast moving air. You have go to the perch, feeder, perch, feeder, and back and forth and you turn the air knife on and don't tell the birds. You can be vertical, top down, or sideways. We have a few different types of manipulations and then you just look at the response. It depends on a few factors, like how fast the air is moving. In terms of aircrafts, we call it "gust rejection," so no problem for a 747, a little gust. But these birds can tuck up or tail up, all kinds of crazy behavior depending on these factors. So we're kind of interested in that, so we're doing gust rejection.

BSJ: BSJ would like to thank you for your time.

Image Sources

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