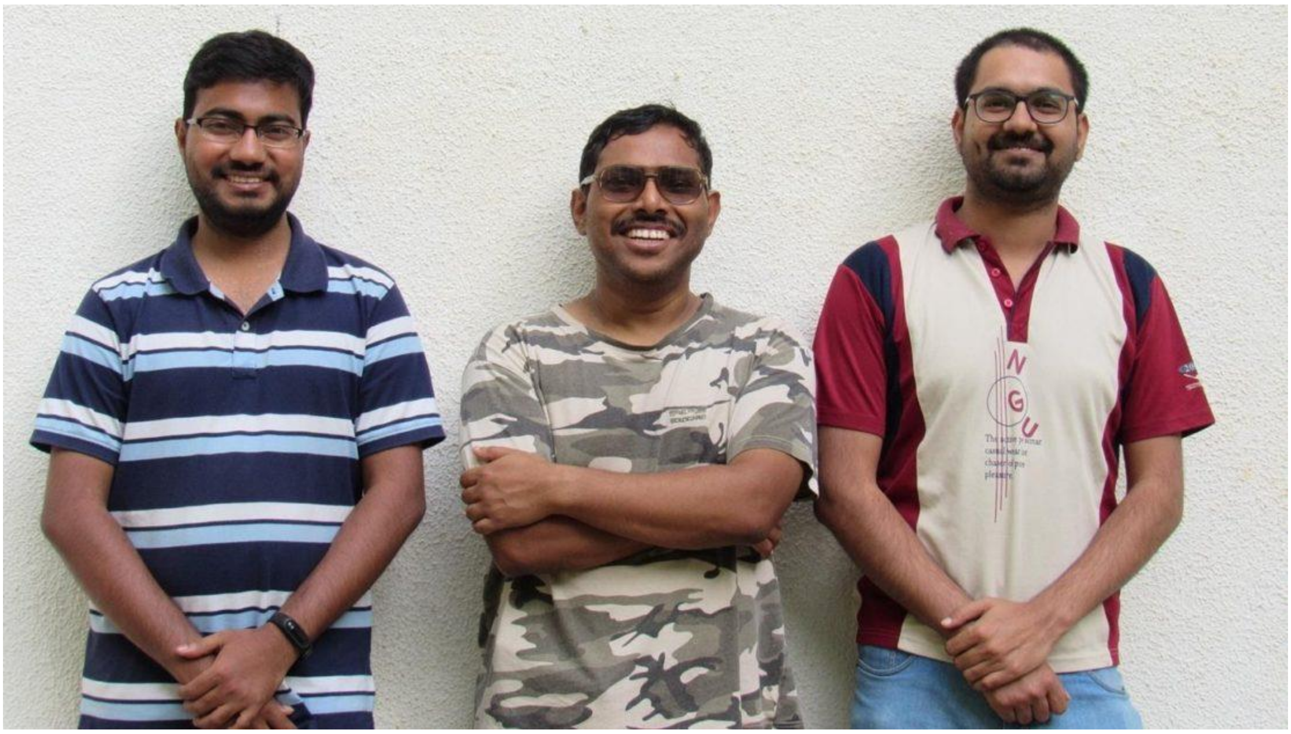
More Fun Than Fun: Learning How Fruit Flies Disperse – From a Tabletop

17/03/2021



L-R: Sudipta Tung, Sutirth Dey and Abhishek Mishra, the trio that created nomadic fruit flies in their lab in IISER Pune. Photo: Sutirth Dey.

RAGHAVENDRA GADAGKAR

This article is part of the 'More Fun Than Fun' column by Prof Raghavendra Gadagkar. He will explore interesting research papers or books and, while placing them in context, make them accessible to a wide readership.

Spectacular advances in genetic technology in the past couple of decades have revolutionised our understanding of how different parts of the globe came to be occupied by *Homo sapiens*. We now have evidence that *Homo sapiens* evolved in Africa between 300,000 and 150,000 years ago; successfully dispersed out of Africa between 100,000 and 70,000 years ago; reached Central Asia (including India), Europe and Australia some 65,000 years ago; and reached the Americas about 16,000 years ago.

All present-day humans worldwide can thus be traced back to Africa, and their current distribution can be accounted for by a single episode of dispersal out of Africa. We are also rapidly obtaining new and equally surprising information about many subsequent dispersals from one region to another outside Africa.

These findings and conclusions have captured the public imagination for two reasons.

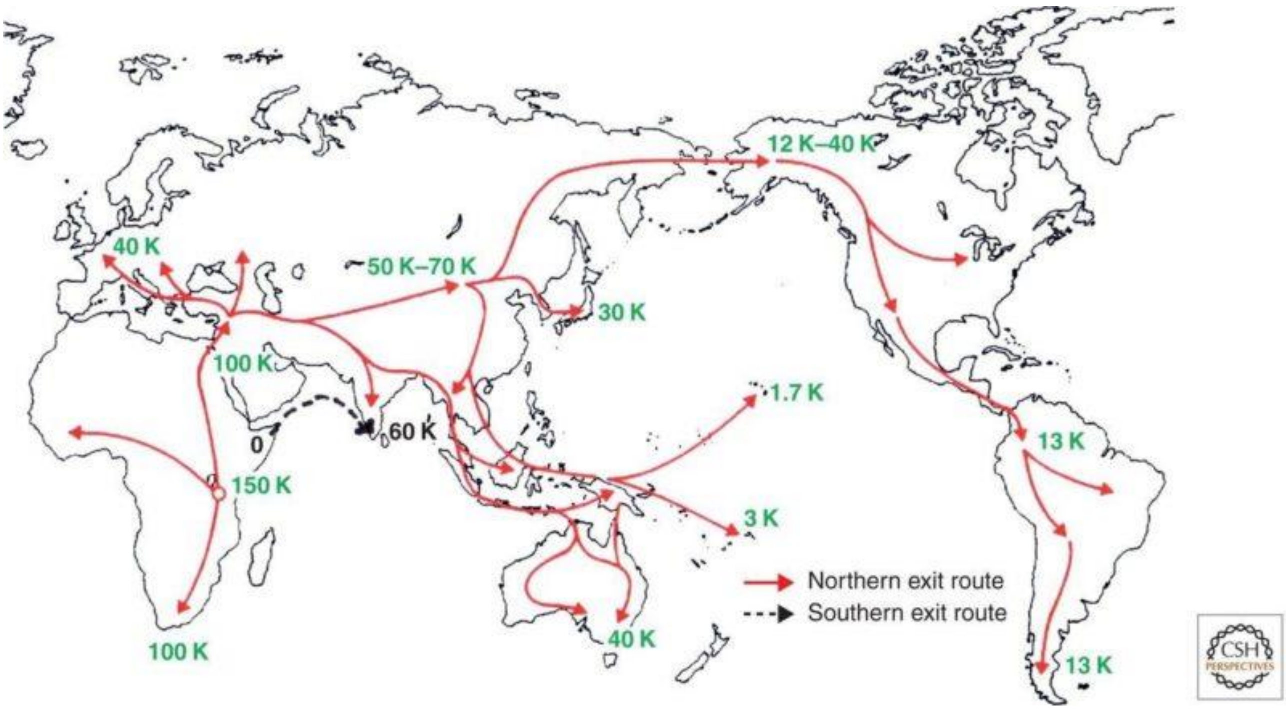
One is the amazing new technology and what we can do with it. Today, we can sequence and compare mitochondrial DNA, which is passed on unshuffled and only along the female line and thus trace every living person back to the so-called mitochondrial Eve who lived in Africa over 70,000 years ago. We can also sequence and compare the Y chromosome, which is also passed on (almost) unshuffled but, in this case, only along the male line, a technique that can trace everyone back to the so-called African Adam and reconfirm the story told by the mitochondrial DNA.

In addition to these so-called Adam and Eve genes, we can also use the sequences of ancient DNA derived from ancient bones and teeth found at archaeological sites. We can now send a sample of our saliva and receive our entire genome sequence by mail. Sequencing the human genome is passé. In 2014 Svante Pääbo's research group sequenced the entire genome of a 50,000-year-old Neanderthal from Siberia.

There is a second and more important reason why these findings have entered the popular consciousness. DNA evidence for a single successful out-of-Africa dispersal and the timing, direction and routes of subsequent human dispersals across the globe have overturned some of the most cherished, egoistic and politically charged assumptions about our origins and movements.

Many ardent adherents of the so-called multi-regional hypothesis have had to reluctantly abandon their beliefs and hopes that different human races evolved independently from different pre-human ancestors. Many people around the world are struggling to cope with the evidence that "the African ancestors of all non-Africans came out of Africa already painting, talking, singing, and dancing – and fully modern!"

People are finding it hard to reconcile their long-cherished beliefs with the knowledge that the language, culture, religion and art, not to mention the genes that we are so proud of, were brought in from outside our geographical regions. But "we now know, from ancient DNA, that the people who live in a particular place today almost never exclusively descend from the people who lived in the same place far in the past", says David Reich in *Who We Are and How We Got Here: Ancient DNA and the New Science of the Human Past* (2018).



The out-of-Africa journey and dispersal of anatomically modern humans. Numbers indicate the estimated dates in years before present. Reprinted with permission from Majumder and Basu 2015-A Genomic View of the Peopling and Population Structure of India. Cold Spring Harb Perspect Biol 2015; 7: a008540. © Cold Spring Harbor Laboratory Press.

But I believe that there is a third, more important and altogether different reason why we should find the new knowledge of our ancient history so compelling. Let us pause and pay homage to those individuals in many generations ranging from 70,000 to 16,000 years ago who decided to move. Who were these dispersers? Why did they decide to colonise new habitats while others stayed back? Were they the most brave, adventurous, clever, restless pioneers? Or were they the unwanted, marginalised outcasts driven out by the dominant and successful territory owners?

We will probably never know, but it is to them that we owe our very existence. What we might seek to know more generally, however, is what makes some individuals disperse and others to stay – *what makes some into settlers and others into nomads?*

Origin of Indian fauna
Instead of restricting ourselves to a single species (*Homo sapiens*), let us cast our net wider and explore this question. I recently heard an excellent talk by Praveen Karanth of the Centre for Ecological Sciences, Indian Institute of Science, Bengaluru. Karanth and his students have asked remarkably similar questions – not about the peopling of the world but about the 'tetrapoding' of India. They have investigated the origin of the tetrapod fauna of India. Tetrapods are the four-limbed animals, namely, amphibians, reptiles, birds and mammals.

Praveen Karanth (left) and his team members Roy, Luba, Rohini, Chetan in Pavagada, Karnataka looking for skinks and geckos. Photo: Praveen Karanth

The overall message that Karanth gave was uncannily similar to that from the human dispersal story. Until recently, it was believed that the so-called 'Vicariance' hypothesis could explain the patterns of distribution of the tetrapod fauna of India and its surroundings. Some 160 million years ago, the present-day Indian subcontinent, the islands of Seychelles and Madagascar and the continent of Africa were all part of one contiguous landmass known as the Gondwana supercontinent.

Then it broke up. The Indo-Madagascar landmass separated from Africa 120 million years ago. Madagascar separated from India 90-85 million years ago. Finally, Seychelles separated from India 65 million years ago. India finally collided with Eurasia some 35 million years ago. According to the Vicariance hypothesis, animals already living on the Gondwana supercontinent also got split up during the splits of these landmasses. In other words, the species we see today are of ancient Gondwanan origin and have always been here.

Dispersal all the way
The alternate hypothesis considered by Karanth and his students for the Indian fauna is the dispersal hypothesis. According to this, the animal groups we see today were not always here but have dispersed into India mostly from Southeast Asia, after the Gondwana supercontinent split up. Karanth and his students have been attempting to understand when and where the various animal species present in India evolved. (This kind of study is called phylogeography, and here 'evolved' means diversifying from their ancestors to become different.)

They soon began to find evidence that our lizards such as skinks, for example, belong to a relatively new clade that diversified more recently than the Gondwanan split. So they suspected that our lizards might have dispersed into India after the Gondwanan breakup. Following this clue, they compared our lizard fauna with that in Southeast Asia. Sure enough, they now have clear evidence of their dispersal into India. Suspecting that this may be true of other animal groups as well, Karanth recently studied the various global phylogenies published for different tetrapod lineages and came to the radical conclusion that "dispersal into India accounts for almost all of the tetrapod clades in India".

The common garden skink Eutropis carinata, previously called Mabuya carinata, member of a group for which Karanth and students have good evidence for dispersal into India from Southeast Asia. Photo: Praveen Karanth

So, it's dispersal again! Not only humans but most higher animals around us have all got here by dispersing from somewhere else – we are all immigrants indeed. Dispersal into new places is an important feature of most animals and plants, and is an integral part of their survival kits. Most patterns of the distribution of biodiversity we see on Earth today testify to the ability and tendency of living organisms to disperse.

But why do some individuals disperse, and others don't? Is dispersal an innate tendency that can be acted upon by natural selection? Who are fitter, the dispersers or the settlers? Dispersal involves at least three steps: an ability to leave, an ability to travel and an ability to survive at the destination. Are these three kinds of abilities correlated, or can some individuals be good at one but not at another? These are important questions and we need to find ways to answer them.

Evolution of dispersal

The study of dispersal has always been an important part of ecological research. However, we had to be content with documenting patterns of biodiversity and inferring dispersal indirectly in the past. Observing dispersal in action was a luxury available for only a handful of species. Besides, the questions raised above regarding the evolution of dispersal could barely be answered by such methods.

Today evolutionary biologists can do much better: they can selectively breed individuals of their interest and speed up their evolution, much as plant and animal breeders do to create useful new varieties. This technique of experimental evolution is best applied to fast-breeding and easy-to-rear species, and there is scarcely a better organism satisfying these criteria than the fruit fly *Drosophila melanogaster*. Ever since Thomas Hunt Morgan pioneered the fruit fly in biological research some hundred years ago, it has become the favourite model for genetics, developmental biology, neurobiology and, more recently, experimental evolution.

Sutirth Dey and his students at the Indian Institute of Science Education and Research (IISER), Pune, have embarked on a long-term investigation of the evolution and ecology of dispersal using the fruit fly and experimental evolution. What they do in their laboratory is charmingly simple. They hand-pick flies that like to disperse from their places of birth and selectively breed them for many generations. They have thus produced a breed of super-nomadic flies in Pune.

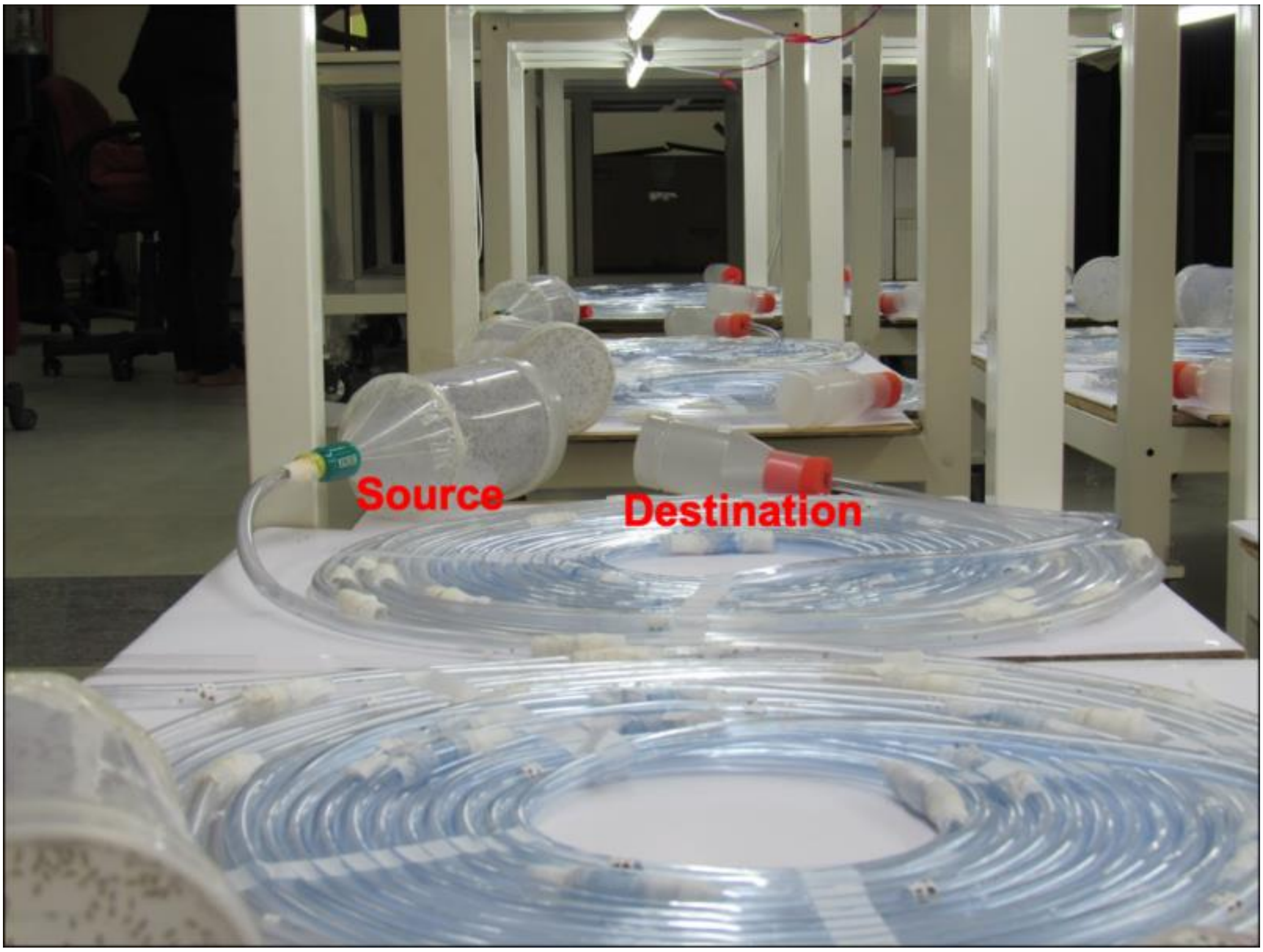
Some years ago, I went to IISER Pune, to participate in a symposium to celebrate the 60th birthday of a colleague. Dey delivered a mesmerising talk. He captured the imagination of his audience from the first sentence. He began by saying, "Let me first define dispersal', and went on to say, "Many of you have travelled to Pune to celebrate our colleague's birthday but, unless you also contribute to Pune's gene pool, this does not count as dispersal."

After the talk, Dey took me to his lab and showed me their experimental setup. I am always curious about how different people design their experiments. Features of the experimental designs that excite me include novelty, making do with locally available materials and facilities, capitalising on one's strengths, and minimising the dependence on technology and money. Dey's experimental setup scored high on all counts.

He had some flies in a bottle and another bottle nearby into which the flies in the first bottle could disperse to if they wanted. But the distance the flies had to travel to reach the second bottle was in his control and could be made to be in the order of hundreds of meters. Dey accomplished this by simply connecting the two bottles with a long, coiled, transparent plastic tube whose length varied from 10 m to 200 m, depending on the experiments. Dey and his students have thus studied dispersal in *Drosophila melanogaster* for more than 100 m on the space of a single laboratory table. Some people have said table-top experiments are a thing of the past; I think they are wrong.

I have always felt that the process of science is as important as the product, but the process gets the short-shrift in science *communication*. Let me quote from Dey's recent email to me.

“We had absolutely nothing to go by. Therefore every tiny detail of the experimental set up had to be manufactured by us through trial and error. For this, I and my students made several forays into the old part of Pune city in search of suitable materials and fabricators. Finally, we ended up purchasing carpentry tools and used them to fabricate the setups ourselves using plastic storage containers used in kitchens and kilometres of plastic tubing. Almost everybody in the lab would gather together, sit on the floor, and form essentially an assembly line. Initially, we were using hand tools. However, after a few calluses, cuts and blisters, we realised that the hand tools were simply not practical at our scale, and moved to power tools. Those moments of fabricating the various dispersal setups are among my most treasured ones as a scientist.”



The dispersal setup. Around 2,400 flies are introduced into the source, from where they must travel to the destination through the path (coiled plastic tubes). When the experiment began, the flies could travel an average distance of ~4m. After 165 generations, the length of the path stands at 58 m and increasing! Photo: Sutirth Dey

The making of nomadic fruit flies

Along with Sudipta Tung and Abhishek Mishra, who studied the evolution and ecology of dispersal, respectively, for their PhDs, and several undergraduate students and short-term trainees, Sutirth Dey has blazed a new trail in dispersal research. They experimented with four different laboratory populations of *Drosophila melanogaster*, with about 2400 flies in each population placed initially into an empty source container. This container had no food or water, and flies that were capable of dispersing could try to reach the destination container. After about 50% of the flies had done so; these dispersers were allowed to breed among themselves, and their offspring would start the next cycle of experimentation in a new source container.

In all cases, the researchers maintained a control population of flies that were not allowed to disperse, so that the flies selected to disperse could be compared with the corresponding control flies. They measured both their dispersal propensity (proportion of flies dispersing) and dispersal ability (distance dispersed). Both [propensity and ability increased] with an increasing number of generations of selection. The starting population dispersed to about 4 m, but after 33 successive generations of interbreeding among the dispersers, the resulting experimentally evolved (selected) populations dispersed to about 6 m. After 165 generations, they dispersed to a whopping 58 m. After 33 generations, flies began to disperse even if they were provided food and water in the source container. Clearly, it was dispersal for the sake of dispersal, nomadism for the sake of nomadism.

Interestingly, both male and female flies evolved into nomads. Even more interestingly, flies selected for increased dispersal were not different from control flies in their body size, fecundity and longevity but had greater locomotor activity, exploratory tendencies and aggression. Never before has anybody recorded such a rapid evolution of dispersal merely by giving organisms an *opportunity* to disperse.

Left: Sutirth Dey working on an assay designed to estimate the number of eggs laid by the flies. Right: Abhishek Mishra and Sudipta Tung transferring flies from the vials before introducing them into the dispersal setup. Photo: Sutirth Dey

We can imagine that organisms are often free to disperse in nature and that the dispersers will usually breed only with other dispersers out of necessity. The rapid evolution of dispersal may, therefore, be the norm. We can speculate that such a propensity to disperse may have led to the rapid and repeated colonisation of much of the globe by all kinds of animals, plants and microbes. The same dispersal ability in other species such as pests and pathogens and those we call invasive species may also cause much damage to us. The damage is likely to be exacerbated by anthropogenic habitat fragmentation and climate change, imparting a utilitarian function to this curiosity-driven research of the making of nomadic fruit flies in Pune.

Raghavendra Gadagkar is a Department of Science and Technology (DST) Year of Science Chair Professor at the Centre for Ecological Sciences at the Indian Institute of Science, Bengaluru.

Gadagkar, R., 2021. More Fun Than Fun: Learning How Fruit Flies Disperse – From a Tabletop. URL https://science.thewire.in/the-sciences/humans-animals-plants-dispersal-fruit-flies-elegant-experiment-iiser-pune/