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Science AMA Series: I'm Chris Jones here to talk about the genetics of 'high-flying insects' and what drives the long-distance migrations of some of our most important insect pests. AMA!

Chris-Jones [1] and r/Science AMAs[1]

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April 17, 2023

Abstract

Hello Reddit! I'm Chris Jones, BBSRC Future Leader Fellow at Rothamsted Research in the UK. At 14 I wanted to be a soccer player. At 32 I am not a soccer player but instead spend my time attaching insects to pieces of wire. How did this come to pass? Biologist? Molecular entomologist? Molecular ecologist? It's hard to know what box I tick. But what I do know is that I am interested in researching the genetic basis of the fascinating migrations of insects, and more specifically, insects of agricultural importance. Every year billions of insects take to the skies migrating vast distances to find suitable habitats in which to breed. Forgoing food and reproduction, these journeys are arduous and risky, but the rewards are high. These migrations are often multi-generational - in other words - the offspring inherently know when and where to go. But what is the genetic programme that drives this behaviour? What are the genes involved? And how can we study this in the lab? The goal of my research is to understand the 'migratory gene package' in greater detail. So go ahead. Ask me anything. I will be back at 4pm BST. In the meantime you are welcome to find out more about me and my work in a blog entry I recently wrote for Rothamsted Research's 'A day in the life of a Research Scientist'http://www.rothamsted.ac.uk/day-life-dr-chris-jones blog series. I'll be back at 11 am ET to answer your questions, ask me anything! POST-AMA Hi all, it's 6pm and time to catch what's left of the UK spring evening. Thanks for all your questions on insect migration. Some really good questions. Thoroughly enjoyed it! Sorry I haven't answered everything. I will come back and answer a few more tomorrow. If you are interested more in the work I/we do here in the Insect Migration Group at Rothamsted then please find our contact info in the usual places. Enjoy the rest of your Monday folks. All the best.

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REDDIT

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CHRIS-JONES R/SCIENCE

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How big of an influence is the light of the moon, earths magnetic field and temperature on these bugs?

Cyberpickle

Thanks cyperpickle. Temperature certainly is an important cue for an insect population to migrate. This is associated more with the propensity to migrate. As for the Earth's magnetic field and lunar cues? Well we know the Monarch Butterfly uses the sun as part of its time compensated suncompass to navigate. Lunar cues? Dung beetles, for example, use the Moon and its surrounding polarization pattern, as well as the Milky Way, for rolling balls of dung! So there's no reason we can't hypothesise that moths use similar cues (or maybe the stars) but the honest answer is we don't know yet and it is a strand of research we wish to pursue! Super exciting stuff.

If you had to say the most surprising thing you have discovered in your research, what would that be?

our most important insect pests. AMA!, *The Winnower* 3:e146279.94704 , 2016 , DOI: 10.15200/winn.146279.94704

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Thank you!

lulzmort

That a single moth can fly 42 km over the course of a night on our tethered flight mills (our experimental system which we can measure the distance of individual flights). Equivalent of a marathon! That's an awful amount of flight power.....

I was once flying in Oklahoma at 13,000' (I'm pretty sure, it may have been 9,000') and something hit our windshield that left such a large splatter that we almost thought it was a bird. However, due to the color of the remains and lack of feathers we decided it must have been a bug.

My questions are these: was this bug intentionally flying that high? How does it even reach such an altitude - under its own power, or does it catch a thermal like glider pilots and soaring birds use?

skyraider17

It is certainly not inconceivable that the 'smudge' on your windshield was an insect. We know that insects can reach an altitudes of 4.6 km! Insects use favourable winds (like a glider with a little self-propelled flight) to reach such high altitudes. Once there they are not simply at the mercy of the wind. They actively orientate themselves with the wind to maximise the distances they can travel.

Is there a particular high flying insect, that If it were to go extinct would have major repercussions (that we can predict)?

Also, is climate change effect these high flying insects in anyway such as lengthened summers/seasonal changes?

Astrolemon

I think the loss of any insect would have some repercussions, positive and negative, depending on the system. Many insects migrate so there extinction would no doubt have an impact on the ecosystem, particularly in terms of the movement of biomass.

As for climate change. Yes, in many insects, including the insect I study (cotton bollworm moth), the decision to migrate or hibernate (over-winter), is influenced by external cues such as temperature, photoperiod and availability of food etc. These cues (we think) are experienced at the larval or caterpillar stage and the decision to migrate is manifested in the adult. So any effect of climate change would have an impact on these 'facultative' (or opportunistic) migrations. There have been some work in the species I work with estimating the potential spread of the species - not using CC models I must stress. These models are based on current climate predictions. So yes, I would say climate change would impact on their global distribution and invasiveness making studies on how theses insect spread/move very pertinent.

Hello! How high flying are these "high flying" insects? Do different species fly at preferred altitudes? How long can they maintain said altitude? Do they interfere with airplane traffic? Does airplane traffic interfere with their migration routes? Thanks!

TurquoiseKnight

Hi TurquoiseKnight, when we say 'high-flying' we're talking about altitudes we're talking about altitudes of up to 1200m (using our entomological radar). But that is not to say they cannot fly at higher altitudes

- it just the level of detection we have with the current radar technology. We know that some insects have been recorded as high as 4.6km! As for interfering with airplanes - unless they are huge swarms of locusts hitting light aircraft perhaps - I don't know of any troubles!

These migrations are often multi-generational - in other words - the offspring inherently know when and where to go

Is it true that the Monarch Butterflies need 3 generations to migrate to Mexico? How something like that gets coded into a DNA? "It" has to know what "stage" is it in among other things... is it expressed by environmental factors like maybe temperature?

This is really fascinating, thank you.

aleczapka

Hi aleczapka, A single individual travels the 4000 km to Mexico. On the return journey in the spring it is three generations to return to the breeding grounds (they follow the milkweed). External cues such as temperature and photoperiod undoubtedly play a role in signifying when it is time to go. For example, coldness triggers the return migration of Monarch northwards. Monarch butterflies must therefore have the genetic architecture to respond to this 'cold-treatment'. Photoperiod is probably the most reliable cue for insects to migrate and in our lab we are simulating increasing/decreasing daylengths to see how this affects their ability to fly. We can then see how this environmental cue interacts with potential genetic mechanisms (e.g. internal clock) to stimulate flight.

What's your favorite bug? Which bug do you like the least?

OneBildoNation

I have a new favourite insect actually. The Bogong moth Agrotis infusa. It might not be much to look at but its migration is fascinating. These moths migrate in the summer to caves hidden in the Australian Alps in the south-east of the country. Thousands of them converge in cave walls escaping the heat. The migration is fascinating because the same individual migrates from breeding grounds to these areas of hibernation (strictly speaking in this case aestivation) and back. So it is very much a hard-wired process. They've also played a major role in the history of the Aborigines. It is truly fascinating! I'd love to see these caves someday. There's a lovely review of them from the group at Lund University here

Least favourite. The cockroach of course. And unfortunately they will outlive us all

What does your experimental process look like? For example, the attaching insects to wire experiment- what are you doing start to finish? What experiments came before this one? And what are some interesting things you've learned about working with insects?

semitones

Thanks semitones, It looks like this..... https://www.youtube.com/channel/UCuN19AhMUaeRszU9Vwshy0w Bear in mind this is a 'baby' version of our flight mills we use for moths and the insect you can see in action is a tiny Drosophila. Using this system we measure the flight activity of our moths over night as use the behaviour to infer migratory potential. We do this in our controlled environment facilities that simulate (to the best we can!) the conditions you would find in the field (so by no means perfect). From this we have shown that populations of our species of interest, Helicoverpa armigera, have different migratory potentials

allowing us to look at some of the genetic changes in those which fly further/shorter distances. http://onlinelibrary.wiley.com/doi/10.1111/mec.13362/full

Hi Chris.

What are your thoughts on the study from a couple of months ago that suggests a tiny dragonfly migrates across the Pacific? Really interesting finding, but would be great to hear your opinion it too. Think it was the first genetic evidence provided that it is the same species and there is gene flow between Asia and the Americas, but correct me if I'm wrong! The dragonfly is Pantala flavescens and a link to the paper is here.

Thanks for your time!

AsheNoodle

Thanks AsheNoodle, I had seen this but haven't read the paper in detail. From what I can see they use mitochondrial markers to infer gene flow. The question is whether the markers have big enough resolution enough. A cracking species to study migration in though! Let me have a 'proper' read and get back to you.

Hi Chris, I'm 17 years old, french and very interrested by Enthomology. What kind of studies have you made for becoming Enthomologist ? Does a official career exist or it is biology studies with a specialisation in Enthomology ? P.S : sorry for my English.

Felocs

Hi Felocs. Pas de probleme! Well I never thought I would end up in entomology that's for sure! But when I was an undergrad I had an excellent lecturer in vector borne diseases (e.g. mosquitoes, Tsetse) and went on to do a specific MSc on the Biology and Control of Disease Vectors at the London School of Tropical Medicine. And now here I am. So yes, there are plenty of opportunities and these don't necessarily have to be in academia. Industry, entomological societies and conservationists all need entomologists….and we need more. So if you're enthusiastic enough I'm sure you can make a career out of it!

I learnt last year that some insects can fly hundreds of feet up in the air and travel vast distances. These insects are tiny so how can you record the height and distance of an insect?

Thanks!

Plasmodioom

Yes Plasmodioom....they can! Depending on the size of the insect we can record insects to a height of 1200 m using radar (500mg at this height). We can even determine the speed and heading they are travelling in.

How do insects and their offsprings know where to go: do they just aim a straight path towards a specific direction like a compass or use a complicated path with multiple transit points? And do they change their path if there is an obstacle like a tornado on the way? If so, how do they plan a new route?

jnaankat

Great question! Like most of our knowledge on migratory journeys we know most about the Monarch. There is an interesting ongoing debate about whether the Monarch is a true navigator or not – in other words do the insects inherently know where it is in relation to where it is going or does it just have fixed direction irrespective of its current position. The jury is very much out! http://www.pnas.org/content/110/39/E3680.full?sid=0b676504-9e9a-406f-8fb0-cae2229f3284 http://www.pnas.org/content/110/18/7348.full?sid=0b676504-9e9a-406f-8fb0-cae2229f3284 However, they certainly have a compass and will follow that path give or take some tangents. Some insects go get 'lost' and have been found on the ships out at sea. For insects flying at high altitudes we know they have an internal compass as they use favourable winds to maintain headings. http://www.cell.com/current-biology/fulltext/S0960-9822(08)00362-X What this internal compass is, particularly for moths, we just do not know yet but I certainly hope to explore this area in the future.

When David Attenborough did his AMA, I remember him saying that migrations were the biggest unsolved mystery in the natural world, or something along those lines. What's the best explanation for how animals are born with migratory knowledge? What are the animals feeling?

DeadPrateRoberts

Thanks. Well if David says it is the biggest then I'd happily agree..... The best explanation is that animals have an inherited propensity to migrate and that selection acts upon the genetic architecture that allows them to do so. This selection acts differently under changing environmental conditions. For some species, the propensity to migrate will be a product of the genes and the environment, in other more stable environments, genes will play a larger role. It is under the threshold model for migration beautifully spelled out in this paper

Hello Dr Jones. I am an entomologist from the other side of the pond. Thanks for doing this AMA.

Have you found any similar genes in unrelated species of insects that only share in common the fact they migrate. Such as the migrating dragonflies and butterflies?

For pest species do you foresee using any time of genetic engineering in the future, such as removing the gene that regulate migration and releasing non migrating individuals to muddy up the pest's gene pool?

Thanks!

abugguy

Hello abugguy from across the pond! Thanks for the great question that gives me a chance to highlight some of my recent findings! We have indeed found some evidence that similar genes may be involved in migration/flight in unrelated insects. In the most comprehensive study on insect migration genetics to date in the Monarch, it was shown that signatures of selection were acting upon a gene encoding a subunit of the protein collagen – the stuff that holds bones together in me and you. The authors showed that this gene was down-regulated in migratory compared to non-migratory insects and used this as evidence for improved flight efficiency. We also found the down-regulation of collagen in our moth species, Helicoverpa armigera. So maybe we're on to something there?? A lot more to be done though. In answer to your second question. Yes. Absolutely. That would be a feasible but long-way off goal of this research.

Can you give a summary of the progress made in your field? What have you contributed to this?

ridoncules

Summary of the progress I have made? Well, I think we (there is always a 'we') have made the leap from studying a trait associated with migration that we can reliably measure in the lab – in our case flight behaviour – and combined that with next-generation sequencing to tweak out[some (AND I MEAN SOME) of the genes that we believe are associated with the propensity of insects to migrate. I have been able to use my broad experience of DNA sequencing and insect biology to combine the two. I'm definitely more of a 'jack of all trades, master of none' kind of scientist and I like to bring disciplines together working with others to get the most out of our science.

Hi this stuff actually really interests me thanks for take the time out of your day to do this AMA! I know it's not a huge question that needs a huge answer, but at what altitude would you find the most bugs cruising around in the current?

fearmypoot

No worries. My pleasure. Insects will cruise at altitudes in 'layers' corresponding to the warmest part of the atmosphere as the cooler airstreams are not suitable for flight. When the atmosphere is warmer then, for example, moths can select the altitude that promotes the fastest flight. This can be hundreds of metres above the ground.

How do these insects know where they are going? Are they usimg magnetoreception? Is this migratory pattern unique to either heterometabolous or homometabolous insects?

Domo_Bromosexual

Magnetoreception or a magnetic compass is certainly a major candidate mechanism for insect orientation/navigation. Particularly when it is a cloudy day or for insects that migrate at night. Cryptochromes are thought to be important photoreceptor molecules that facilitate magnetoreception. Using flight simulator studies it has been shown that these proteins may have the capacity to detect magnetic fields in the Monarch aiding their ability to orientate themselves towards their preferred direction when the sun is not available So the question is do moths use a similar system? Well, we don't know at present but this is an area, insect nocturnal navigation, that we hope to pursue in the near future. So watch this space!

How do you gather information on the migratory/behavioral patterns of these insects while they are in flight? Is it possible to get the data that you need with enough accuracy to create realistic conclusions when they are such small, fast-moving, subjects?

gmanz33

Good question! As with any system looking at animal/insect behaviour it is really hard to replicate conditions in the wild when taking your experiments into the lab. At Rothamsted, we use a system called tethered flight mills to measure the speed, duration and distance of each flight. These are housed in our controlled environment facilities that simulate the photoperiod and temperature the insects would usually experience in the wild. From these we can get an assessment of their flight behaviour and can control for these conditions depending on what we're interested in (e.g. say, increased temperature). We can also look at different populations, genotypes, species etc. It is not perfect. No bioassay or experimental system is but it is a good way to infer the migratory potential of

insects. We have successfully used insects from the system to look at differences in gene expression (genes that are switched on or off) between insects showing the strongest/weakest migratory potential.

How do these insects know the direction of where to go? Does earth's magnetic field has something to do with it?

Amrit44b

Hi Amrit44b. Hopefully I've answered your question in another post but if you want more info then please ask!

What is the contribution of epigenetics to the inheritance process you described? If there is a contribution, can one generalize it to epigenetic effects on behaviour in mammals? Thanks!

ecooevo

Good question, Well the species I study, the cotton bolloworm moth, is a facultative migrant. It responds to environmental cues that signify a deterioration in local conditions. Say, temperature, photoperiod, host availability etc. These cues we believe, although not entirely sure, are experienced by the caterpillar stage. So the adults (moths) are making their decision to migrate in the same generation. Therefore, there may just be a crucial epigenetic component. We are in fact looking at this with DNA methylation - a phylogenetically common marker across all kingdoms. In insects, DNA methylation is much less prevalent than in humans for example (about 70% of potential methylation sites, known as CpG islands, are methylated in mammals; in insects it is approximately 1%). But is a potential factor. Other epigenetic factors we can study are histone modifications, small RNAs.....so much to look at, so little time!

Thanks for your time Dr Jones, can you share your thoughts on what have been the most exciting discoveries of recent times for these long-distance migrations?

AussieSpacePirate

Well, I'm biased so I'll pick the research in our group that uses radar to track insect migrations over hundreds and up to a thousand of kilometres. Some of the radar papers have shown that moths use favourable winds to maximise the distance they travel. That is absolutely baffling in my opinion. Also, the uncovering of the precise details of the integrated time-compensated sun compass in the Monarch is a truly impressive feat of biology. We know the genes involved, where they are inside the insect nervous system, how these interact with the sun. Even Brian Cox agrees…..
https://www.youtube.com/watch?v=_-nnc6dWUJg

How big, genetically, do you think the "migration package" is? It seems for something this complex, within an organism, could have 1000s of routes and systematic turns. How long do you think it will take to map it out?

Also, what outcomes can you see coming from the mapping of this genomic system? Are you doing it for some greater cause or purely the scientific passion to "know"?

Thanks again!

lemons230

Fair question. I think it is fairly large to be honest. In our early studies we have shown that there are at least 200 genes 'expressed' (or switched on or off) between insects that show differing migratory potential on our tethered flight mill system. And this is just one study with specific populations, in one species, under one set of conditions! When you think of the behavioural, morphological and physiological processes that contribute to the syndrome then there certainly will be many pathways contributing to the migratory phenotype. For example, genes involved in hormonal control, wing structure, metabolism, circadian rhythms. And then you have the question of whether it is hard wired mutations or expression differences that are the principal driver. Throw in some epigenetics, that I am convinced play a role in more facultative migrants (like my species of interest, Helicoverpa armigera), and you have a large genetic syndrome! But that's the challenge and why I love the topic so much.

Outcomes. Well once we have a greater handle on the genes and mutations that contribute to the migratory phenotype – if we're thinking big and bold – then it is not insurmountable that we could predict movement propensity in insect populations. Long way off but can't help but think that is possible.

Have you researched any of the fascinating work being done by Iain Couzin and the mechanics of swarms? I know there was some interesting stuff with how crickets and grasshoppers end up biting each other that instigates mass migrations. They strike me as similar processes and I'd love tips on what genes to investigate in these kinds of migrations. Been studying dopamine and serotonin in ants and bees for fun.

[ref: Sensory Networks and Distributed Cognition in Animal Groups]

ultimape

I have. And yes. This is a fascinating group of scientists and research! The serotonin story in locusts is one of my favs! What we are looking at in our insects is what stimulates their migration. We know that external cues play a major role. Particularly temperature and photoperiod. But we also think larval density can play a part and we are conducting some 'garden experiments' to look at the impact of rearing insects, at the larval stage, at different densities to see if this affects their flight. Now, whether this stimulates similar pathways, like dopamine and serotonin, I don't know but will be keen to investigate. Thanks for the question!

What is known about the predators of high flying insects? Is it safe up there for them?

remotectrl

Nope. Bats. The mass of bats (Brazilian free-tailed bats, Tadarida brasiliensis) and moth abundance is associated with certain weather patterns in Texas. The moths clearly play a crucial role in the migration of these bats. Great example of looking at different trophic levels of migration