How a brain chemical changes locusts from harmless grasshoppers to swarming pests

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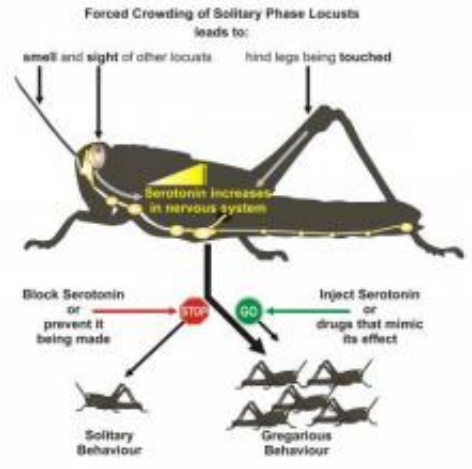

This flow diagram summarizes the major findings of the paper. Image copyright Steve Rogers

(PhysOrg.com) -- Scientists have uncovered the underlying biological reason why locusts form migrating swarms. Their findings, reported in today's edition of Science, could be used in the future to prevent the plagues which devastate crops (notably in developing countries), affecting the livelihood of one in ten people across the globe.

A collaboration between a team of scientists in Cambridge and Oxford, UK and Sydney, Australia has identified an increase in the chemical serotonin in specific parts of the insects' nervous system as initiating the key changes in behaviour that cause them to swarm.

Desert Locusts are one of the most devastating insect pests, affecting 20% of the world's land surface. Vast swarms containing billions of locusts stretching over many square kilometres periodically devastated parts of the USA at the time of the settlement of the West, and continue to inflict severe economic hardship on parts of Africa and China. In November 2008 swarms six kilometres (3.7 miles) long plagued Australia.

Locusts belong to the grasshopper family but unlike their harmless relatives they have the unusual ability to live in either a solitary or a gregarious state, with the genetic instructions for both packaged within a single genome.

Pictured are side views of late-stage larvae (nymphs) of locusts showing typical Gregarious phase (left) and Solitarious (right) coloration.Image copyright Tom Fayle

Locusts originate from barren regions that see only occasional transient rainfalls. While unforgiving conditions prevail, locusts eke out a living as solitary individuals with a strong aversion to mingling with other locusts. When the rains come, the amount and quality of vegetation expands and the locusts can breed in large numbers.

In deserts, however, the rains are not sustained and food soon becomes

more and more sparse. Thus large numbers of locusts are funnelled into dwindling patches of remaining vegetation where they are forced into close contact with each other. This crowding triggers a dramatic and rapid change in the locusts' behaviour: they become very mobile and they actively seek the company of other locusts. This new behaviour keeps the crowd together while the insects acquire distinctly different colours and large muscles that equip them for prolonged flights in swarms.

As Steve Rogers from Cambridge University emphasises: "The gregarious phase is a strategy born of desperation and driven by hunger, and swarming is a response to find pastures new".

Solitary and gregarious locusts are so different in looks and behaviour that they were thought to be separate species until 1921. But the realisation that crowding triggers swarming posed a new problem: how can the mere presence of other locusts have such a dramatic effect? The new research, which was funded by the Biotechnology and Biological Sciences Research Council, the Natural Sciences and Engineering Research Council of Canada and the Royal Society, solved this 90 year old question by identifying an increase in the chemical serotonin in specific parts of the locust's nervous system as launching the fundamental changes in behaviour that lead to the gregarious phase.

In the laboratory, solitary locusts can be turned into gregarious ones in just two hours simply by tickling their hind legs to simulate the jostling that locusts experience in a crowd. This period coincides with a threefold but transient (less than 24 hours) increase in the amount of serotonin in the thoracic region of the nervous system. Experiments were then designed to show that serotonin is indeed the causal link between the experience of being in a crowd and the change in behaviour.

First, locusts were injected with specific chemicals that block the action

of serotonin on its receptors: when these locusts were exposed to the same gregarizing stimuli, they did not become gregarious. Second, chemicals that block the production of serotonin had the same effect. Third, when injected with serotonin or chemicals that mimic serotonin, locusts turned gregarious even in the absence of other locusts. Finally, chemicals that increased the natural synthesis of serotonin enhanced gregarization when locusts were exposed to the tickling stimuli. This indicates that it is the synthesis of serotonin that is driven by these specific stimuli and in turn changes the behaviour.

Dr Michael Anstey, an author of the paper from the University of Oxford, said: "Up until now, whilst we knew the stimuli that cause locusts' amazing 'Jekyll and Hyde'-style transformation, nobody had been able to identify the changes in the nervous system that turn antisocial locusts into monstrous swarms. The question of how locusts transform their behaviour in this way has puzzled scientists for almost 90 years, now we finally have the evidence to provide an answer."

Dr Swidbert Ott, from Cambridge University, one of the co-authors of the article, said: "Serotonin profoundly influences how we humans behave and interact, so to find that the same chemical in the brain is what causes a normally shy antisocial insect to gang up in huge groups is amazing."

Professor Malcolm Burrows, also from Cambridge University: "We hope that this greater understanding of the mechanisms causing such a big change in behaviour will help in the control of this pest, and more broadly help in understanding the widespread changes in behavioural traits of animals."

Professor Steve Simpson of Oxford and Sydney Universities said: "No other biological system is understood from nerve cells to populations in such detail or to such effect: locusts offer an exemplar of the how to

span molecules to ecosystems - one of the greatest challenges in modern science."

The paper 'Serotonin Mediates Behavioral Gregarization Underlying Swarm Formation in Desert Locusts' will be published in the 30 January 2009 edition of *Science*.

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