Smithsonian

Spotlight on Science at the Smithsonian

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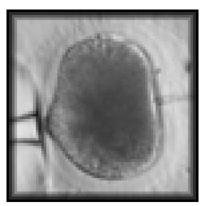

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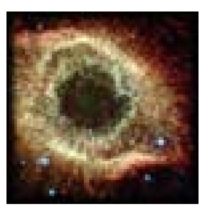

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- Theresa Mellendick, Editor, mellendickt@si.edu

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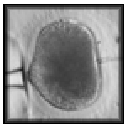

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Introduction from the Under Secretary for Science

In this installment of Spotlight on Science, we first consider a long-standing puzzle of biodiversity: Why are reefs, rainforests, and other tropical ecosystems so much richer in species than ecosystems in the temperate zone? For years many biologists have linked high tropical biodiversity to ecological specialization among species, but an international team of researchers including Smithsonian scientists have found that, at least for insects, this isn't necessarily so. Next we visit the Zoo, where reproductive biologists have come up with a solution to the problem of infertility among cat species. They are literally rebuilding defective sperm cells. Finally, astronomers at the Smithsonian Astrophysical Observatory take us to the magnificent Helix Nebula, where the researchers have shed new light on what it takes to get its hydrogen molecules excited.

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Leaf-eating insects in tropical forests are no more specialized in their diets than are insects in temperate forests, despite the greater number of tropical insect species. Photo by Marcos Guerra, STRI

Why are there so many species of herbivorous insects in tropical rainforests?

Reference

V. Novotny, P. Drozd, S. E. Miller, M. Kulfan, M. Janda, Y. Basset, G. D. Weiblenet , "Why Are There So Many Species of Herbivorous Insects in Tropical Rainforests?", 2006. *Science*, **313**, 1115-1118.

Why are tropical ecosystems so rich in biological diversity compared to ecosystems at higher latitudes? Coral reefs and tropical rainforests are justly famous for their spectacular variety of species. Why aren't the tide pools of Maine or the forests of Germany equally rich? One theory is that competition among species is more intense in the tropical ecosystems than elsewhere, driving species to specialize more narrowly. The result is biological communities with a large number of specialist species, rather than a smaller number of generalists. The theory makes sense, but it has been difficult to test. For many species, especially in the tropics, data is patchy and anecdotal. And the great disparity between tropical and temperate ecosystems has made them seem as difficult to compare as apples and oranges.

But this year, an international team of scientists led by Museum of Natural History research associate Vojtech Novotny, of the University of South Bohemia, Czech Republic, and including Yves Basset of the Smithsonian Tropical Research Institute, Scott Miller of the Smithsonian's National Museum of Natural History, and George Weiblen of the University of Minnesota, has made a fundamental advance in solving the puzzle of tropical biodiversity. The team combined the Smithsonian's vast taxonomic resources, data from molecular genetics, and more than a decade of detailed tropical field studies to see whether leaf-eating insects in tropical forests really are more specialized than their counterparts in the temperate zone.

To answer these questions, the researchers sampled the insects feeding on trees at two study sites: a lowland rainforest in Papua New Guinea and a flood plain forest in Moravia, central Europe. A key to the study's success was that at both sites the sampling methods were precisely the same: all beetles, caterpillars, and other insects were hand-collected from the leaves of 14 tree species. The researchers chose the tree species on the basis of molecular data to include a similar array of closely and distantly-related species at both sites. For the insect species, the dietary preferences of each were determined by field observations and feeding experiments, amounting to nearly 27,000 observations for 850 insect species.

The results, published in the August 25 issue of the journal *Science,* came as a surprise to many ecologists. There was no significant difference in specialization between the two sites. The tropical and

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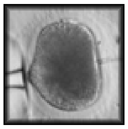

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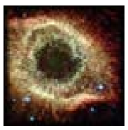

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temperate-zone insects fed on a similar range of trees. And trees in both sites hosted comparable numbers of insect species. In fact, the researchers found slightly more herbivorous insect species per tree in Moravia than in New Guinea.

So, at least for herbivorous insects, tropical species are *not* more specialized than temperate species. Insect diversity is higher in the tropics because tree diversity is higher – by a factor of six. So the question becomes: Why do tropical forests have so many species of trees? Researchers at the Smithsonian's Center for Tropical Forest Science in Panama are tackling this question.

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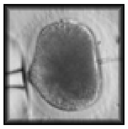

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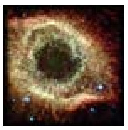

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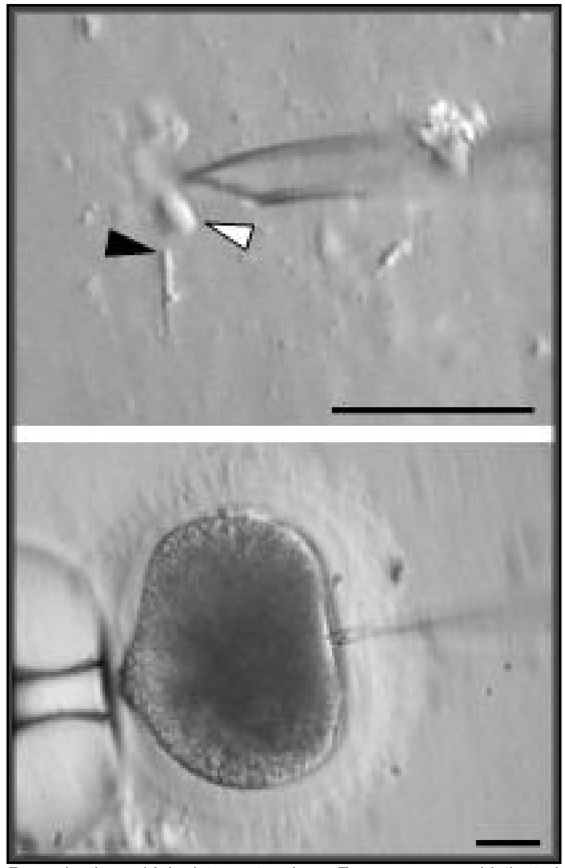

Reproductive biologists at the Zoo use sophisticated micromanipulation techniques to solve the problem of poor-quality sperm in cats. Top: the head of an immature testicular sperm (white arrow) is joined to a centrosome-bearing midpiece from ejaculated sperm (black arrow). Bottom: The reconstructed sperm cell is then injected via micro-pipette into an unfertilized egg (bottom image). Bar = 20 µm.

National Zoo Study Sheds Light on Cat and Human Infertility

Reference

Featured article in *Biology of Reproduction* ‘Poor Centrosomal Function of Cat Testicular Spermatozoa Impairs Embryo Development In Vitro After Intracytoplasmic Sperm Injection’ by Pierre Comizzoli, David E. Wildt, and Budhan S. Pukazhenthi, 2006, 75, 252-260.

For more than 20 years National Zoo scientists have studied cats such as the cheetah and clouded leopard to understand infertility caused by poor quality sperm, a phenomenon that also occurs in humans. Because of its relevance to human fertility, much of the research has been funded by the National Institutes of Health.

This work is important for preserving many genetically valuable wild species in which male infertility hampers breeding and propagation efforts. In the cat family (Felidae) there are 37 species in which sperm cells are frequently of poor quality. Problems include abnormal spermatozoa (a condition called teratospermia), physiological disorders, and obstruction of the male reproductive tract. In the latter case, the problem can be circumvented by extracting a sperm cell directly from the testis and microinjecting it into an egg to produce an embryo. This technique has been successfully used to solve fertility problems in several mammal species. But reproductive scientists at the National Zoo have found that for cats the results have been disappointing.

However, new research by the National Zoo’s Department of Reproductive Sciences has not only zeroed in on the reasons for the technique’s poor results in Felids, but also offers a promising new solution. Studies led by Dr. Pierre Comizzoli and published in the journal *Biology of Reproduction* have revealed that the problem lies in the centrosome, a structure located between the sperm head and the flagellum. This structure is not functional in spermatozoa recovered

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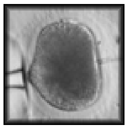

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directly from the cat testis. Because a properly functioning sperm centrosome is critical for cell division during the early stages of embryonic development, eggs fertilized by such sperm have a lower success rate than those fertilized by sperm from ejaculate. The new research determined that the sperm cell's centrosome "matures" as it moves through the male reproductive tract, especially while in a section known as the epididymis. Using sophisticated micromanipulation techniques, Dr. Comizzoli replaced the centrosomes of individual testicular sperm cells with those of ejaculated spermatozoa. He then injected the reconstructed sperm cells into eggs. The fertilized eggs developed normally and produced embryos comparable to those resulting from ejaculated sperm.

This work has identified a critical function of centrosomes previously ignored in Felid reproductive biology, and Dr. Comizzoli's technique could be applied to propagating genetically valuable wild Felid populations suffering high rates of male infertility. Testicular spermatozoa could be recovered from infertile males and their centrosomes replaced by centrosomes from fertile males of the same species or even a more common but related species, such as the domestic cat. And because centrosomal dysfunction is also known in human males, this new information could yield solutions for men with fertility problems.

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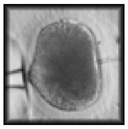

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In this image of the Helix Nebula from NASA's Spitzer Space Telescope, the blue-green heads of "cometary knots" indicate where ultraviolet radiation or shock waves from stellar wind cause molecular material to emit infrared light.

Shocking results on a planetary nebula

Reference

J. L. Hora1, W. B. Latter, H. A. Smith, M. Marengo, “Infrared Observations of the Helix Planetary Nebula”, 2006. *Astrophysical Journal*, in press.

“Do not go gentle into that good night. Rage, rage against the dying of the light.” The poet Dylan Thomas wrote these words to his dying father. But he could have been talking about a fascinating class of celestial objects known as planetary nebulae.

Planetary nebulae get their name from their roughly spherical shape, which reminded early astronomers of planets. But planetary nebulae have nothing to do with planets. They are in reality vast clouds of gas and dust spewed out during the death throes of mid-sized stars like the sun. And observations by modern astronomers have revealed that planetary nebulae are much more than the simple, roundish objects seen in early telescopes.

The closest and best known is the Helix Nebula, some 600 light years away from Earth toward the constellation Aquarius. Like all planetary nebulae, it is too faint to be seen by the naked eye. But if it could, the Helix a would be an impressive sight indeed. It would appear about half the size of the moon, and has a combination of rings and radial streaks that creates the illusion of a human eye staring back from space.

A team of astronomers led by Joseph Hora of the Smithsonian Astrophysical Observatory has been probing the details of the Helix Nebula using infrared instruments on board NASA’s Spitzer Space telescope. Because infrared light can pass through the nebula’s veil of dust, it reveals details hidden from optical telescopes. But most infrared light is blocked by the earth’s atmosphere; so the launch of the Spitzer telescope into orbit has been a boon to the infrared study of the Helix and other planetary nebulae. Not only have Hora and colleagues been able to map new details of the nebula’s intricate structure, but they have also turned up evidence that challenges previously held ideas about why the nebula emits light.

A planetary nebula forms when an aging star runs out of hydrogen fuel and collapses due to its own gravity. As it condenses, the remnant star becomes hotter and hotter, boiling off an expanding cloud of gas and dust. It also emits intense ultraviolet radiation, which ionizes the gases in the cloud, causing the nebula

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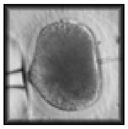

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to glow like a neon sign. This phenomenon is well-understood by astronomers. But, as it turns out, it cannot account for all the radiation emitted by the Helix Nebula.

In their study, published in the *Astrophysical Journal,* Hora and his colleagues found that in the infrared spectrum some of the wavelengths emitted by the Helix nebula are better explained by another mechanism: shock waves produced by streams of electrons and protons smashing into hydrogen molecules in the cloud. The likely source of these energetic particles is the nebula's superheated core. While all stars produce a such a flow of particles, called stellar wind, until this study wind-related shock was assumed to play a minor role in planetary nebulae, especially in the inner realm close to the star where fierce UV radiation dominates. Now this will have to be reconsidered.

In about eight billion years, it will be our sun's turn to collapse and create a planetary nebula. None of us will be around to see it, of course, or to admire its beauty. But we can be sure that like the Helix, it too will rage, rage against the dying of the light.

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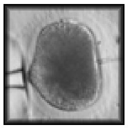

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