

GENOMICS

Poplar Tree Sequence Yields Genome Double Take

Black cottonwoods are the lab rats of the tree world. It's relatively easy to add or knock out genes, and like other members of the poplar genus, they grow quickly enough that researchers can check the outcome of some experiments in less than a year. Foresters love poplars too: Their fast growth rate makes them a good source of fiber for paper, lumber, plywood—and a possible source of biofuels. All these reasons motivated more than 100 researchers to sequence the tree's genome.

On page 1596, the team, led by Gerald Tuskan of Oak Ridge National Laboratory (ORNL) in Tennessee and Daniel Rokhsar of the Joint Genome Institute (JGI) in Walnut Creek, California, describes its first analysis of the more than 45,000 likely genes in black cottonwoods (*Populus trichocarpa*). The group has begun to sketch out the evolutionary history of *Populus*, finding, for example, that a doubling of the genome about 65 million years ago freed up many genes to acquire functions important for trees, such as wood formation.

Cottonwood is the first tree and the third plant genome to be sequenced, coming after the herbaceous annual *Arabidopsis* and rice. The bulk of the sequencing was done at JGI and ORNL, with researchers around the world contributing genetic markers—such as 324,000 expressed sequence tags—which aided in the search for genes. Four groups then independently trained computer algorithms to search for coding sequences, and they all agreed on 45,555 likely nuclear genes.

By comparing the new sequence to that of *Arabidopsis* and sections from other plants, the team determined that the ancestral genome of poplars had been duplicated at least three times: first, at the base of all angiosperms, then about 100 million to 120 million years ago, and most recently 60 million to 65 million years ago. “The genome sequence shows this incredibly complicated evolution, full of diversity,” says Gail Taylor of the University of Southampton, U.K., who is not an author. “It’s like an Aladdin’s cave.” Similar doublings also occurred in rice and *Arabidopsis*, so they appear to be widespread among plants, Tuskan says.



Genome duplications offer new grist for natural selection because a second copy of a gene can evolve a new function. Although the *Populus* genome has lost some of its extra copies, it retained others that might be particularly useful for fending off

Unveiled. The genome of black cottonwood should provide insights into how to improve commercial varieties of it and other poplars.

pathogens, synthesizing lignin and cellulose, transporting metabolites, and bringing about programmed cell death (which may be important for seasonal growth and autumnal senescence).

The next step is to figure out what more of the genes do—half have no known function—by creating mutants with genes that are under- or overexpressed. “There will be thousands of new functions that were not known or fully appreciated in other species,” predicts Steven Strauss of Oregon State University in Corvallis. This will help lead to the development of new varieties of poplars that might have longer growing seasons or pack on more biomass. It could also have payoffs for ecologists, clarifying the keystone role of poplars in riparian and other ecosystems. “There’s a whole new area of science opening up,” Taylor says.

—ERIK STOKSTAD

ASTROPHYSICS

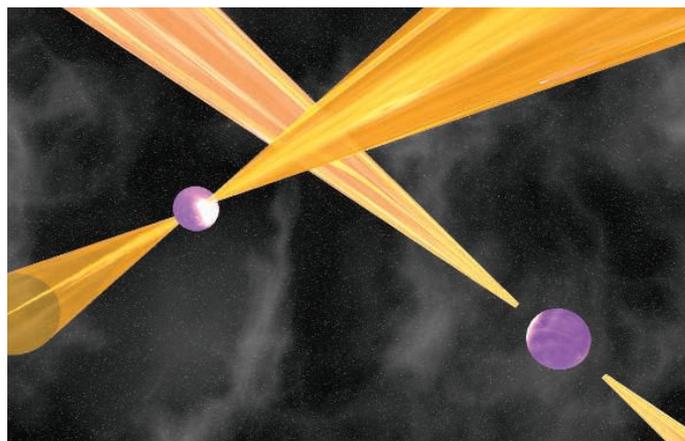
Pulsars' Gyration Confirm Einstein's Theory

Comparing a pair of massive stellar clocks known as pulsars, an international team of astronomers has put Einstein's theory of gravity to its toughest test yet. Published online by *Science* this week (www.sciencemag.org/cgi/content/abstract/1132305), the results show that the theory of general relativity (GR) is accurate to within 0.05%, even in the ultrastrong gravity of a

pulsar, a spinning neutron star measuring roughly 20 kilometers wide but weighing more than the sun. Further observations could enable researchers to peek into the structure of neutron stars, the hearts of which may contain a bizarre form of nuclear matter that flows without resistance.

Most physicists agree that GR cannot be the last word on gravity because it clashes with quantum mechanics. The new observation limits the possibilities for tinkering with GR, says Joseph Taylor, a physicist at Princeton University. “They’re tightening the constraints on any alternative to Einstein’s theory,” he says.

According to GR, matter and energy warp space and time, making free-falling objects travel along curved paths and producing the effects ▶



Timepieces. Taking the pulses of two pulsars as they whiz around each other, astronomers have determined their orbit and tested general relativity.

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we call gravity. Einstein specified a particular mathematical connection between the density of matter and energy and the curving of spacetime. To test the theory, a team led by astronomer Michael Kramer of the Jodrell Bank Observatory in Macclesfield, U.K., studied a unique astronomical object: a pair of pulsars 2000 light-years away that orbit each other at a distance of just a million kilometers (*Science*, 9 January 2004, p. 153).

Spinning like a lighthouse beacon, a pulsar beams radio waves into space, creating a pulsing signal that's nearly as steady as an atomic clock. If a pulsar orbits another object, the rate of pulsing rises and falls repeatedly as the pulsar speeds alternately toward and then away from Earth. By tracking the variations in the rates of both pulsars from April 2003 to January 2006, the researchers deduced the details of their orbit, such as the length of its elliptical shape, the rate at which the ellipse rotates, and how the orbit is tilted relative to the line from the pulsar to Earth.

They quantified the details in several so-called post-Keplerian parameters and found that all the parameters were consistent with one another and with GR to within the uncertainties. "General relativity does a perfect job of describing what we know of the system so far," says Ingrid Stairs, an astronomer and team member from the University of British Columbia in Vancouver, Canada.

Taylor and others had tested GR by studying single pulsars orbiting other objects. But with just one pulsar, researchers cannot directly determine certain details, such as the relative masses of the orbiting objects, says Taylor, who won the Nobel Prize in physics in 1993. Moreover, the pulsars in the double pulsar are moving faster than those in the other systems, he says, which accentuates relativistic effects.

As well as testing GR, further observations might reveal a subtle interplay between the rate at which the pulsars orbit and the rate at which each spins on its axis. That would give scientists a direct measurement of the distribution of mass within a neutron star and a first real glimpse into its mysterious insides, says Thibault Damour, a theoretical physicist at the Institut des Hautes Études Scientifiques in Bures-sur-Yvette, France. "This is not for today," he says, "but it shows that high-accuracy measurements might open a new window on nuclear physics." It might take more than a decade to see the effect, but all say it will be worth the wait.

—ADRIAN CHO

PALEOANTHROPOLOGY

Mild Climate, Lack of Moderns Let Last Neandertals Linger in Gibraltar

One of the few things researchers agree on regarding the Neandertals is that the story of these European hominids ends in extinction. But just when the last Neandertal died, and whether modern humans or a changing climate sealed their fate, are matters of lively debate (*Science*, 14 September 2001, p. 1980). Now a team working at Gibraltar, at the southern tip of Spain, reports radiocarbon dates suggesting that some Neandertals survived thousands of years longer than previously thought, taking refuge in southern Europe where the climate and environment were favorable, and where moderns were still fairly



The good life. Did Neandertals find refuge from a harsh climate and modern humans along Gibraltar's lush coast?

thin on the ground. "While pioneer modern humans were staking tenuous footholds" in the region, says team leader Clive Finlayson, a biologist at the Gibraltar Museum, the last Neandertals "were hanging on."

Anthropologist Eric Delson of the City University of New York says that "the dates appear fully supported," and that the notion of Neandertal refugia is "quite reasonable." But some archaeologists believe contamination from younger material might have skewed the dates. "I have considerable reservations," says archaeologist Paul Mellars of the University of Cambridge in the United Kingdom.

The new dates come from Gorham's Cave in Gibraltar, where Neandertals left their

characteristic Mousterian stone tools, although no fossils have been found. The international team obtained 22 radiocarbon dates from small pieces of charcoal in Mousterian layers dug between 1999 and 2005. The dates, reported online this week in *Nature*, range from 23,000 to 33,000 with a cluster at about 28,000 raw "radiocarbon years"; these must be calibrated to provide true calendar years. Although the calendar age is probably at least several thousand years older than the radiocarbon years, the calibration is uncertain (see p. 1560), and the team has stuck to uncalibrated dates. Reconstructions suggest that Gibraltar was surrounded by coastal wetlands and woodlands and blessed with mild temperatures at this time, Finlayson says, and the Neandertals enjoyed a rich cornucopia of resources including shrubs, birds, reptiles, and mollusks.

The Gibraltar dates appear to be the youngest accepted for a Neandertal site, although sites in Spain and Portugal have been dated as late as 32,000 radiocarbon years ago. But the Gibraltar Neandertals were not entirely alone: Although there are very few modern human sites in the region older than 30,000 years, one site about 100 kilometers east at Bajondillo, Spain, has been dated to about 32,000 uncalibrated years ago. The team concludes that Neandertals did not rapidly disappear as moderns advanced but rather co-existed with them in a "mosaic" of separate, low-density populations over thousands of years.

Mellars counters that many of the new dates actually cluster around 30,000 to 31,500 years ago, and the later ones could be contaminated. And archaeologist João Zilhão of the University of Bristol in the U.K. dismisses the idea that Neandertals and moderns lived near each other but had only limited contact. "This really stretches the bounds of credulity," Zilhão says.

But the Gibraltar Neandertals used only Mousterian technology rather than copying some modern techniques as late Neandertals did elsewhere in Europe, notes Katerina Harvati of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany. In the end, Harvati says, the Neandertal groups who stuck to their own traditions might have had the better strategy, and survived longer.

—MICHAEL BALTER