

GENETICS

Volvox Genome Shows It Doesn't Take Much to Be Multicellular

How a single cell made the leap to a complex organism is one of life's great mysteries. Biologists have thought that new genes and gene networks would be needed to make possible the move to multicellularity. But, at least in green algae, that turns out not to be the case. On page 223, a comparison between the genomes of the 2000-cell *Volvox carteri* and a single-celled green alga, *Chlamydomonas reinhardtii*, has revealed surprisingly few differences in their gene makeup. "Even major evolutionary transitions can be accomplished via relatively subtle genetic changes," says David Kirk, a developmental biologist at Washington University in St. Louis. As a result, solving this mystery "is going to take a lot more work."

Ever since the Dutch microbiologist Antonie van Leeuwenhoek discovered a multicellular *Volvox* in 1700, biologists have thought it would be a good model for study-

ing how complex organisms arose. It belongs to a group that includes single-celled and multicellular species of varying degrees of complexity. *Chlamydomonas reinhardtii*, for example, is a single cell powered by two flagella that lives in soil and fresh water.

By contrast, *Volvox carteri*, which is found in temporary and permanent ponds, has a much more complex life cycle. Adults consist of 2000 flagellated cells embedded in a spherical extracellular matrix, with 16 larger germ cells inside. Germ cells give rise to embryos in which dividing cells remain connected by cytoplasmic bridges from one cell interior to another, forming a hollow ball. At first all of the embryo's flagella face inward, but soon the newly formed embryo turns itself inside out, putting the flagella on the outside. Now called juveniles, these balls begin expanding by adding to their extracellular matrix and eventually burst out of

the parental sphere. Soon after the juveniles leave the sphere, the rest of the cells die.

In 2005, James Umen, a cell and developmental biologist at the Salk Institute for Biological Studies in San Diego, California, teamed up with Simon Prochnik and Daniel Rokhsar of the U.S. Department of Energy Joint Genome Institute (JGI) in Walnut Creek, California, and others to sequence the *Volvox* genome. JGI had already deciphered the genome of the single-celled *Chlamydomonas*.

The 138-million-base *Volvox* genome proved to be 17% bigger than the *Chlamydomonas* genome, but not because of new genes. Instead, it contained more repetitive DNA, Prochnik, Umen, Rokhsar, and their colleagues report. Moreover, it has roughly the same number of genes—about 14,500—as *Chlamydomonas*. The researchers found few, if any, *Volvox* genes coding for novel proteins or protein subunits that could account for the difference in morphology between the two species. The gene networks that likely underlie the cytoplasmic bridges, the inversion of the sphere, and asymmetric cell division were quite similar

POLAR RESEARCH

Broken-Down Icebreakers Hamstring U.S. Science

Biologist Carin Ashjian is hoping that her research cruise next winter will fill in some of the many blanks about how the Arctic ecosystem behaves during that forbidding

season. But to do so, she'll need help from a good mechanic.

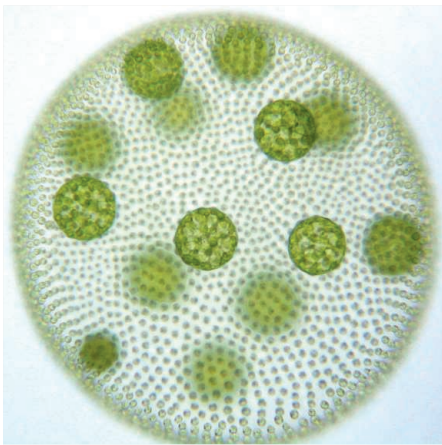
That's how it works these days for scientists whose access to the polar regions

depends on an over-the-hill and increasingly fragile U.S. icebreaking fleet. A 2006 report from the National Academies called for building two new icebreakers (*Science*, 6 October 2006, p. 33), but Congress has so far been unwilling to pony up the estimated \$2 billion or more that would be needed to upgrade the fleet. The most that supporters have achieved to date is a Senate-backed call for a cost-benefit analysis of the nation's icebreaking needs.

Such an analysis won't help Ashjian, a scientist at the Woods Hole Oceanographic Institution in Massachusetts. Her 6-week cruise aboard the Coast Guard cutter *Polar Sea*, the world's most powerful icebreaker, would be the first such scientific exploration of the Bering and Chukchi seas in January, Ashjian says. The goal is to provide information on water temperature, nutrient chemistry, and other biological and physical characteristics of this poorly understood ecosystem.



Crunch time. Neither of the U.S. Coast Guard's two polar-class icebreakers, shown operating in Antarctica in 2002, are currently serviceable.



Complex cousin. The juvenile *Volvox* (above), with its sphere of flagellated cells and 16 germ cells, is not much different genewise from the single-celled *Chlamydomonas* (left).

in both species as well, says Umen.

“It’s surprising how few differences were found,” says Arthur Grossman, a plant biologist at the Carnegie Institution for Science

in Stanford, California. “The findings suggest that it doesn’t take very large changes in gene content to transition from a single-cell to a multicellular lifestyle.” He suspects that some genes have altered their function in *Volvox* to account for the changes, and he calls for a more in-depth look for small changes in gene—and protein—sequence.

The findings parallel what Nicole King of the University of California, Berkeley, and her colleagues saw when they compared the genomes of a choanoflagellate—a close single-celled relative to animals—and several animals. The choanoflagellate had protein subunits, or domains, previously thought to be unique to metazoans, leading her to conclude that multicellularity in that part of the tree of life arose not so much from new genes but from a shuffling and recombining of existing genes and parts of genes.

“What we found was even more similarities between the unicellular and multicellular organism,” says Umen. “The key transition is not inventing a whole bunch of genes and proteins; you just have to change the way you use what you have.”

—ELIZABETH PENNISI

“Right now, when we run our Arctic models, we don’t know what to do with the winters because we know so little about what happens during that season,” she says.

But the *Polar Sea* may not be available. In May, the 32-year-old ship limped into its home port of Seattle, Washington, after suffering engine trouble during a spring Arctic cruise. On 25 June, the Coast Guard announced that a 3-month scheduled maintenance had turned into a \$3 million repair job that will stretch until “at least January 2011.” The Coast Guard has already canceled two fall events—one in support of a simulated oil spill in Arctic waters—and has told the National Science Foundation that the ship won’t be able to provide backup support for the annual clearing of a winter passage through McMurdo Sound to the main U.S. research station in Antarctica.

There’s no other vessel in the U.S. ice-breaking fleet that can do those jobs. The *Polar Sea*’s older twin, the *Polar Star*, has been out of the water since 2006, and its \$62 million “life extension” won’t be finished until 2013. A third—and slightly younger—Coast Guard cutter, the *Healy*, is much less powerful, and a fourth, newer vessel operated by NSF, the *Nathaniel B. Palmer*, is a research ship with limited icebreaking capa-

bility. That thin bench is why NSF has relied in recent years on Swedish and Russian icebreakers to clear a passage to McMurdo (*Science*, 19 August 2005, p. 1164).

Coast Guard officials have tried unsuccessfully to win approval for new polar icebreakers from both the Bush and Obama administrations. Legislators from maritime states aren’t happy with the status quo. “On a national level, this eliminates the nation’s only heavy icebreaking capability and seriously imperils our ability to respond to emergencies in ice-covered and ice-diminished waters,” said Senator Lisa Murkowski (R-AK), in response to the latest breakdown. “This could clearly impact our ability to preserve and protect U.S. interests in the Arctic.”

A reauthorization bill now awaiting a House-Senate conference would require the Coast Guard to carry out a study by outside advisers “with extensive experience in the analysis of military procurements” of the cost of improving or adding to the fleet as well as the implications of not upgrading the nation’s icebreaking capacity. “This subject’s been studied to death,” says a Senate aide who follows the issue. “We’d like to see more, but right now it may be the best we can do.”

—JEFFREY MERVIS

ScienceInsider

From the *Science* Policy Blog



In the latest twist in a contentious debate about a possible tie between a retrovirus and **chronic fatigue syndrome**, the journal *Retrovirology* last week published a study that failed to find a key virus in blood samples from 51 CFS patients and 56 healthy people. The study, led by federal researchers, was held up in publication because it conflicts with another pending government study that confirms the connection. <http://bit.ly/retrovstudy>

In what amounts to an unprecedented experiment, scientists are **moving 700 turtle eggs** from the beaches of Alabama and Western Florida to Florida’s eastern shores. Protecting the creatures from the gulf oil spill is worth the risk that the embryos may be damaged or that the species’ population genetics may be affected by the move, say scientists. <http://bit.ly/eggsmove>

For the second time, an investigatory panel at Pennsylvania State University has **cleared climate scientist Michael Mann** of charges of scientific malfeasance. The allegations had arisen after the release last year of hundreds of e-mails between climate scientists. <http://bit.ly/mannpanel>

In its first action on the 2011 budget for several science agencies, a **House appropriations panel** gave the National Science Foundation, NOAA, and NIST increases roughly matching the White House’s request. But an unusually fuzzy budget picture could eventually render the numbers meaningless. <http://bit.ly/nsfmoney>

A new report by the Massachusetts Institute of Technology calls for a variety of new research efforts to better exploit the large supply of **natural gas** in the United States. <http://bit.ly/gasreport>

AAAS, which publishes *Science*, has condemned **indictments issued** by an Italian prosecutor against six scientists and a bureaucrat for failing to predict an earthquake that struck L’Aquila, Italy, in April 2009, calling them “unfair and naïve.” <http://bit.ly/quakeletter>

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