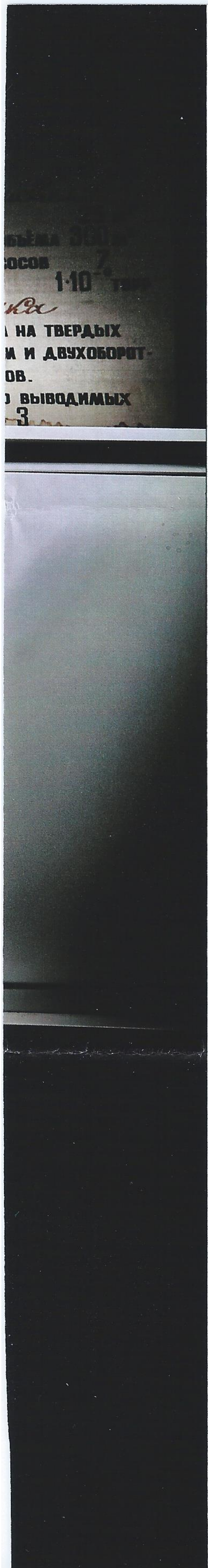
ELEMENT HUNTERS

All the elements found in nature—the different kinds of atoms—were found long ago. To bag a new one these days, and push the frontiers of matter, you have to create it first.

Yuri Oganessian, chalk in hand, heads a Russian team that is credited with creating 11 new heavy elements.



By Rob Dunn

Photographs by Max Aguilera-Hellweg

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LAST OCTOBER 22, at 9:29 a.m., a bell rang in the main office of Yuri Oganessian's lab in Dubna, north of Moscow. In a cramped warren partitioned by bookshelves and whiteboards, 12 nuclear physicists sat at desks stacked high with papers or strewn with snacks. Across the hall, a rebuilt but venerable cyclotron was flinging calcium atoms against a bit of foil at 67 million miles an hour. The chime of the little bell signaled that one of those collisions had worked: A new atom was born. At that moment it was the only atom of element 117 on Earth, and only the 19th ever to exist. The others had also been made in this lab, and all had quickly vanished. After a fraction of a second, this one was gone too.

Dubna, which sits on the Volga River, was carved out of a forest as a new city of science after World War II. Georgy Flerov, who had helped launch the Soviet Union's nuclear weapons research, founded the laboratory that Oganessian later took over. Early in the war Flerov had noticed that the flow of articles about radioactive elements from American and German scientists had suddenly stopped. He suspected they were building atomic bombs, and he wrote to Soviet leader Joseph Stalin in April 1942. Stalin charged Russian physicists with building a bomb too. For his part Flerov was rewarded with a car, a dacha, and, most significant, the lab in Dubna. There he focused on the hunt for new elements.

Everything you know and love on Earth, and everything you don't, is built of elements—the different types of atoms. They're billions of years old, most of them, scattered into space by the big bang or exploding stars, then incorporated into the newborn Earth, then endlessly recycled as they moved from rock to bacteria, president, or squirrel. In the late 1800s another Russian, Dmitry Mendeleyev, tried to make sense of them all, grouping them by mass and other attributes in his periodic table. Later scientists traced Mendeleyev's order to the structure of atoms. Each element got a number: the number of protons in its atomic nucleus.

By 1940, researchers had discovered everything that is durable and ancient on this Earth, right up to uranium, element 92. They'd filled in every gap Mendeleyev had left. But they weren't finished. Beyond uranium lies a world of possibilities—elements too radioactive and unstable to have survived billions of years. To explore that world, you have to create it first.

The first steps of creation changed more than just the periodic table. In 1941, after Glenn Seaborg and his colleagues at the University of California, Berkeley produced element 94, plutonium, Seaborg was promptly recruited to the Manhattan Project—Flerov was right. After helping to engineer the plutonium bomb that was dropped on Nagasaki, Japan, ending the war, Seaborg returned to Berkeley. He continued to make new elements, with less dramatic applications—smoke detectors, for instance—or none at all. By 1955

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his team had gotten as far as element 101. He named it mendelevium.

For a time it seemed Mendeleyev's table might end there, with his namesake. The protons in an atomic nucleus are always trying to tear it apart; their positive electric charges repel one another. Neutrons—electrically neutral particles that outnumber the protons—help bind the nucleus together. But that binding force works only at extremely close range. It weakens sharply as the size of the nucleus increases. So there has to be a final box on the periodic table, a maximum size beyond which an atom won't be stable even fleetingly, as a sort of chemical mayfly. With mendelevium, which has a half-life of 51.5 days, researchers seemed to be getting close.

The Berkeley team pressed on regardless, rivaled by the Flerov Laboratory of Nuclear Reactions at the Joint Institute for Nuclear Research in Dubna. From 1965 to 1974, Berkeley claimed to have produced elements 102, 103, 104, 105, and 106—but so did Dubna. Those mayflies died within hours. The dispute over who made them first got ugly anyway, heightened perhaps by the Cold War. In the end, compromise prevailed: Element 105 was named dubnium and element 106 seaborgium. Nuclear war was averted.

Meanwhile theorists had given new purpose to the quest. A very large

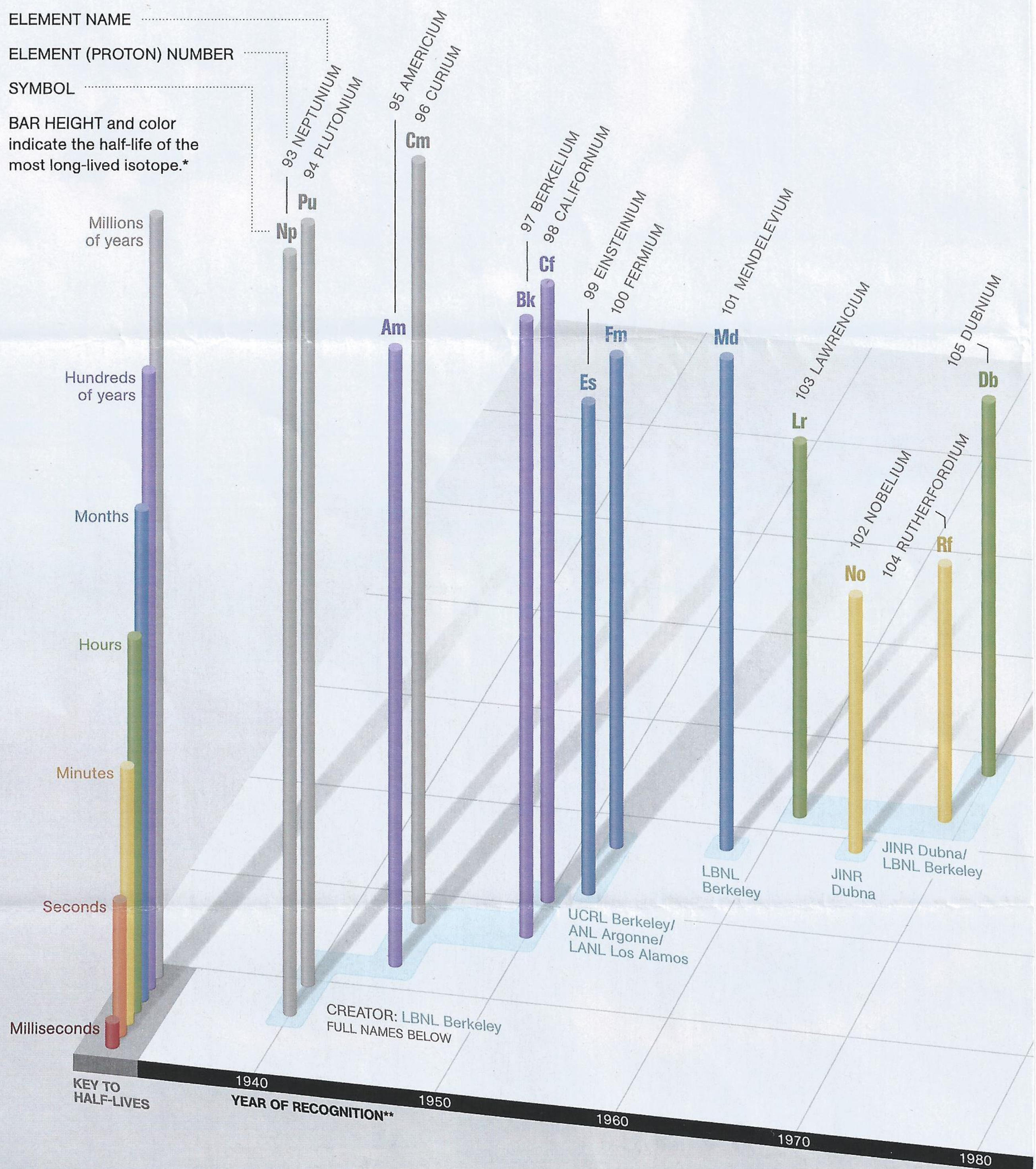
ON THE "ISLAND OF STABILITY," MONSTROUSLY HEAVY ELEMENTS MIGHT LAST THOUSANDS OF YEARS.

nucleus might be surprisingly stable, they decided, if it had "magic numbers" of protons and neutrons—enough to just fill the discrete shells the particles occupy. That insight, if right, would change everything. It would mean that maybe, just maybe, there was an "island of stability" beyond the horizon, where monstrously heavy elements with 114, 120, or 126 protons might last minutes, weeks, or even thousands of years. That fuzzy dream of a new world made the journey suddenly more compelling. It was around this time that Oganessian joined Flerov's lab.

ONE EVENING LAST FALL IN DUBNA my translator and I knocked on the door of Oganessian's modest yellow house on Flerov Street. Snow clouds hung low overhead; rooks hopped around streetlights. Oganessian loaned us slippers and led us to his dining room, where he poured tea. When the tea was done, we had coffee, then homemade Armenian wine. We talked about American folk music, our children, and our travels. After some time we turned to Oganessian's journey to the island of stability.

When he was a young man and the island first captured his imagination, it seemed impossible to reach. The Berkeley and Dubna labs had gotten as far as element 106 by slinging light nuclei against heavy ones with such force that they fused into a single superheavy nucleus. But beyond 106 the collisions were so energetic they were blowing the new nucleus apart

Ecologist Rob Dunn wrote about leaves in the October 2012 issue.
Max Aguilera-Hellweg photographed robots for the magazine in August 2011.

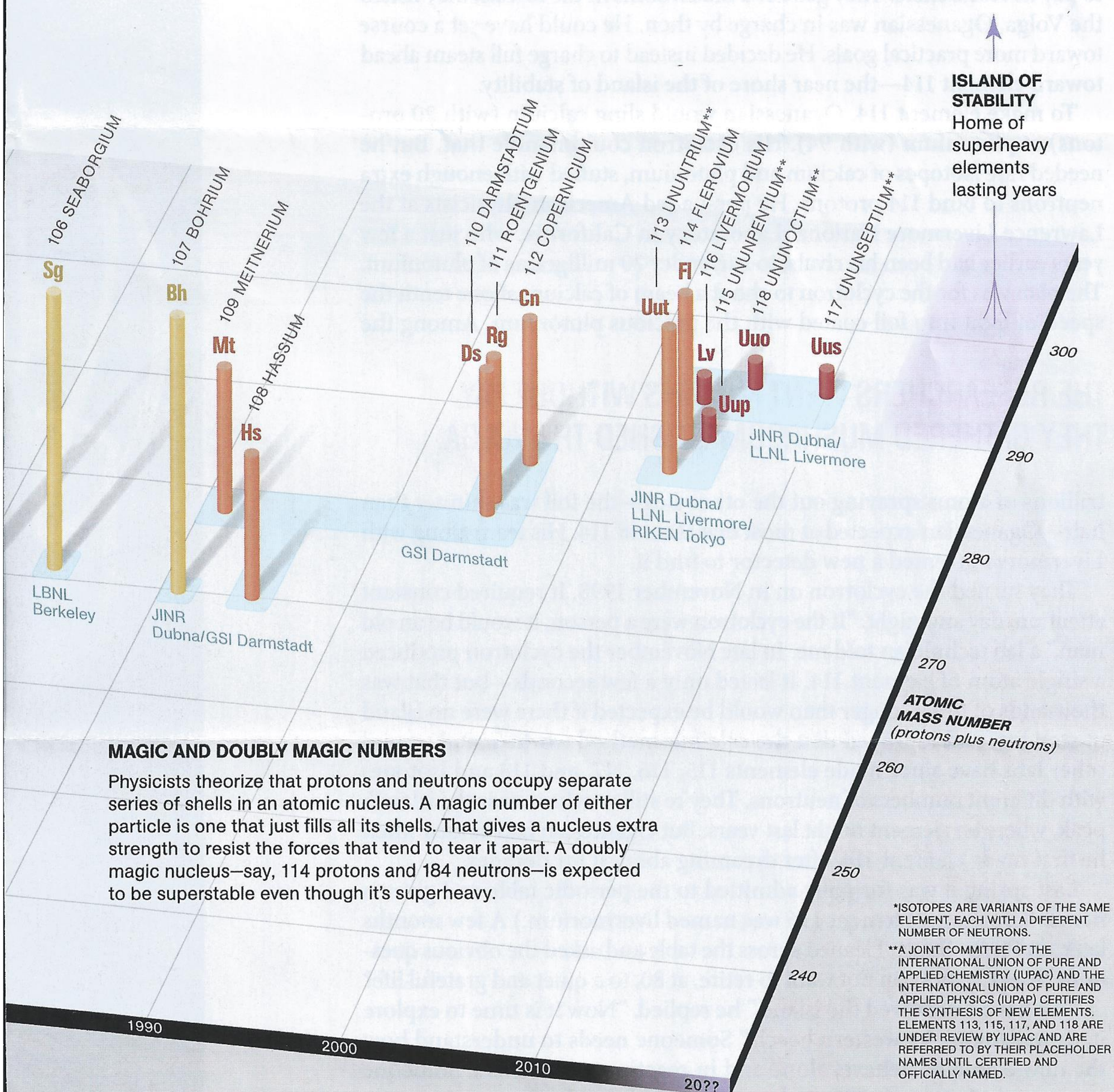


KEY TO CREATORS

LBNL Berkeley	Lawrence Berkeley National Laboratory, Berkeley, California
UCRL Berkeley	University of California Radiation Laboratory, Berkeley, California
ANL Argonne	Argonne National Laboratory, Argonne, Illinois
LANL Los Alamos	Los Alamos National Laboratory, Los Alamos, New Mexico
JINR Dubna	Joint Institute for Nuclear Research, Dubna, Russia
GSI Darmstadt	GSI Helmholtz Center for Heavy Ion Research, Darmstadt, Germany
LLNL Livermore	Lawrence Livermore National Laboratory, Livermore, California
RIKEN Tokyo	RIKEN Nishina Center for Accelerator Based Science, Tokyo, Japan

TWENTY-SIX NEW ELEMENTS

Over the past 73 years scientists have probed the frontiers of the atomic nucleus, synthesizing heavier elements one by one. The first step beyond uranium, the heaviest natural element, was neptunium, number 93 in the periodic table. The synthetic atoms are all radioactive: They decay into lighter elements, sometimes within milliseconds. In general, the heavier the element, the shorter its half-life. For decades researchers have been crossing a sea of short-lived elements in quest of the "island of stability," where "magic numbers" of protons and neutrons might combine to make superheavy atoms that last long enough to be studied.



MAGIC AND DOUBLY MAGIC NUMBERS

Physicists theorize that protons and neutrons occupy separate series of shells in an atomic nucleus. A magic number of either particle is one that just fills all its shells. That gives a nucleus extra strength to resist the forces that tend to tear it apart. A doubly magic nucleus—say, 114 protons and 184 neutrons—is expected to be superstable even though it's superheavy.

*ISOTOPES ARE VARIANTS OF THE SAME ELEMENT, EACH WITH A DIFFERENT NUMBER OF NEUTRONS.

**A JOINT COMMITTEE OF THE INTERNATIONAL UNION OF PURE AND APPLIED CHEMISTRY (IUPAC) AND THE INTERNATIONAL UNION OF PURE AND APPLIED PHYSICS (IUPAP) CERTIFIES THE SYNTHESIS OF NEW ELEMENTS. ELEMENTS 113, 115, 117, AND 118 ARE UNDER REVIEW BY IUPAC AND ARE REFERRED TO BY THEIR PLACEHOLDER NAMES UNTIL CERTIFIED AND OFFICIALLY NAMED.

JOHN TOMANIO, NGM STAFF; TONY SCHICK

CONSULTANTS: PAUL KAROL, CARNEGIE MELLON UNIVERSITY; ROGER HENDERSON, LAWRENCE LIVERMORE NATIONAL LABORATORY
SOURCES: INTERNATIONAL UNION OF PURE AND APPLIED CHEMISTRY; NATIONAL NUCLEAR DATA CENTER, BROOKHAVEN NATIONAL LABORATORY

On our digital editions, explore a gallery of elements and see how they're created.

before it even formed. In 1974 Oganessian proposed that slightly heavier projectiles and lighter targets might make for gentler, more fruitful collisions. A lab in Darmstadt, Germany, seized on the idea to make elements 107 through 112. Oganessian's day was still a quarter century away.

The Dubna lab went through hard times. Flerov died in 1990; the Soviet Union collapsed in 1991. The lab went months without being able to pay its researchers. They gathered mushrooms in the forests; they fished the Volga. Oganessian was in charge by then. He could have set a course toward more practical goals. He decided instead to charge full steam ahead toward element 114—the near shore of the island of stability.

To make element 114, Oganessian would sling calcium (with 20 protons) at plutonium (with 94). His cyclotron could handle that. But he needed rare isotopes of calcium and plutonium, stuffed with enough extra neutrons to bind 114 protons. He persuaded American physicists at the Lawrence Livermore National Laboratory in California, who just a few years earlier had been his rivals, to surrender 20 milligrams of plutonium. The plan was for the cyclotron to shoot a beam of calcium at one tenth the speed of light into foil coated with the precious plutonium. Among the

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trillions of atoms spraying out the other side—the foil was thinner than hair—Oganessian expected at most one atom of 114. His team along with Livermore's invented a new detector to find it.

They turned the cyclotron on in November 1998. It required constant attention, day and night. "If the cyclotron were a person, it would be an old man," a lab technician told me. In late November the cyclotron produced a single atom of element 114. It lasted only a few seconds—but that was thousands of times longer than would be expected if there were no island of stability, and it proved that the calcium method worked. Dubna and other labs have since made elements 115, 116, 117, and 118 and isotopes with different numbers of neutrons. They're still nowhere near the island's peak, where an element might last years. But Oganessian had landed when he first made element 114, after dreaming about it for decades.

Last spring it was formally admitted to the periodic table and given a name: flerovium. (Element 116 was named livermorium.) A few months later, on Flerov Street, I leaned across the table and asked the obvious question: Does Oganessian not want to retire, at 80, to a quiet and grateful life?

"We have discovered the island," he replied. "Now it is time to explore it, to walk along its western beach." Someone needs to understand how the new elements behave, alone and in reaction with others. Someone needs to find a way to pump the magic number of neutrons, 184, into flerovium, to reach the peak of the island. Someone needs to see if there are other peaks at elements 120 or 126. At the moment those goals seem almost impossible. Oganessian won't retire yet. □