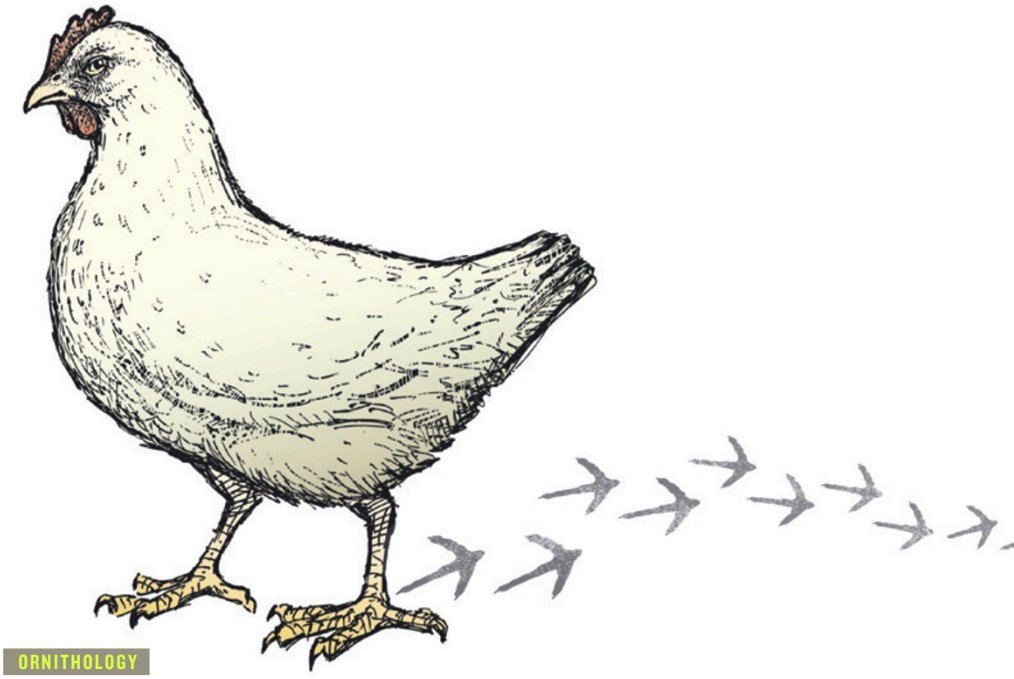
the peak of the cold war, 10 countries — including the United States, the Soviet Union, Britain and China — had built 65,000 nuclear warheads. But before the first bomb had been built, nuclear scientists had been lobbying politicians to change the mandate from building nuclear weapons to controlling them. The lobbying, partly through avenues such as the Pugwash Conferences on Science and World Affairs, was fairly successful: the number of nuclear weapons in those 10 countries has fallen to around 17,000.

But the fuel — fissionable plutonium or uranium enriched in a rare isotope of uranium — is still with us. Neither occurs naturally, so bomb-builders manufactured them. At the end of the Second World War, 100 kilograms of weapons-grade material had been made; now, it is 1,900 tonnes, enough for 100,000 bombs. As the authors show, material from dismantled bombs can be downblended to a less fissionable form and stored or used in power plants, but it cannot be destroyed, and it remains available for nuclear weapons or for low-tech radiological weapons. In 1945, only the United States could build a nuclear warhead; now, 35–40 countries can, and the margin of security is "too slim for comfort", says a former director-general of the International Atomic Energy Agency.

Feiveson, Glaser, Mian and von Hippel convincingly argue that this problem demands a real and immediate solution. Along with the history of nuclear weapons, they cover attempts to control the weapons' spread, including the 1970 Treaty on the Non-Proliferation of Nuclear Weapons; the physics and technology of producing, downblending and storing fuel; and the complexities of convincing nations to agree to be supervised and controlled by an international agency.

The authors' suggested long-term policy is to reduce the amount of fissionable material in military and civilian stockpiles, and to regulate it "as if the world is preparing for complete nuclear disarmament". Countries should stop hiding the sizes of their stockpiles, the authors write, and stop manufacturing weapons-grade uranium and plutonium; they should also downgrade or bury all fissionable material, even if they must give up nuclear energy. Finally, they should agree to international verification of declarations about weapons production — even if that means relying on nuclear scientists rather than politicians to tell the truth. ■

Ann Finkbeiner *is a freelance science writer in Baltimore, Maryland, who often covers scientists advising governments. She blogs at* The Last Word on Nothing, *www.lastwordonnothing.com.*



DZHAMILIYA ERMAKOVA/GETTY

ORNITHOLOGY

Fowl domination

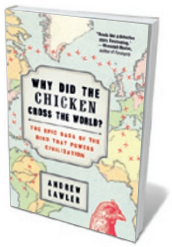
Ewen Callaway relishes a study tracing the chicken's eventful march from Asian jungles to global ubiquity.

The chicken is the Swiss army knife of livestock. Since its domestication in Southeast Asia as early as 18,000 years ago, the bird has been religious sacrifice, pet, research subject, fighting machine and, of course, dinner. The Victorians paid enormous sums for exotic breeds, and in the 1960s, NASA imagined the birds feeding Martian colonies. Around 20 billion are alive at any one time, bred to meet global demand. Science journalist Andrew Lawler explores the chicken's multipronged place in human civilization in his rip-roaring, erudite *Why did the Chicken Cross the World?*

Genome data and resemblance have pinpointed the red jungle fowl *Gallus gallus* — a furtive bird that roams the subtropical forests of southern Asia — as the wild ancestor of *Gallus gallus domesticus*. The birds are considered one species, because unions between them still produce fertile offspring. A few thousand years of separation is an evolutionary blink of the eye, too brief to create reproductive barriers.

Scientific efforts to unpick the origins of the domestic chicken are muddied by the fact that few, if any, living red jungle fowl are free of the genetic vestiges of their ancestors' romps with domestic chickens. The last purebred jungle fowl on Earth may reside, as Lawler shows, on a farm in the northeast of the US state of Georgia, rather than in a forest in Malaysia.

That is down to ornithologist Gardiner Bump. In the 1950s and 1960s, faced with a shortage of game birds in the US southeast, Bump set out to populate forests with imported wild red jungle fowl. He paid trappers to collect eggs — the more remote the better, because he wanted purebred birds — and deliver them to US hatcheries. The birds never thrived, and the US government pulled the plug on the programme in 1970. Descendants of Bump's birds survive in a handful of flocks. An evolutionary geneticist has sampled their blood, in the hope of discovering what truly sets chickens apart from their wild forebears.



Why Did the Chicken Cross the World?: The Epic Saga of the Bird That Powers Civilization
ANDREW LAWLER
Atria: 2014.

From their initial domestication, Lawler traces the chickens' journey to Mesopotamia and ancient Egypt, where the earliest known depiction of the bird was made, and then on to Polynesia and South America, where DNA from ancient chicken bones offers contentious evidence for a pre-Columbian trans-Pacific chicken trade. The author does not dwell on such controversy for long. For much of the book, science has a supporting role to history, ethnography and even advocacy.

Lawler's discussion of cockfighting is among the book's most compelling material. In ancient Greece, Babylon and China, pitting roosters against each other was embedded in religious practice. Now mostly illegal, it still thrives in parts of South America and Asia, especially the Philippines, as Lawler demonstrates with a harrowing dispatch

from the World Slasher Cup in Manila. He shows cockfighting as the brutal pastime it is, while recognizing it as an important chapter in human–chicken relations.

Chicken's mealtime ubiquity dates from the twentieth century. African Americans and Jewish immigrants brought the bird into US cities, and farmers who had once viewed chicken-keeping as women's work survived the Great Depression thanks to income from the birds. But wartime rationing of other meat put chicken on every plate. First held in 1948, the US Chicken of Tomorrow contest was conceived by supermarket chain A&P (and later sponsored by the US Department of Agriculture) to improve the efficiency of poultry production and expand the fledgling market. Before the contest, chickens bred for meat took 70 days to reach an average of 1.4 kilograms. Modern birds take 47 days to reach 2.6 kilograms, and they convert feed to meat 50% more efficiently (although many spend their lives in chronic pain because of the extra body mass). US chicken consumption is now four times what it was before the contest.

Readers of Michael Pollan's *The Omnivore's Dilemma* (Penguin, 2006) or Christopher Leonard's *The Meat Racket* (Simon & Schuster, 2014) will know the rest of the story. Leonard used the term "chickenization" to describe the 'vertical integration' of meat production developed and perfected by conglomerates such as Tyson Foods, whereby farmers have no ownership or control over the flocks they breed, which often number tens of thousands of birds. Americans eat more chicken meat per capita than any other nation, but the rest of the world is catching up. China surpassed the United States in overall chicken consumption in 2012. Meanwhile, the mass culling of chickens across Asia to stop an avian-influenza pandemic shows that chicken health is a global concern.

Lawler is not the first to denounce the inhumane treatment of the animals or to raise the red flag about bird flu. But his perspective as a science reporter gives fresh insight into the problems created by the ubiquity of chickens — as well as possible solutions. Especially compelling is the profile of Janice Siegford at Michigan State University in East Lansing, who is studying how to improve the welfare of chickens bred for food ('cage free' labelling is no guarantee that a chicken does not suffer throughout its life). Lawler recognizes that modern chickens — perhaps unlike genuine red jungle fowl — are here to stay. Who knows, maybe they will one day make it to Mars. ■

Ewen Callaway *writes for* Nature *from London.*

STEPHEN CUMMISKEY

CLIMATE SCIENCE

A climate trance

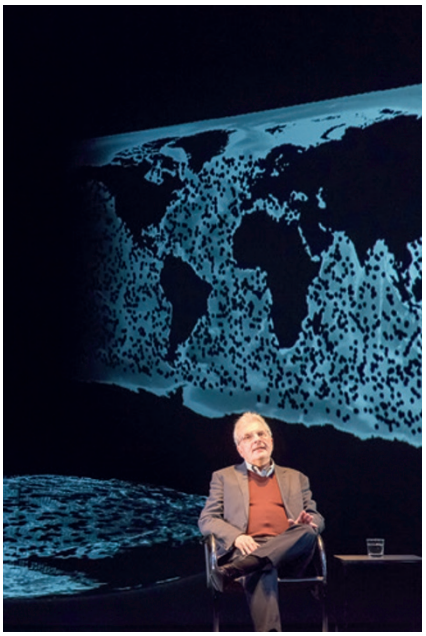
Richard Van Noorden considers a technical lecture that ultimately fails as theatre.

House lights down. A spotlight picks out a man, seated: climate scientist Chris Rapley. "I'm here to talk about the future," he says. Behind him on three giant video walls swirl greyscale images of tides and seas, and satellite views of Earth. So begins *2071*, a piece about climate change at London's Royal Court Theatre.

Rapley calmly lays out his credentials. Professor of climate science at University College London; former director of the British Antarctic Survey; former director of London's Science Museum. At a measured pace, he unfolds what he has seen and what scientists have learned, through means such as satellites, ocean buoys and ice cores, about the crumbling West Antarctic Ice Sheet, sea-level rise, the Holocene and Anthropocene epochs, and the interactions between lithosphere, biosphere, hydrosphere, cryosphere and atmosphere. The grey backing visuals break into big, moving white-on-black bar charts.

After 15 minutes, the audience realizes that there will be no let-up: *2071* is not a play, but an address just over an hour long. Rapley is the sole performer. This is a scientific lecture.

Global sea-levels are rising by 3.3 millimetres a year, Rapley says. The ocean is acidifying. Changes in solar radiation are not responsible for the observed temperature rise, because we see that the upper atmosphere is not warming, but cooling. The multisyllabic drone goes on, a flow of data lent emotional resonance only by a tense, unsettling soundtrack.



Climate scientist Chris Rapley in *2071*.

2071
WRITTEN BY DUNCAN MACMILLAN AND CHRIS RAPLEY; DIRECTED BY KATIE MITCHELL
Royal Court Theatre, London. 5–15 November 2014. The Deutsches Schauspielhaus, Hamburg, Germany. 17–18 December 2014.

Rapley and director Katie Mitchell are trying, perhaps in response to the histrionic climate politics of recent years, to establish a quiet, concentrated atmosphere in which to lay out the facts. But Rapley's monochrome recital risks sending his viewers into a climate trance, eyes glazed over by science. At one point, he starts quoting verbatim from the latest report of the Intergovernmental Panel on Climate Change; his delivery hardly changes in tone. The script's worst sin is that it fails even on its own terms. Although he sets himself up as bringing home scientific truths, Rapley in fact makes no effort to convey the human realities of acidifying oceans, rising sea levels, or two- or four-degree rises in global temperature. (The play's title makes a stab at humanizing the proceedings — *2071* is the year when Rapley's eldest grandchild will be the age he is now. But it's an awkward attempt.)

Mitchell's critically acclaimed 2012 play on population, *Ten Billion*, featured another professor, computational scientist Stephen Emmott, delivering another talk, in a stage recreation of his office. But where that was an entertaining polemic ("I think we're fucked," Emmott concluded), *2071* is sober and technical. Despite the scientific consensus behind Rapley's words, it is difficult to imagine that it will engage even a willing audience. Aiming for authenticity, Mitchell and Rapley have missed a chance to create a piece of drama that really gets under the skin of the issue; one that might seamlessly blend instruction and inspiration. But for those with an appetite for the stark facts on climate change, *2071* is just the ticket. ■

Richard Van Noorden *is a senior reporter at* Nature.