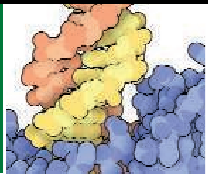
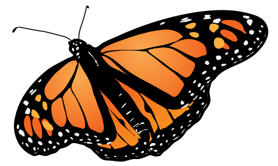




LETTERS

edited by Jennifer Sills

Preserving Starry Nights

THE 24 APRIL NEWS FOCUS STORY "STARS IN DUSTY FILING CABINETS" (Y. BHATTACHARJEE, p. 460) describes well the need to preserve astronomical glass plate collections and the difficulties encountered in doing so. The Carnegie Institution has a collection of some 200,000 plates of all kinds, gathered over decades from Mount Wilson Observatory, Palomar, and Las Campanas Observatory. Private funding has allowed us to preserve and archive the direct astronomical image and spectrographic plates in the collection, and small sets of these plates have been digitized when researchers needed them. Similarly, a project headed by Roger Ulrich at the University of California at Los Angeles and funded by the National Science Foundation has digitized large sections of our solar plates; these scans can be seen at www.astro.ucla.edu/~ulrich/MW_SPADP/index.html. In total, 39,500 plates (including direct image, spectra, and solar plates) have been digitized so far.

As the news story notes, space and funding needs for current projects often take away from efforts to preserve old data. Hopefully, greater awareness of the value of such plates, which are our only record of the past night sky, will lead to a corresponding increase in support for their protection.

WENDY FREEDMAN
Observatories of the Carnegie Institution, Pasadena, CA 91101, USA. E-mail: wendy@obs.carnegiescience.edu

Forecast for Reproducible Data: Partly Cloudy

M. R. NELSON'S PERSPECTIVE "BUILDING AN Open Cloud" (26 June, p. 1656) projects a vision of scientific computing that is enticing in some ways, but worrisome in others. Scientists can benefit considerably from being able to tap vast computing resources without knowing where the data or processing software reside or how these resources are provided. But ignorance of the nature—and more important, the provenance—of such resources creates novel problems for science and scientists.

Repeatability, reproducibility, and transparency are the hallmarks of the scientific enterprise. As more and more scientific research in every field is based on elaborate computation (*1*), it becomes more and more challenging to reproduce the results of these computations (*2*). This challenge is greatest when computational resources are proprietary and unknown even to the scientists who use them, as is the case for Nelson's "Many Clouds" and "Hazy Skies" scenarios. These two scenarios raise the specter that even the scientists producing and publishing results from Cloud computation will be unable to reliably reproduce their results, thereby undermining one of the foundations of scientific research.

The importance of documenting the provenance of scientific data—including the algorithms, tools, and versions of software used to generate it—is increasingly understood by scientists from a wide range of disciplines to be a problem of fundamental importance (*3*, *4*). Computing in the Cloud will complicate this problem, which—although by no means insoluble (*5*, *6*)—should be added to Nelson's list and viewed as a counterweight to the advantages of putting enormous amounts of anonymous computational resources at the ready disposal of scientists.

LEON J. OSTERWEIL,[1] LORI A. CLARKE,[1] AARON M. ELLISON[2]*

[1]Department of Computer Science, University of Massachusetts, Amherst, MA 01003, USA. [2]Harvard Forest, Harvard University, Petersham, MA 01366, USA.

*To whom correspondence should be addressed. E-mail: aellison@fas.harvard.edu

References

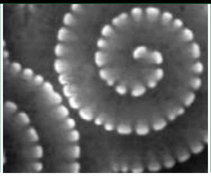
1. C. Anderson, "The petabyte age: Because more isn't just more—more is different," *Wired* 23 June 2008 (www.wired.com/science/discoveries/magazine/16-07/pb_intro).
2. L. J. Osterweil *et al.*, *Lect. Notes Comp. Sci.* **3840**, 403 (2006).
3. P. Arzberger *et al.*, *Science* **303,** 1777 (2004).
4. J. D. Baldwin, C. Duke, *Bull. Ecol. Soc. Am.* **86**, 61 (2005).
5. E. Boose *et al.*, *Ecol. Inf.* **2**, 237 (2007).
6. B. Ludäscher *et al.*, *Concurrency Comput. Prac. Exp.* **18**, 1039 (2006).

Response

OSTERWEIL *ET AL*. ARE RIGHT TO HIGHLIGHT how it will become increasingly difficult for the work of one research team to be precisely reproduced by another as the size and complexity of computational research problems grow. Very subtle differences in computer hardware, operating systems, math libraries, and applications software can be compounded when trillions of calculations are done and petabytes of data are stored and transferred.

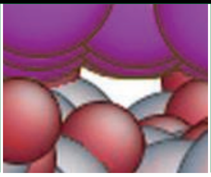
Cloud computing will make this problem even more important and provide even more incentive to address it properly. The good news is that the Cloud, by providing easier and cheaper access to computing cycles and storage, will make it far simpler to detect the very subtle hardware and software problems that can lead the same applications software to yield different results for the same inputs (*1*, *2*). Because Cloud computing can dramatically cut the cost of computing, researchers will be able to run their problems multiple times on different platforms. Furthermore, they will more easily be able to do the thorough testing required to spot discrepancies, and to design software that is less susceptible to subtle variations in the implementation of particular algorithms.

Computer scientists and mathematicians should be able not only to help the computational research community, but also to develop techniques that can be used in the full range of commercial Cloud computing applications. As Osterweil *et al*. stress, there are ways to tackle the reproducibility problem,



Emergent phenomena

1632



Stimulating simulation

1634

but more research is needed to avoid delaying the adoption of Cloud computing for research and commercial use. Even with technical solutions, legislation and regulation may need to be modified to account for the fact that companies rely more and more on a computing infrastructure that is constantly in flux.

As Osterweil *et al*. note, technical solutions will be far easier to implement if the evolving Cloud is built on open standards and nonproprietary code—the "Blue Skies" scenario I described. This will make it far easier for computational scientists to build the tools that enable them to monitor precisely how their algorithms are being run and how their data is being stored and analyzed, no matter where in the Cloud that happens.

MICHAEL R. NELSON

Communication, Culture, and Technology Program, Georgetown University, Washington, DC 20057, USA. E-mail: mnelson@pobox.com

References

1. N. J. Higham, *Accuracy and Stability of Numerical Algorithms* (SIAM, Cambridge, UK, 2002).
2. B. Cipra, *What's Happening in the Mathematical Sciences* (American Mathematical Society, Providence, RI, 1996), vol. 3, pp. 39–47; www.ams.org/ams/happening-series/divide.pdf.

Immune System: Not So Superior

IN HIS NEWS FOCUS STORY "ON THE ORIGIN of the immune system" (1 May, p. 580), J. Travis nicely lays out some of the issues surrounding the evolution of the adaptive immune system, particularly the biologically novel VDJ recombination process. The selective advantage of the adaptive immune system is, however, not at all clear. Citing the view of "many immunologists," Travis describes the notion that the adaptive immune system allowed more complex organisms to deal with more complex threats. He also cites Craig Thompson's suggestion that the adaptive immune system conserves resources, implying that the innate immune system is more resource intensive. These arguments fail by simple inspection. Whatever organismal complexity means, there is no evidence that invertebrates are less complex than gnathosomes or agnatha (which has its own version of adaptive immunity). On the issue of resource intensity, as T. Pradeu points out in his reply ("Immune system: 'Big Bang' in question," Letters, 24 July, p. 393), the adaptive immune system never works on its own; it is activated first by an intensive innate response. In addition, adaptive immunity further amplifies innate reactions. An equally likely possibility is thus the adaptive immune response, with its high rate of cellular expansion and contraction, is actually more resource intensive. In any event, neither of these conjectures has been supported by experimentation.

The underlying theme of the Travis news story as well as the reply by A. M. Silverstein ("Immune system: Promethean evolution," Letters, 24 July, p. 393) is that the adaptive immune system is somehow a great advance ("Big Bang") in the evolution of free-living organisms. Proponents of this view would thus be obliged to show that gnathosomes have a

LIFE IN SCIENCE

Having a Blast in Kenya

Our task? To position and detonate two 1000-kilo explosive charges on the bottom of Kenya's Lake Turkana. The year was 1990, and these blasts would allow seismometers placed up and down remote parts of the East African Rift to record sound waves from explosions and measure the structure of crust being pulled apart. To collect accurate data, we had to detonate the explosions exactly on time. As an inexperienced graduate student, my job was to pilot the Zodiac raft laden with plastic explosives. Setting the charges on the glassy lake in the morning was easy; we just had to pitch the explosive sausages overboard into a big pile on the lake bottom. We cleverly marked the shot locations with buoys made from empty water jugs anchored with rocks.

Returning in the afternoon, we found that the wind had stirred up the lake surface into considerable swells. Finding the small white buoys in a sea of whitecaps was challenging. We found the first of the two, attached the electrical line, reeled off 500 feet of cable, and detonated without incident. But now we had only 10 minutes to find the second, and the wind was fierce. After 9 minutes, we located the small jug. We had time to back off only about 100 feet before hitting the button. The result? Nothing.

What we didn't know was that the wind had blown the buoy about 100 feet away from the charge, dragging its inadequate anchor with it. That shift placed us directly above the explosives. So, although we didn't see the plume of water come off the shot, it wasn't long before we felt it. The blast launched the Zodiac and crew into the air. I dangled from the outboard motor and landed back in the lake with the raft, but my two companions were flung into the water. Luckily, the blast had scared the crocodiles away.

Under a rain of dead tilapia and muddy water, we hauled back into the boat and started it up. Our only wounds were bruised bottoms from the force of the blast under us. We limped back to shore, where a Kenyan Ministry official had come to keep tabs on us and our effects on the fish. We approached him sheepishly, but he only commented that the second blast had seemed much smaller than the first.

TOM PARSONS

U.S. Geological Survey, Menlo Park, CA 94025, USA. E-mail: tparsons@usgs.gov

EDITOR'S NOTE

This is an occasional feature highlighting some of the day-to-day humorous realities that face our readers. Can you top this? Submit your best stories at www.submit2science.org.

reduced incidence of mortality associated with disease, but I know of no such evidence. In fact, invertebrates are plagued by many of the same families of viruses, bacteria, and protists as vertebrates, and yet they do not exhibit high mortality rates due to infection nor do their populations collapse under the weight of parasitism. In fact, the immune system may be the cause of its own necessity (*1*). Incremental immune evolution surely confers a selective advantage, but such an advantage is quickly countered by the more facile evolution of thousands of parasitic agents. Over eons, there has grown an immune appendage that is nonetheless unable to decrease the overall burden of parasitism. This principle was described by van Valen as "The Red Queen Hypothesis" (*2*).

The notion that the immune system plays the bouncer, raising the velvet rope for beneficial bacteria and giving attitude to their less desirable brethren, was taken one step further by Margaret McFall-Ngai. She proposed that the adaptive immune system evolved, in part, to recognize and manage complex communities of beneficial microbes living on or in vertebrates (*3*). In summary, comparative genomics has shown various components of the immune system to be under continuous positive selection, and yet we cannot assume we know the basis for this selective pressure (*4*). **STEPHEN M. HEDRICK**

Department of Biological Sciences, University of California, San Diego, La Jolla, CA 92093–0377, USA. E-mail: shedrick@ucsd.edu

References

1. S. M. Hedrick, *Immunity* **21**, 607 (2004).
2. L. Van Valen, *Evol. Theory* **1**, 1 (1973).
3. M. McFall-Ngai, *Nature* **445**, 153 (2007).
4. C. D. Bustamante *et al.*, *Nature* **437**, 1153 (2005).

TECHNICAL COMMENT ABSTRACTS

Comment on "Infants' Perseverative Search Errors Are Induced by Pragmatic Misinterpretation"

John P. Spencer, Evelina Dineva, Linda B. Smith

Topál *et al*. (Reports, 26 September 2008, p. 1831) proposed that infants' perseverative search errors can be explained by ostensive cues from the experimenter. We use the dynamic field theory to test the proposal that infants encode locations more weakly when social cues are present. Quantitative simulations show that this account explains infants' performance without recourse to the theory of natural pedagogy.

Full text at www.sciencemag.org/cgi/content/full/325/5948/1624-a

Response to Comment on "Infants' Perseverative Search Errors Are Induced by Pragmatic Misinterpretation"

József Topál, Mária Tóth, György Gergely, Gergely Csibra

Spencer *et al*. argue that infants' perseverative search errors cannot be ascribed to an interpretive bias induced by communicative cues as we proposed. We argue that their model leads to different predictions about infant behavior from those derived from natural pedagogy in certain situations and therefore fails to provide a viable alternative to ours.

Full text at www.sciencemag.org/cgi/content/full/325/5948/1624-b

Letters to the Editor

Letters (~300 words) discuss material published in *Science* in the previous 3 months or issues of general interest. They can be submitted through the Web (www.submit2science.org) or by regular mail (1200 New York Ave., NW, Washington, DC 20005, USA). Letters are not acknowledged upon receipt, nor are authors generally consulted before publication. Whether published in full or in part, letters are subject to editing for clarity and space.