

WARNING CONCERNING COPYRIGHT RESTRICTIONS

The copyright law of the United States (Title 17, United States Code) governs the making of photocopies or other reproduction of copyrighted material.

Under certain conditions specified in the law, libraries and archives are authorized to furnish a photocopy or other reproduction. One of these specified conditions is that the photocopy or reproduction is not to be used for any purpose other than private study, scholarship, or research. If electronic transmission of reserve material is used for purposes in excess of what constitutes "fair use", that user may be liable for copyright infringement.

Citation: Ewald, Paul W., "The Evolution of Virulence," *Scientific American*, April 1993, vol. 268, no. 4, pp. 86-93

Copyright: 1993 Scientific American, Inc.

46

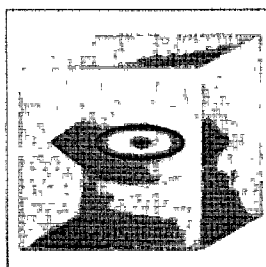


The Aging of the Human Species

S. Jay Olshansky, Bruce A. Carnes and Christine K. Cassel

For the first time in the history of humanity, our species as a whole is growing older. Toward the middle of the next century the population will stabilize near the practical limit of human longevity. Instead of focusing only on explosive growth, as in the past, policymakers must also rethink many social and economic institutions so that they will address the needs of an older population.

54

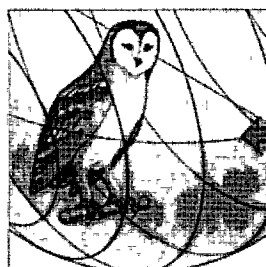


Cavity Quantum Electrodynamics

Serge Haroche and Jean-Michel Raimond

The terasecond jitteriness of individual atoms would seem beyond control. Yet when atoms are constrained in small superconducting cavities, transitions between their energy states can be slowed, halted or even reversed. Studies of the photons that imprisoned atoms emit illustrate the principles of quantum physics. The results also point the way to a new generation of exquisitely acute sensors.

66

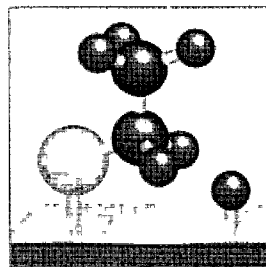


Listening with Two Ears

Masakazu Konishi

Just as depth perception requires two eyes, a pair of ears is needed to pinpoint a sound. The brain combines the signals into a unified directional cue. Studies of barn owls, which capture their prey in total darkness by relying on sound alone, have revealed almost every step of this remarkable computational exercise. Humans and other mammals probably process sound in a similar manner.

74

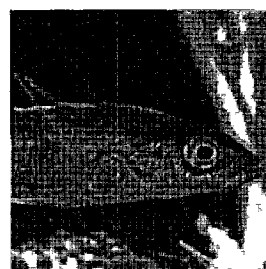


Catalysis on Surfaces

Cynthia M. Friend

Rapid advances in the field of surface chemistry have made it possible to view the action of catalysts at the molecular level. The work has contributed to a more complete understanding of the ways in which various metals facilitate reactions. And it has important implications, from refining petroleum products to removing pollutants from automobile exhaust and industrial smokestacks.

80



The Reproductive Behavior of the Stickleback

Gerard J. FitzGerald

This tiny fish has been a staple of animal behavior experiments since Dutch ethologist Nikolaas Tinbergen began studying its courtship practices earlier in this century. The author continues this fascinating inquiry by observing mating sticklebacks in tide pools along the Saint Lawrence estuary. His research helps to explain the adaptive significance of the stickleback's reproductive strategies.

86



The Evolution of Virulence

Paul W. Ewald

Why do some pathogens evolve into harmful forms that cause severe diseases, such as AIDS, whereas others inflict no more than a runny nose? Reasons include the way in which the organism is transmitted and, interestingly, human behavior. Our ability to direct the evolution of pathogens may herald a new approach to medicine.

94



Modern Humans in the Levant

Ofer Bar-Yosef and Bernard Vandermeersch

The idea that Neanderthals were primitives who were suddenly swept aside by modern *Homo sapiens* possessing a rapidly evolving technology is confounded by discoveries in Israel. There modern humans preceded the arrival of Neanderthals by thousands of years. Moreover, the Neanderthals wielded tools of similar quality.

102



TRENDS IN MATERIALS

Concrete Solutions

Gary Stix, staff writer

The government will have to pour billions of dollars into rebuilding the nation's aging highways and bridges. But unless the effort utilizes high-tech versions of such mundane materials as concrete, attempts to make U.S. infrastructure the rival of the best public works in Europe may stall. Research is under way, but getting new technology out of the laboratory and onto the highway is difficult.

DEPARTMENTS

18



Science and the Citizen

The contraceptive gap.... Gigamolecules.... Close encounters with asteroids.... Methuselah microbes.... Caged chromosomes and calico cats.... The fractal cosmos.... PROFILE: Presidential science adviser John H. Gibbons.

12



Letters to the Editors

These April missives do not fool around.

16



50 and 100 Years Ago

1893: Professor Hertz pioneers the first phosphorescent light.

120



Mathematical Recreations

Picking the right number of colors to map an empire.

113



Science and Business

A new enterprise ventures into commercial space.... Fighting cancer with viral proteins.... A promising architecture for optical computing.... Anchors for supertankers.... THE ANALYTICAL ECONOMIST: Is it time to reregulate the airlines?

123



Book Reviews

Living machines.... Maya decipherer.... Docile Astrid.

128



Essay: *Anne Eisenberg*
Blame Hollywood for the negative image of scientists.

The Evolution of Virulence

Human behavior appears to influence whether pathogens evolve into benign or harmful forms. Health policy should therefore include evolutionary considerations

by Paul W. Ewald

Some pathogens, such as those that cause cholera, smallpox, tuberculosis, malaria and AIDS, have quite severe effects. Others rarely inflict any damage beyond a cold or a sore throat. Recent studies suggest there are several evolutionary reasons for these varying levels of virulence. They include a pathogen's mode of transmission as well as its ability to survive outside a host organism for long periods. Human behavior may also play a significant, largely unrecognized role in the evolution of pathogens because it often determines the route and timing of transmission.

Understanding the forces that shape changes in virulence could become a powerful tool for medicine. By examining these variables, evolutionary biologists have already been able to predict patterns of morbidity and mortality in several diseases—including cholera, dysentery and AIDS. Using such an approach, medical scientists may be able to anticipate alternative evolutionary courses of pathogens and to tailor treatment and social behavior accordingly. They might even be able to transform virulent adversaries into mild ones.

Until recently, the understanding of how virulence evolves has generally been limited to one view. Most physicians and medical writers have concluded, unjustifiably, that the evolution of



host-parasite relations ultimately leads to benign coexistence. Their opinion is based on the idea that parasites that do not harm their hosts have the best long-term chance of survival: they thrive because their hosts thrive.

Some biologists, however, have arrived at a different conclusion. Evolutionary theory holds that what is best for a species may differ from what is best for its component individuals and that what is best for these individuals is defined by which genes are passed along most successfully. Even if a pathogen reproduces so extensively that it causes its host to become gravely sick, its host-impairing instructions may still win out over the less damaging instructions of a less aggressive competitor. The more virulent pathogen would achieve this success if its increased replication led to a level of transmission into new hosts that exceeded the loss of transmission resulting from the host's illness or death. In this scenario, the extinction of the host may eventually cause the demise of any pathogen that relies exclusively on one host. But the possibility of extinction does not inhibit the spread of the more virulent genes within the population of pathogens.

This perspective suggests that a parasite's virulence may reflect its mode of transmission. If the illness of a host impairs transmission, evolutionary biologists would predict that parasites would evolve to have milder effects. In contrast, if the host's disability does not inhibit transmission, pathogens could gain a competitive advantage by reproducing more rapidly.

Consider, for instance, a pathogen that relies on the mobility of its host. Rhinoviruses, causes of the common cold, reproduce in the cells that line the nasal passages. The viruses are shed in nasal secretions that trickle out as a runny nose or blast out during a sneeze. A person's finger may wipe away the mucus and may then touch the fingers of another person in the course of a handshake or by way of a borrowed pencil. The exposed individual may later touch fingers to nose or inhale the contaminated air, planting rhinoviruses on fertile ground.

Whichever route is taken, the ability of the host to move is critical. If the pathogen reproduces so extensively that the host is too unwell to leave home, thousands of rhinoviruses shed that day will die of exposure. A few might squeak by if they infect a family member, but such transmission could hardly be considered a great accomplishment, especially if the new host also becomes bedridden. For rhinoviruses, a person's movement improves prospects for transmission. Accordingly, rhinovirus replication is restricted to cells scattered in a sea of uninfected nasal mucosa, and virulence remains slight.

UNPROTECTED WATERS, including wells (above) and rivers, such as the Yamuna in India (right), have been infamous disseminators of disease. Purification limits the spread of infection. It also may provide an unrecognized benefit: it may force pathogens to evolve into mild forms.

PAUL W. EWALD is associate professor and chair of the biology department at Amherst College. In 1980 he received his Ph.D. in zoology from the University of Washington, where he studied the evolutionary and ecological aspects of aggression in birds. Two years ago the Smithsonian Institution named Ewald the first George E. Burch Fellow of Theoretical Medicine and Affiliated Science. When not researching evolutionary epidemiology, Ewald continues to investigate animal behavior. He also works as an unpaid carpenter with the hope of nursing his colonial-period farmhouse into its second quarter-millennium.