

The Dark Side of DNA

Fred Gould

GENES IN CONFLICT: The Biology of Selfish Elements. Austin Burt and Robert Trivers. x + 602 pp. The Belknap Press of Harvard University Press, 2006. \$35.

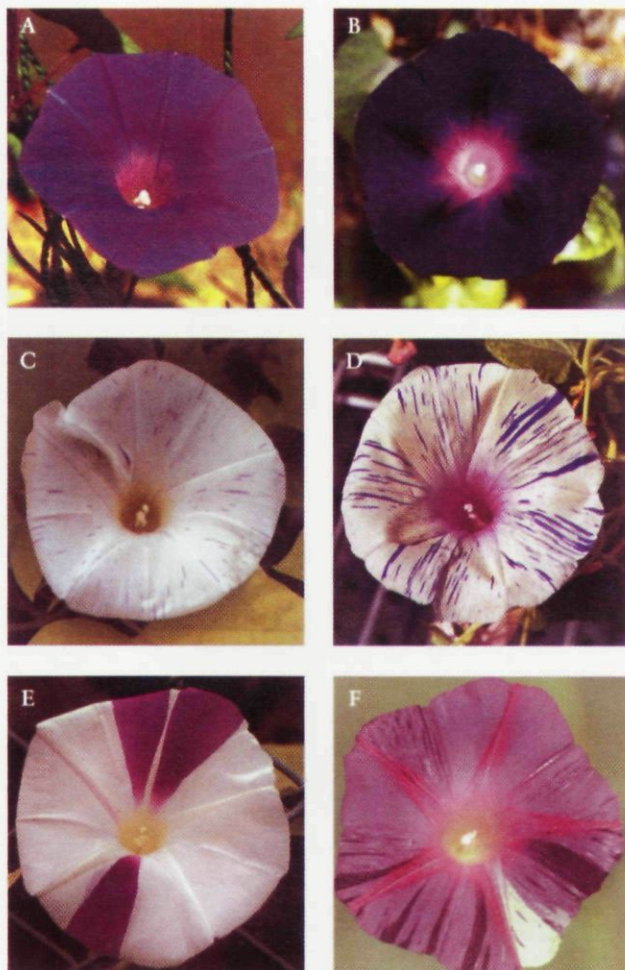
Although many of us have gotten used to the idea that our bodies serve the needs of a variety of viruses, bacteria, mites and other parasitic species, it comes as a surprise to most people when they hear that their bodies are also hosting alien parasitic DNA.

Analysis of output from the Human Genome Project makes it clear that just one form of such alien DNA, transposons, makes up about 50 percent of our genome. Every time one of your cells divides, it uses time and energy to replicate this parasitic DNA. There is even evidence that the size of your cells is set to accommodate this extra genetic load. In return, this type of DNA typically does nothing useful for you or any of the other organisms it inhabits.

So why do humans and the vast majority of other species serve as homes for parasitic DNA? This is one of many questions about selfish genetic elements that Austin Burt and Robert Trivers address in their scholarly, thought-provoking new book, *Genes in Conflict*. As can be gleaned from the title, the authors don't envision an easy alliance between selfish genes and the rest of the genome.

As background, it is worth noting that all specific sequences of DNA manage to persist over time by causing their host organisms to keep passing them on to their progeny. There are two basic evolutionary mechanisms that DNA sequences use to improve their odds of getting into that next generation. The first method involves increasing the number of viable offspring produced by the host relative to competing individuals. This process fits within our typical understanding of adaptation and natural selection.

The second evolutionary mechanism is for a DNA sequence somehow to increase the percentage of the host's offspring in which it is contained. A DNA sequence that is represented by one copy in a diploid sexual organism is generally expected by Mendelian principles to be inherited by 50 percent of progeny. If a DNA sequence can manage to wind up in, say, 90 percent of the offspring, it has a greater chance of persisting over time—even if that DNA sequence causes a decrease in fitness. Burt and Trivers consider genetic elements that use this second strategy to be “selfish DNA.” Of course, there is a balancing act here, because if the negative impact on fitness is too great, the host species could go extinct, taking the selfish DNA with it.



Although typical morning glories are uniform in color (A, B), the insertion and excision of transposable genetic elements can cause variable “knockout” mutations in the gene for pigment production, resulting in variegated flowers (C through F). From *Genes in Conflict*.

Over time, numerous types of genetic elements have evolved diverse parasitic strategies for proliferation in genomes and, as a result, have become very abundant in many organisms. But some species appear to lack selfish DNA of any kind. Whenever selfish DNA reduces fitness, natural selection will favor any mutant gene that decreases the probability of that selfish DNA being passed on. Burt and Trivers provide a long list of examples demonstrating a coevolutionary battle between selfish genetic elements and genes that negate their impact. In some species it seems that the selfish DNA is winning; in others it is taking a beating.

The dynamics of “gamete killer” genetic elements in the fungus *Neurospora*, and genes for resistance to these gamete killers, illustrate this coevolutionary tug-of-war. *Neurospora* has a brief diploid phase of its life cycle. This stage is followed by three cell divisions—two meiotic and one mitotic—giving rise to eight haploid spores arranged in a neat row. Researchers found that when they made genetic crosses between two particular strains of this fungus, four of the resulting eight spores in a set were always dead. Genetic analysis revealed that one of the strains, called the gamete-killer strain, has a tightly linked set of genes that somehow kills the four spores in which it was not present. The current hypothesis is that during spore formation, one or more of the gamete-killer genes code for a toxic substance, which is deposited in all of the forming spores. Four spores can survive, though, because they inherit genes from the killer strain that neutralize the toxin.

The important result here is that the gamete-killer genes wind up in 100 percent of the viable spores instead of just 50 percent. If even one spore in a population had this set of genes, it would in some situations be expected to increase in frequency until it was carried by all individuals, despite the substantial decrease in reproductive capacity experienced when only a minority of spores carry these genes.

A survey of *Neurospora* populations around the world found that these gamete-killer genotypes are typically rare but can indeed reach a frequency of 100 percent in populations of some species. Genes that confer resistance to the gamete killers are typically more common than the killer genes. Once a resistance gene enters a population and negates the ability of the killer genes to be overrepresented in progeny, the killer genes are selected against if they cause fitness reduction. So in the case of *Neurospora*, the selfish DNA seems to be losing the coevolutionary battle.

These gamete-killer genes, which are also found in invertebrates and vertebrates, are just one form of selfish genetic element, and they are far from the most diverse type. Transposons, sometimes called “jumping genes,” are found in a wide array of taxa and vary dramatically

ALSO REVIEWED IN THIS ISSUE

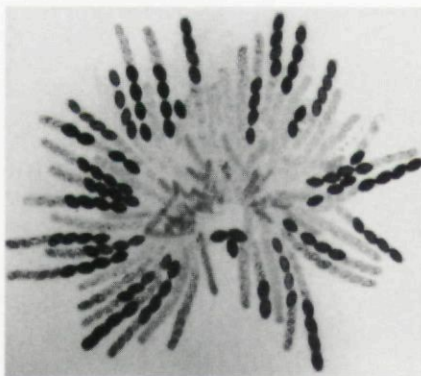
- 554 **EINSTEIN'S JURY: The Race to Test Relativity.** By Jeffrey Crelinsten. Reviewed by Suman Seth. *Einstein was catapulted to fame when observations of bending starlight gathered during a 1919 eclipse verified his theory of general relativity. But that experimental confirmation was not nearly as clear-cut as many people believe*
- 556 **ARTHUR CAYLEY: Mathematician Laureate of the Victorian Age.** By Tony Crilly. • **JAMES JOSEPH SYLVESTER: Jewish Mathematician in a Victorian World.** By Karen Hunger Parshall. Reviewed by Daniel S. Silver. *For a time, these highly regarded mathematicians of 19th-century Britain, pioneers in the development of linear algebra, had day jobs as lawyers*
- 559 **THE FIRST HUMAN: The Race to Discover Our Earliest Ancestors.** By Ann Gibbons. Reviewed by Jeffrey K. McKee. *The attention given to high-profile animosities among paleoanthropologists obscures the fact that cooperation is just as prevalent as competition*
- 561 **IN SEARCH OF MEMORY.** By Eric R. Kandel. Reviewed by Larry R. Squire. *This scientific memoir of a Nobel laureate reveals how the study of psychology in the wake of Freud gave way to a focus on the various cellular and molecular mechanisms operating in the brain*
- 563 **LOST MOUNTAIN: A Year in the Vanishing Wilderness.** By Erik Reece. Reviewed by David W. Orr. *According to Reece, mountaintop-removal mining has had a devastating effect on communities and ecosystems in Appalachia*
- 564 **THE RELUCTANT MR. DARWIN: An Intimate Portrait of Charles Darwin and the Making of His Theory of Evolution.** By David Quammen. Reviewed by Bettyann Holtzmann Kevles. *In this concise biography, acclaimed science writer David Quammen examines why it took Darwin so long to publish his revolutionary ideas*
- 566 **THE PSYCHOLOGY OF SCIENCE AND THE ORIGINS OF THE SCIENTIFIC MIND.** By Gregory J. Feist. Reviewed by Ryan D. Tweney. *This rich and diverse book makes a strong case for developing the field of psychology of science, says Tweney*
- 567 **ONE PLANET: A Celebration of Biodiversity.** By Nicholas Hulot. Reviewed by Roger Harris. *This collection of images highlights what we stand to lose every time another species disappears*
- 568 **TECHNOLOGY MATTERS: Questions to Live With.** By David E. Nye. Reviewed by David M. Hart. *An enlightening—and maddening—text that introduces some of the most important debates in the field of history of technology*
- 569 **23 PROBLEMS IN SYSTEMS NEUROSCIENCE.** Edited by J. Leo van Hemmen and Terrence J. Sejnowski. Reviewed by James M. Bower. *A century after David Hilbert outlined essential unsolved problems in mathematics, a number of prominent neuroscientists attempt to do the same for future studies of the brain*
- 571 **NANOVIEWS.** *Short takes on three books: How Everything Works • Another Day in the Frontal Lobe • The Structure and Dynamics of Networks*

in the mechanisms they use to become overrepresented in offspring. Burt and Trivers devote an entire chapter to transposons, which are able to replicate themselves within a genome and move to new locations on the chromosomes. An individual organism can start life with one copy of a transposon and end up with two or more in its germline cells.

Barbara McClintock discovered transposons in 1952, but the first selfish genetic elements revealed themselves as early as 1906. And new forms are still being found. A challenge to researchers is to think creatively enough to anticipate what an as-yet-undescribed selfish element might look like and how to design experiments for its recognition. Burt and Trivers discuss a wonderful example of this creative thinking by the renowned evolutionary biologist George Williams, who in 1988 wrote,

Perhaps it is just a matter of time before someone discovers (or invents in the lab) an all-male species. It makes diploid sperm that inseminate eggs of related species and give rise to diploid nuclei that exclude the egg pronuclei.

This would seem to be the ultimate in parasitic DNA—an entire eukaryotic genome that has no body of its own, surviving only by stealing the eggs of a related species in each generation. Although it may seem to be



Crossing normal *Neurospora* with the gamete-killer strain of this fungus produces a rosette of spores. Each linear appendage contains eight spores, only four of which carry the set of gamete-killer genes. The presence of these genes somehow allows those four spores to remain viable (black). Evidently, this set of genes codes for both a toxic substance, one that gets into all eight spores early on, and its antidote, which is present only in the four spores containing this special set of genes. From *Genes in Conflict*.

the subject matter for a science-fiction novel, this type of system was recently discovered in a clam, a conifer and a stick insect. Very cool!

But these examples are only the tip of the iceberg. In their 602-page opus, Burt and Trivers provide a plethora of exciting case studies. Although there is no lack of data to discuss, the authors emphasize repeatedly how little we really know about this area of evolution and biodiversity.

I found the tone of this book to be very engaging. It is full of details that have been woven together into a very readable, well-organized package. Of importance for the nonspecialist reader, Burt and Trivers succeed in conveying complex concepts in population genetics without using mathematical equations. Detailed mathematical treatment of these topics is certainly warranted, but that will be another book. The authors clearly reveal their attitude in the first chapter:

We review the evidence in more detail than we can make sense of and we describe logic beyond what the evidence will verify. Our aim is to strike a balance between what is known and what is not, the better to invite others to join in generating the missing logic and evidence.

What a gift to graduate students and all researchers who are just entering this field of evolutionary biology! I found at least a dozen good projects for Ph.D. theses suggested within the pages of this book, and I am sure that there are many more.

Fred Gould is a professor in the Departments of Entomology and Genetics at North Carolina State University. His current research is focused on assessing how naturally occurring and artificially engineered selfish genetic elements can be used for controlling or altering pest populations.

HISTORY

Paradigm Lost

Suman Seth

EINSTEIN'S JURY: The Race to Test Relativity. Jeffrey Crelinsten. xxx + 397 pp. Princeton University Press, 2006. \$35.

In a letter written on February 6, 1920, astronomer Keivin Burns of California's Lick Observatory expressed his doubts about Einstein's general theory of relativity. "Of course no one at Lick believes in the Einstein effect," he wrote, referring to the gravitational redshift in spectroscopic lines predicted by the theory, "it being contrary to philosophy, judgment, and horse sense. But since so much is being said on the subject it is necessary to be interested. It may take a long while to

show the error of the ways of the English astronomers."

The timing, location and subject of Burns's epistle are all central to our understanding of the early reception and testing of one of the pillars of modern physical theory. Most popular accounts of Einstein's theory tend to depict the 1919 eclipse expedition, led by Arthur Stanley Eddington, as the crucial test for general relativity. Eddington's announcement that the paths of starlight were deflected or "bent" by the Sun's

gravitational field by almost exactly the amount predicted by the theory was met with incredulity and amazement among scientists and sparked an international press furor. Within two weeks of the first media reports, the British humor magazine *Punch* recorded in lines of doggerel that an English "patriot" had been forced to write a funeral march, "To record, as he said, that a Jewish-Swiss-Teuton / Had partially scrapped the *Principia* of Newton."

As Jeffrey Crelinsten's crisply written and impressively researched book shows, however, the "patriot fiddler-composer of Luton" gave up his faith in Newtonian physics long before American astronomers were convinced to do so. The ongoing skepticism of the Americans was to have real import, for in the 1920s it was increasingly to the Lick and Mount Wilson observatories, both in California, that European and

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