only the sketchiest allusion to atomic orbitals. The problem remains that, as one physicist has put it, we have no words for the quantum world.

Trefil is a physics professor who served time as a high-energy physicist, and his entries in the physical sciences are accordingly the most authoritative. There are some curious errors nevertheless: what, for instance, is the Rydberg constant doing in the Clausius–Clapeyron equation? Was this introduced (in place of the gas constant) by the errant hand of a copy-editor? The shear elastic modulus is wrongly defined, the description of Oersted's famous experiment misses the point, and the section on spectroscopy recognizes only the electronic sort, with not a mention of vibrational, nuclear magnetic or electron-spin-resonance spectra.

The biological topics are for the most part clearly laid out, but again they are not altogether devoid of errors. Most are trivial, but blue-eyed children are not born to brown-eyed parents, nor does a B-cell display many kinds of antibody on its surface; the experiments of Miller and Urey and their successors on the origins of life have never given rise to anything that can decently be called a protein or a lipid; bacteriophages do not all contain DNA, nor, when they do, is it necessarily stitched into the host genome; and there are 20 protein amino acids.

The material is abundantly cross-referenced, yet there is a good deal of repetition. A few entries, says Trefil, are "just plain fun"; so there is the 'beauty criterion', Occam's razor and Murphy's law (although without the various well-known corollaries — when you want to do something, there is always something else you have to do first, and so on). Fermat's last theorem surfaces, presumably because it has of late entered into public consciousness (as reflected by the graffito in the New York subway: "I have a beautiful proof of this theorem but can't give it here because my train is coming").

This is a handsomely produced and stylishly illustrated volume, and should make a helpful and attractive basic reference source. I am now better informed on several topics of which I knew little before for having read it. So more power to Trefil for a brave and largely successful effort. ■

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Mergers and acquisitions

Darwin's Blind Spot: Evolution Beyond Natural Selection
by Frank Ryan
Houghton Mifflin/Texere: 2002/2003. 320 pp. $25/£18.99

Steven A. Frank

Photosynthesis arose in several independent bacterial lineages. Traditional evolutionary analysis would suggest that photosynthetic biochemistry originated independently in each of the separate lines of descent. However, recent genomic comparisons between five groups of photosynthetic bacteria show that there has been widespread horizontal gene transfer. Several bacterial groups acquired key components of photosynthesis by getting genes from other lineages.

The plant *Dichanthelium lanuginosum* grows in geothermal soils that get very warm. Like nearly all land plants, *Dichanthelium* has symbiotic fungi. These fungi enhance the growth of *Dichanthelium* at temperatures below 40 °C but are essential above 40 °C; plants without symbiotic fungi die at higher temperatures. So colonization of geothermal soils by *Dichanthelium* requires symbiosis.

Retrotransposons make up about 38% of mouse and human genomes. Those transposons presumably invaded ancestral genomes by retroviral infection. It is not yet clear whether retrotransposon DNA contributes significantly to host characters. However, the origin of some important host characters will probably be traced to this vast genomic component descended from viral genes.

According to *Darwin's Blind Spot*, if you are shocked by these observations, you are a true darwinian; if not, you are a radical symbiologist. Frank Ryan's darwinians believe that evolutionary change can arise only by descent with modification within clearly defined lineages. The radical symbiologists believe that major evolutionary innovation often arises by the joining of genetic information from different lineages.

The three observations on symbiosis quoted above come not from Ryan's book, but from a few recent issues of *Science* and *Nature* that I happened to read last night. Must we conclude that these journals have abandoned traditional darwinism and quietly gone radical?

Ryan has built an exciting story of heroic outsiders and fierce conflict over the nature of evolutionary innovation. There were indeed mighty battles over the origin of mitochondria and the eukaryotic cell, but they ended decades ago. Now everyone accepts that mitochondria descended from an independent bacterial lineage, and that the eukaryotic cell has symbiotic origins.

I agree with Ryan that mainstream evolutionary biologists still often fail to consider symbiosis as a plausible hypothesis to explain puzzling characters. But this failure does not arise from deep convictions about the nature of evolution. Rather, the mainstream comes round to a new way of thinking only after the evidence has piled up. Genomics will help greatly here because it allows us to trace the evolutionary history of lineages and untangle the complex web of descent.

Studies of symbiosis will surely lead to great progress in understanding ecological interactions and evolutionary history. On this most important point, Ryan is right. So why is it necessary to have heroes and villains, and to portray mainstream science as hopelessly conservative and plainly wrong?

Sales. Ryan is a successful author who

J. BURGESS/SPL

On the move: the broken, variable colour of dahlias is caused by transposons, or 'jumping genes'.

knows what he is doing. The story moves along. Anecdotes fascinate, personalities excite. Reviewers for www.amazon.com loved his earlier book, *Virus X* (Little, Brown, 1997). The style owes much to recent popular literature in biology. Come into my living room for a few hours and let me regale you with stories, he says. It'll be fun. And in the end, you'll know why most scientists understand little of the wonders of nature — they are blinded by their conservatism and prejudice. So, just by listening to me, you'll end up smarter than the professionals. It feels nice.

Ryan sometimes takes too broad a view of symbiosis. For example, he emphasizes that humans depend on food sources for certain essential vitamins and amino acids that we could, in principle, make for ourselves. "Viewed from a Darwinian standpoint, this makes little sense. Viewed from a symbiotic standpoint… we humans have evolved in a diffuse exosymbiotic relationship with the living providers of these 'missing genes'… With the exception of autotrophic bacteria, every life form on Earth has similar exosymbiotic needs." So, if you are a darwinian, eating puzzles you.

Despite Ryan's caricature of darwinism, he does understand well enough the basic principles of natural selection. However, his emphasis often creates the impression that symbiosis is the only way to achieve major evolutionary change. For example, he approves of panspermia, which holds that life came to Earth on a meteorite. Maybe it did, I don't have an opinion. But if Earth acquired life from another source, where did life originate?

This question reminds me of a story about Bertrand Russell. He gave a lecture in which he mentioned some properties of the Solar System. Afterwards, a woman told him that the Sun was held up on a turtle's back. Russell asked what held up the turtle. "You think you are so clever," she replied. "It's turtles all the way down." ■

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Science in culture

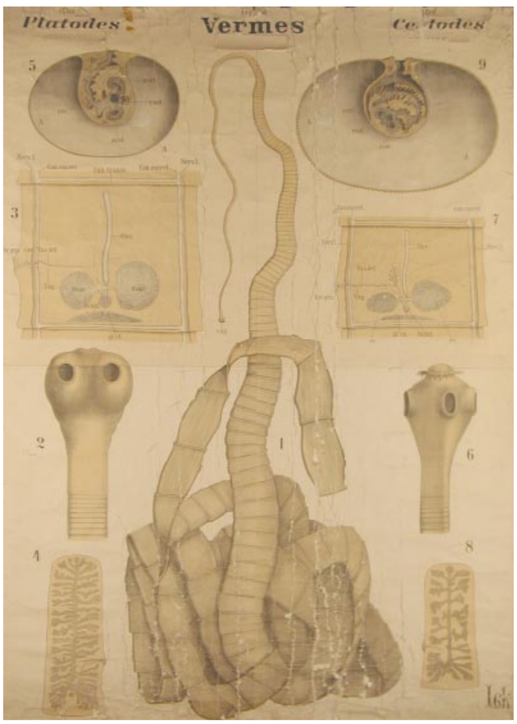
Visual zoology

Historic zoological wall charts found in Pavia.

Alison Abbott

Rudolf Leuckart (1822–98) was a respected zoologist and parasitologist. He lived in the heyday of the 'new zoology', which was influenced by both darwinism and the new discipline of physiology, and was increasingly scientific in its approach.

At a time when the life cycles of organisms were just starting to be understood, Leuckart was at the forefront. In one notorious experiment, for example, he found a volunteer to swallow four cysticerci, the larvae of the human tapeworm, to prove that these 'bladder worms' would develop into tapeworms using the human as host. One month later, the unfortunate volunteer was duly purged of two 2-metre tapeworms, and the prevailing concept that such parasites were generated spontaneously was finally laid to rest.



But Leuckart, who became rector of the University of Leipzig in 1877, left just as powerful a legacy in the form of his didactic *Wandtafeln*, or wall charts. The use of large scientific wall charts as teaching aids became popular in universities in the second half of the nineteenth century. The fashion followed the introduction of *Wandtafeln* in German schools as part of broad educational reforms inspired by Johann Heinrich Pestalozzi, who believed that children should see and experience, rather than learn by rote. Zoological wall charts in particular were valued at universities around the world.

Leuckart's beautiful series was neither the first nor the last to be produced, but is arguably the most significant, particularly given its extensiveness. There were 101 wall charts in his series on invertebrates, although the second series, on vertebrates, co-edited by his younger colleague Carl Chun, peters out after just 12.

The artwork was mostly produced by a series of Leuckart's assistants, who inevitably needed artistic as well as scientific skills. Leuckart himself illustrated only one of the charts with his own hand, that of his tapeworm (shown on the left). Each chart presents a single species, depicting its anatomy in different stages of growth or life cycle, and often alluding to function.

Their styles vary somewhat. But the 22 artist-zoologists all owe a debt to their contemporary Ernst Haeckel, a vociferous promoter of Darwin's new theory of evolution, whose superbly composed and beautifully drawn illustrations revolutionized the presentation of zoology. Haeckel used some of his own charts in his public lectures, happily compensating for his reportedly poor verbal skills.

Leuckart 's wall charts are not labelled with any explanatory text. Detailed explanations are instead provided in pamphlets intended for teachers, in three languages: German, English and French.

Production of the charts was technologically challenging and labour-intensive. Their size — 1 metre by 1.4 metres — required that they be printed in four sections, before being joined together and touched up. A complete set cost more than twice as much as the most expensive microscope of the time, yet they sold widely.

Unfortunately, very few of the charts have survived. So the discovery in 1997 of an almost complete collection, with full explanatory texts, at the University of Pavia in northern Italy is exciting. The charts were found when several of the university's science departments moved out of the eighteenth-century Palazzo Botta, where they had been situated for more than two centuries, into modern laboratories. Cleaning out long-forgotten attic and cellar stores, zoologist Carlo Redi stumbled across a large, 18-drawer chest in which the charts had been collecting dust for decades. The invertebrate series is complete, and only three charts in the vertebrate series are missing; these have since been located in Hamburg.

Only one other nearly complete series with explanatory texts is known to exist. It is held at the Marine Biological Laboratory in Woods Hole, Massachusetts. Again the invertebrate series is complete, but four charts are missing from the vertebrate series. Some 40 individual charts have been located in Hamburg, Leipzig, Rome and Padua.

The Woods Hole collection is available digitally on the laboratory's homepage. The Pavia collection has also been digitalized and has just been published as a sumptuous book, *Visual Zoology*, with an accompanying CD. Redi hopes to make the collection available on the University of Pavia's homepage soon.

Alison Abbott is Nature*'s senior European correspondent.*

The Pavia collection can be seen in *Visual Zoology: The Pavia Collection of Leuckart's Zoological Wall Charts, 1877*, edited by Carlo Alberto Redi, Silvia Garagna, Maurizio Zuccotti, Ernesto Capanna & Helmut Zachirias (Ibis, 2002).

Woods Hole collection

➧ **http://www.mbl.edu/leuckart**