hedgehogs (they know only one thing, but it's important). If Johnson is a fox, then Michael Behe (a biochemist at Lehigh University) is a hedgehog, because he has made much of the notion that some biological structures are "irreducibly complex" and no intermediates from simpler functional forms are possible. As Kitcher shows, Behe is saying that because science has yet to solve (or, in some cases, even study) some problems, they are insoluble—even though many problems previously considered insoluble and gaps previously considered unbridgeable have been solved and bridged. Moreover, evidence of scientific ignorance is not evidence for creation, which Behe is unable to test in any empirical sense. Kitcher is equally good at showing how Behe's and Johnson's books are full of sophistries and cover-ups that deny the truly impressive evidence of evolution, specific claims of which are explained and vindicated in the chapter by Matthew Brauer and Daniel Brumbaugh.

Another ID "hedgehog" is William Dembski, who claims to have invented a probabilistic "explanatory filter" that can distinguish among the increasingly improbable effects he interprets as caused by regularity, chance, and design. Dembski seems not to understand that in any attempt to explain the distribution of a set of phenomena, chance is the simplest (null) hypothesis, but this is the least of his problems. Even allowing Dembski most of his questionable propositions, Peter Godfrey-Smith still easily shows that Dembski's explanatory filter is merely a restatement of the fact that some events are highly unlikely to have arisen by chance, and evolution is clearly not driven by chance. Dembski's smoke-and-mirrors approach to causality (which he never effectively separates from statistical probability) is exacerbated by the confusion he generates with the meanings of "information." In information theory, the term can imply increasing predictability or increasing entropy, depending on the context. Godfrey-Smith also demonstrates that Dembski does not realize the concepts of "chance and necessity" that François Monod discussed are merely metaphors and they do not adequately describe evolution (or any other life process).

Pennock's book is an invaluable compilation for anyone who wants to learn about the scientific and philosophical failures of intelligent design and the long-term political and social strategies of its advocates. The book's principal shortcoming is that one-fifth of its length is spent on the arguments of and responses to Alvin Plantinga, a philosopher of religion at the University of Notre Dame. He seems neither fox nor hedgehog, and he has little to offer except assertions of "what Christians know"—as if other religious groups know nothing, and as if he could speak for all Christians. Plantinga's specious logic and his general ignorance of even basic scientific concepts reveal that he doesn't take science seriously enough to be considered seriously himself. People like Plantinga and Johnson claim the high ground without earning it, and so they seldom hold it long. Johnson believes that the more people learn about the philosophy behind evolution, the less they'll like it. Wait until they learn what's behind intelligent design.

BROWSINGS

The Shape of Life. Sea Studios Foundation, Monterey, CA, and National Geographic Television, Washington, DC. On PBS, Tuesday evenings, beginning 2 April 2002.
The Shape of Life. *Nancy Burnett and Brad Matsen.* Monterey Bay Aquarium, Monterey, CA, 2002. Paper, 136 pp. $19.95. ISBN 1-878244-39-6.

The focus of this television series and the accompanying book is much narrower than the title suggests. But the eight metazoan phyla that are covered—sponges, cnidarians, flatworms, annelids, arthropods, molluscs, echinoderms, and chordates—encompass more than 95% of all animal species. Viewers and readers are introduced to the diversity of forms and variety of lifestyles that have evolved within these basic body plans. For example, the annelids include both dull-colored earthworms that plow through the soil- and tube-dwelling polychaetes such as the "christmas tree worm" *Spirobranchus*, which extracts food from the water with its tentacular crown.

CREDIT: SEA STUDIOS

BOOKS: ENGINEERING

Keeping Swaying Bridges from Falling Down

Henry Petroski

> **In the Wake of Tacoma Suspension Bridges and the Quest for Aerodynamic Stability**
> *by Richard Scott*
> ASCE Press, Reston, VA, 2001. Paper, 314 pp. $69. ISBN 0-7844-0542-5.

When the Tacoma Narrows Bridge was completed in July 1940, its 853-meter main span made it the third longest suspension bridge in the world. In comparison to its length, however, the bridge was not at all a very wide or deep structure. The area south of Seattle where it had been built was then very sparsely populated, and traffic projections had justified only a two-lane crossing. Also, in keeping with the aesthetics of long-span bridges during the late 1930s, the bridge's deck structure was very shallow. To achieve the desired extremely slender appearance, the roadway rested on solid plate girders only 2.4 meters deep, a far cry from the 7.6-meter deep open trusswork that stiffens San Francisco's Golden Gate Bridge (completed in 1937).

The consulting engineer for the state-of-the-art steel structure at the Tacoma Narrows

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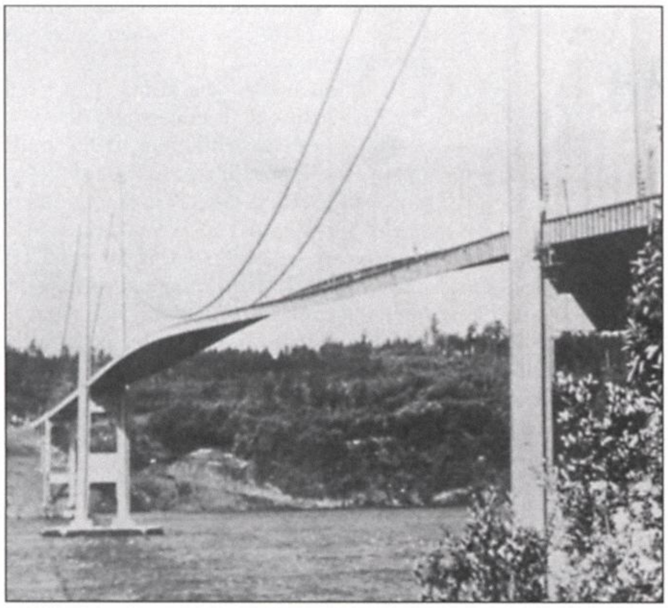


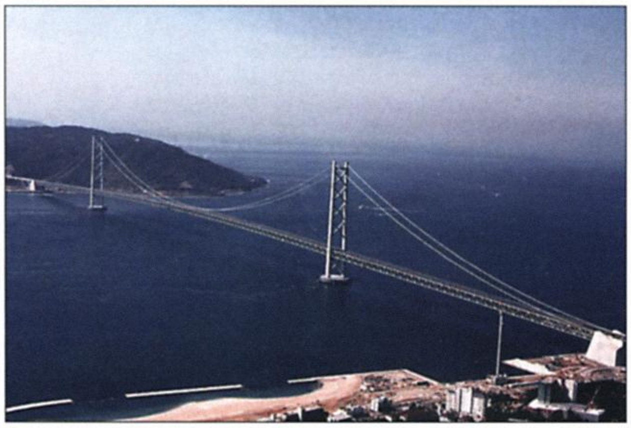
Twisting the bridge away. Engineers watching the Tacoma Narrows Bridge were startled by the sudden development of the torsional oscillation that led to the collapse of the span.

was Leon Moissieff, whose deflection theory had guided the design of virtually every major suspension bridge built during the previous three decades. This theory, which provided a more accurate calculation of how loads were distributed among the various elements of the structure, enabled the construction of relatively light and economical bridges.

There are three main kinds of loads on a suspension bridge. The weight of the structure itself is by far the greatest. Indeed, most long-span bridges require the bulk of their strength to just hold themselves up. Traffic loads may account for no more than 20% of the downward forces on the structure. Winds produce a horizontal loading, and in the 1930s bridges were stiffened in the plane of the roadway to enable it to resist being blown sideways. Such forces were considered static ones, however, and the dynamic wind forces—a focal interest of aeronautical engineers at the time—were not seen as relevant to large stationary structures like suspension bridges.

That assumption was proved invalid when the decks of several bridges completed in the late 1930s began to oscillate in the wind. For four months after it opened in July 1940, the deck of the Tacoma Narrows Bridge displayed a vertical oscillating movement that earned the span the nickname "Galloping Gertie." Not surprisingly, the unexpected motion became the subject of theoretical and experimental studies. The bridge remained open to traffic, there being little concern for its integrity. Then on 7 November 1940, the winds of an approaching storm initiated a torsional mode of vibration, and within hours the bridge had twisted itself to destruction. Although there can be little doubt that the cause of the failure was some form of aerodynamic instability, more than six decades after the fact the exact mechanism for the collapse remains open to debate among and between engineers and scientists. Any theory put forth to explain the failure is, of course, basically untestable on a full scale, because the original (unique) structure is no longer standing. But this is not to say that bridge engineers have not responded to what (until the collapse of the World Trade Center towers) had been perhaps the most infamous structural failure in history.

As its title suggests, Richard Scott's *In the Wake of Tacoma* is principally about suspension-bridge design and construction in the latter half of the 20th century. Scott is an environmental planner with the National Capital Commission in Ottawa, Canada, with a long-standing interest in the design and aesthetics of bridges and freeways. He provides some historical background, including a review of the state-of-the-art work that led to the events at Tacoma Narrows, as well as a clear description of the failure itself and its immediate aftermath. But the book's real subject is how engineers responded to the problems revealed by the Tacoma collapse and how they have designed the notably longer bridges that now stand against the wind.



Current champion. The suspended span of the Akashi Kaikyo Bridge (1998) near Kobe, Japan, extends 1990 meters.

Scott appropriately gives considerable attention to two rival engineers, Othmar Ammann and David Steinman. It was Ammann's daring and innovative George Washington Bridge, completed in 1931, that set the theoretic and aesthetic tone for the rest of the decade and emboldened engineers to exercise their hubris. The 1067-meter main span of the George Washington effectively doubled the main suspended length for the genre. Bridges that Ammann and Steinman completed later in the 1930s were among the first contemporary spans to exhibit unanticipated flexibility in the wind. The two engineers, with their antithetical personalities, held diametrically opposed technical opinions about how to retrofit their flexing bridges, with Steinman favoring cable stays and Ammann advocating stays between the towers and deck. Steinman's Mackinac Bridge (1957) between the upper and lower peninsulas of Michigan was perhaps the most significant suspension bridge built in the immediate wake of Tacoma, but it was Ammann's Verrazano-Narrows (1964) that captured the coveted world record for main-span length from the Golden Gate.

Rather than the stories of the engineers, it is the personality of the bridges themselves that is Scott's real interest. The second half of his book carries the story beyond the United States to elsewhere in the world, where the most significant suspension bridges of more recent decades have been built. The British innovation of the box-girder deck, which in section somewhat resembles that of an airplane wing, is given its due. The author treats in some detail the design and construction of suspension bridges in Scandinavia, Turkey, Japan, and China. He also describes several projects currently under consideration, including the long-discussed proposal to bridge the 3300-meter Messina Strait between Sicily and the Italian peninsula, as well as approaches to ensuring the aerodynamic stability of ultralong spans.

If the book has a fault, it is the absence of illustrations of the many remote and unfamiliar bridges of which Scott paints such effective word pictures. But *In the Wake of Tacoma* is an excellent source of information on its subject, and readers are likely to catch some of the author's obvious enthusiasm for suspension bridges.