

# 2006 Challenge Bibendum

# The bionic car



Despite its clumsy-looking features, the boxfish is a near-perfect paradigm of aerodynamics and rigidity. **Challenge Bibendum Home** 

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by Larry E. Hall

DaimlerChrysler turns to the boxfish as the model to create an aerodynamic and fuel-efficient car.

Box and aerodynamic seem to be contradictory. So too, do diesel and clean. But when DaimlerChrysler engineers from the Advance Concept Studio at the Mercedes Technology Center in Sindelfingen, Germany, collaborated with scientists from the company's Research and Body unit, these terms became harmonious in the form of the Mercedes-Benz bionic car, a concept vehicle that was designed consistently in accordance with the principles of nature.

The term *bionics* was coined in 1958 by an American Air Force major when he combined the words *biology* and *mechanics*. But the world's first student of bionics was the Italian Leonardo da Vinci. No less than 500 years ago, this ingenious all-rounder designed a flying machine and derived the principle of the helicopter from what he observed in nature.



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#### The Bionic Car Is the Real Thing

The word *bionic* became part of American pop culture in the 1970s via the TV series, "The Six Million Dollar Man." This bionic wonder could perform incredible feats of strength and speed and was later joined by a bionic woman (which became a separate series), a bionic boy and ... ahem ... a bionic dog.

While the TV show was just make-believe, the bionic car is the real thing. And in this case, the word bionic is condensed from a quite recent field of scientific discipline called "biomimetics," which is derived from the words *biology* and *mimesis* (imitation).

Biomimetics is an interdisciplinary subject which combines engineering science, architecture and mathematics. The basic principle is to make nature's problem solutions usable for man. The reason is simple: Nature, through billions of years of trial and error, has produced effective solutions to innumerable complex real-world problems.

The challenge for the assembled biologists, bionics scientists and automotive researchers from various disciplines was to design an aerodynamic and fuel-efficient car using the bionics principle. The car also had to transport four people comfortably and meet Mercedes' high standards of safety.

# From Clumsy-Looking Fish to Sleek Vehicle

When the project team embarked on their expedition into nature's domain, it led them into the depths of the underwater world where they encountered an unexpected role model—the yellow boxfish, or Ostracion cubicus.

#### **Broadband Video**



At first sight, the boxfish lives up to its name. It is almost laughable to think that this plump, polka-dotted, pug-nosed, aquatic creature could serve as a scientific model.

"Quite frankly, we were surprised when this clumsy-looking fish, of all things, became our model for designing an aerodynamic and fuel-efficient car," said Dr. Thomas Weber,



The bionic c 138-horsepc four-cylinder with a comr injection sys mph in 7.9 s



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DaimlerChrysler's research and development chief.

#### The Boxfish Is An Aerodynamic Marvel

Appearances are deceptive: despite its bulky appearance, the boxfish is a very skillful swimmer. Its boxlike shape does not prove to be a hindrance at all. In fact, on the contrary, the fish has unique characteristics and is an ideal example of the ingenious discoveries of evolution.

Applied to automotive engineering, the boxfish is a near-perfect paradigm of aerodynamics and rigidity. In addition, its rectangular anatomy is practically identical to the cross-section of a car body. It therefore comes close to meeting the requirements of a car that is suitable for everyday use, and has ample place for its passengers.



The bionic car's diesel engine incorporates a state-of-the-art particulate filter to minimize soot exhaust and a Selective Catalytic Reduction system to get rid of excess NOx.

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The first bionic car sub-project tackled by engineers was aerodynamics. Automakers place a high priority on the aerodynamic efficiency of a vehicle's body because of its affects on fuel economy. Using wind-tunnel tests, engineers can measure an automobile's coefficient of aerodynamic drag (Cd), essentially, how easily it moves through the air. About 60 percent of the power required to cruise at highway speeds is used to overcome air drag, and this increases rapidly at high speed. Therefore, a vehicle with significantly better aerodynamics (lower Cd value) will be much more fuel efficient.

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Streamlining specialists consider the water drop shape to be the standard for the ideal aerodynamic form, with a Cd value of 0.04. And the boxfish? Using computer calculations and wind-tunnel tests with an accurately constructed model of the boxfish, Mercedes engineers achieved a value which was very close to the ideal—0.06 Cd. That helps explain why the boxfish is such a good swimmer and is so maneuverable with minimal effort.

Next came a 1:4 clay model of the car whose shape substantially corresponded to the boxfish. The angular outside contours of the living model were adapted in the area of the roof and side skirts, as was the prominent, descending rear end with its heavily scalloped sides and pronounced wedge shape.

Engineers were elated and surprised when wind-tunnel tests of the model revealed a Cd of just 0.09, a value 65 percent better than the best of today's compact cars.

# Wow, a Cd Value of Just 0.19

The final task was to develop the full-size bionic car concept vehicle incorporating the basis of the boxfish contours. Using the Mercedes-Benz European A-Class car underpinnings, the result of the project is a compact two-door car with four comfortable seats, a panoramic windshield, a glass roof and large tailgate—167.3 inches long, 71.7 inches wide and 63.0 inches high. Utilizing the findings from the research in designing the concept, the bionic car offers a Cd ratio of just 0.19—among the most aerodynamically efficient cars ever produced.

In comparison, the **2005 Corvette**'s 0.28 Cd makes it the most wind-cheating 'Vette ever, and the lowest Cd of any production car currently available is **Honda**'s somewhat awkward looking **Insight** hybrid with a value of 0.25.

In addition to the boxfish-like basic shape, the slicing-through-the-wind result is made possible by a number of other aerodynamic features: rear wheels which are almost completely shrouded with sheets of plastic, flush-fitted door handles and the use of rearview cameras rather than exterior mirrors.

#### From Fish Skeleton to Car Body

But there's more, much more about the boxfish that was applied to the bionic car than just its slippery shape.

The boxfish is also a structural achievement. It has a bony external skeleton consisting of numerous bony, thin hexagonal plates, which are interlinked to form a rigid suit of armor. This helps support the fish's basic shape and protects it against injury.

Engineers applied this structure while developing the car's body, whose interim depiction on a computer screen looked surprisingly like the boxfish's skeleton. Consulting with outside bionics experts, DaimlerChrysler researchers developed a computer-assisted process for transferring the growth principle of nature to automobile engineering.

"The boxfish's bone structure, like other animals, obeys nature's principle of maximum strength for the least weight," said Mercedes engineer Dieter Gurtler. "The rate of bone growth is always in line with the forces that are brought to bear on a body."

Based on the SKO (soft kill option) method, computer simulation was used to configure body and suspension components in a manner that the material in areas subject to lower loads were made thinner, and perhaps eliminated ("killed"), while highly stressed areas are specifically reinforced.

Gurtler said developing the computer algorithms for the project was very time consuming, sometimes frustrating, but in the end, extremely rewarding. The SKO method reduced the bionic car's body structure by about one third, yet retained exemplary crash safety, stability and handling dynamics.

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#### A Spacious, Uncluttered and Airy Interior

Belying its awkward exterior styling, the shape offers up generous interior space with tons of headroom and more than adequate leg, hip and shoulder room for both front and rear occupants. Likewise, the cargo bay capacity can handle packing of a decent sized load.

The interior is uncluttered and airy, thanks to the X-shaped cross member that gives the roof its rigidity while yielding lots of space for glass panels. There is one distraction—the two-tone lime and pistachio suede seats and trim.

#### With 70 mpg, Who Needs A Hybrid?

With nature being the emphasis of the bionic car you might think, as I did, that behind the short, stubby nose would be an example of the latest fuel cell technology, or at the very least, a next-generation hybrid system. Instead, propelling the boxfish-looking car is a 2.0-liter four-cylinder turbocharged diesel with a common-rail direct injection system.

**Mercedes-Benz** was the first to implement Rudolf Diesel's combustion engine principle in a passenger car some 70 years ago. That legacy will continue into the future, according to Dr. Weber, who said that DaimlerChrysler is "committed to the diesel engine, not only in Europe, but also in the United States."

Producing 138 horsepower at 4200 rpm and 221 lb-ft of torque at 1600 rpm, the bionic car accelerated briskly (0 to 60 mph in just 7.9 seconds) during my short drive in an immense parking lot at Washington, D.C.'s RFK Stadium. The continuously variable automatic transmission directed power to the wheels in a seamless manner and there was absolutely no telltale diesel clatter from the engine.

The diesel engine, combined with the attributes of the superb aerodynamics and SKO construction, deliver an average of 70 miles per gallon fuel efficiency, topping out at 84 mpg on a straight highway run.

# No Stinky Diesel Odor

After a half dozen laps around the mile-long parking-lot course, I stopped the car, engaged the parking brake, left the engine running, stepped out of the car, kneeled down and sniffed the exhaust to detect how much diesel odor was spewing out.

There goes the NOx emissions. Earlier, Professor Herbert Kohler, DaimlerChrysler vice president, body and powertrain research had explained why.

The bionic car's diesel engine incorporates a state-of-the-art particulate filter to minimize soot exhaust and a Selective Catalytic Reduction system to get rid of excess oxides of nitrogen (NOx). The SCR system sprays a precisely measured urea compound (determined by driving conditions) into the exhaust system. This processes the NOx emissions into benign nitrogen and oxygen. The urea solution, called AdBlue, is stored in the spare wheel recess. At this point, the fluid must be replenished at a typical service interval, or about every 15,000 miles.

SCR technology use has already proven successful in Mercedes-Benz's European commercial trucks. "With the bionic car, we are showing the potential that SCR has when used in passenger cars," Kohler said.

He says that SCR can reduce NOx emissions by up to 80 percent under road conditions in the U.S. When testing is complete and the Environmental Protection Agency gives it the nod, the SCR technology will be offered in the U.S. for light vehicles, Kohler stated.

### **Bionics to Meet Production Cars**

Like nearly all concept vehicles, the bionic car will probably never see a production schedule. However, the benefits of the research are already paying off.

The SKO method has become an integral part of DaimlerChrysler's vehicle development engineering, noted Research and Development Head, Dr. Weber. The first examples will be a variety of small components on several vehicles beginning next year, followed by the A-pillar for the next Mercedes-Benz roadster, scheduled for production in 2008.

The boxfish may not be the most alluring sea creature hanging around coral reefs, but it's a keeper.

Larry E. Hall is editor of Northwest Auto News Service and a freelance automotive journalist based in Olympia, Wash. He has an intense interest in future automotive technology.

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