Abstract—Bionics is an interdisciplinary ground on the way to set up itself as a science. Utilization of structures, methods, processes by man in biological systems in relation to technical development is related to bionics. The term “bionic” was first coined in the mid-twentieth century, which is aimed at applying biological studies to technical aspects such as architecture, industrial design, and material science. In consideration of the global trend of environmental protection, the disciplinary focal point also tends to work on the issue of sustainable development. However, though the researches of sustainable design and green design have been increased, the subjects of these researches yet were mostly undertaken from the aspects of material, structure and form; and the application of ‘bionics’ to architecture or design seems to be treated as a new, contemporary idea. This paper reviewed the aspects of bionics approach related with Modern Automobile Engineering for sustainable development.

Keywords— Bionics, Light Weight Design, Lotus Effect, Sustainability.

I. INTRODUCTION

The term “bionics” is a combination of the Greek word “Bios” (life) and the word “Mechanics” which is inspired by nature. The aerodynamics structure of wings and body of fish, the lightweight structure of mammal bones or the lotus effect on surfaces are only a few examples of how nature’s wisdom is now being used for automobile applications [2].

Instead of making 1:1 copy of nature, Bionic means learning from the nature and implementing the knowledge gained from this in new design solutions. Bionics means “the use of natural prototypes for the design of man-made synthetic systems. Simply Bionics means to study the basic ideology in nature and emerge with applications of principles and processes to the needs of mankind [4].

II. HISTORY AND BACKGROUND

The aim of bionics experts is to translate nature’s solutions into human technology, for there is no doubt that nature is the best engineer and most ingenious designer of all.

- Although the word itself is still relatively new, an American air force officer coined it in 1958. The idea of combining natural principles and technical processes goes back to the 16th century [5].
- Leonardo da Vinci, for example, studied the flight of birds and designed his flying machine based on his findings.
- Some 400 years later, it was Otto Lilienthal who was to achieve the breakthrough with his flying apparatus.
- Nature was also the inspiration for the architect Antonio Gaudi in designing and building the Sagrada Familia Cathedral in Barcelona, Spain with its gigantic towers and pillars that are reminiscent of tree structures and ammonites.

Fig. 1: Lotus Effect at work in Nature and its Applications (Paint, Container of Self Cleaning Food, Self Cleaning Roof)

Fig. 2: History of Bionics (Refer Photos From Top Left to Bottom Right: Concept of Flying Machine by Leonardo da Vinci, Concept of Flying Apparatus by Otto Lilienthal, Concept of Cathedral in Barcelona, Spain by Antonio Gaudi)
The comparatively recent research area of bionics is actually an inter-disciplinary subject which combines engineering science, architecture and mathematics [4].

John von Neumann (December 28, 1903 – 8th February, 1957) was born in Jewish Hungarian and later American applied mathematician, physicist, inventor, polymath, and polyglot. He made major contributions to a number of fields. The definition of bionics as a modern research discipline was given by him and may be translated as: “Bionics is the scientific discipline, which is in charge with the systematic transfer of construction, process and evolution principles of living systems into technical applications”.

Werner Nachtigall (born June 7, 1934 in Saaz, Czechoslovakia) is a one of the pioneers in German bionics, gave a short abstract of this formal definition by the sentence “Bionics is learning from nature for the creation of independent technical solutions”, which is highlighting the important fact that the major goal is not copying of nature.

The English term bionics was coined 1958 by the American Jack E. Steele. It was first discussed at a congress in Ohio with the topic: Optimisation of radar by imitating the biological sonar of bats. Bionics meant, Learning from nature to discover and develop technical solutions. The basic principle of Bionics is to make nature’s ideas and problem solutions, which have stood the test of time over millions of years of evolution, usable for man [1].

III. NECESSITY OF BIONICS IN MODERN AUTOMOBILES

- Bionics is emerging as more and more important in the automobile industry, especially when it comes to vehicle design and the choice of materials.
- The basic aim of engineers is to use intellectual lightweight structure to make the vehicles of the future even lighter, safer, rigid and comfortable.
- Specialists in lightweight construction took mammals bones as a model from nature that is both light and strong.
- In the human thigh bone, e.g. the position and strength of the bone matter are precisely matched to the tensile and pressure loads that the limb has to withstand.
- Branches and roots of trees also grow exactly according to the principle- a perfect lightweight construction strategy on the part of nature.

- Based on this knowledge the car makers such as Daimler Chrysler, BMW or Opel are focusing on a Computer Assisted Process for transferring the growth principle used by nature to Automobile Engineering.
- While braking the Paws of cats widen it by spreading. Due to the enlarged surface, braking is more effective. The paw of a cat is adaptive. This idea was transferred from the fundamental biological research to the structure of a tire, which moderates the fuel consumption, and the braking distance reduced by 10%.

- Inspired by the successful applications of biological non-smoothness, researchers introduced bionic non-smooth surfaces as appendices into vehicle body design, aiming to further reduce aerodynamic drag [3].
- Fish are also very interesting objects of study for bionic specialists. For example, the nose of the dolphin is the model for a pear-shaped bow protuberance which enables ships to cross the oceans of the world with less water resistance and therefore lower fuel consumption.
- Airbus engineers have copied the rough skin of the shark to develop a striated foil coating for the wings of aircraft. The result is up to six percent less friction and considerable savings in aviation fuel.
- Self-cleaning surfaces are based on the example of lotus leaves, highly resistant metallic foams are derived from the bone structure and the latest, self-sharpening cutting tools copy the principle of rodent teeth. Nature even provides ingenious solutions for day-to-day things such as the Velcro fastener.
IV. RELATION OF BIONICS WITH SUSTAINABILITY

Bionics research does not mean copying nature. The aim is rather to understand its principles and use them as a stimulus for innovations. The creations of nature, which have been developed and persistently enhanced over thousands of years, provide never-ending reservoir of thoughts and inspirations from which not only technology can benefit. More than ever before, bionics can also further the cause of environmental protection. Many of the innovative concepts which engineers and scientists are adopting from nature correspond to the principle of sustainability. Nature always achieves its objectives economically, with the minimum energy, conserves its resources and completely recycles its waste [2]. Cross-sectional technologies that can make a contribution to sustainability in many value chains are examined, e.g. new forms of surface coating, innovative methods of product planning or the use of new ‘bionic’ designs/processes modeled after nature. The objective is to develop far-reaching innovations and new technical concepts for achieving specific sustainability goals [1].

V. BIONICS CONTRIBUTED FOR LIGHTWEIGHT DESIGN

Vehicle development is result of requirements like platform architecture, modularity, lightweight construction, safety, comfort, feasibility, costs and recycling. When looking for alternative vehicle concepts, lightweight structures for interior and exterior as well as car bodies which can be produced by using bionics is modern trend in automobile industry [6]. Great rigidity and low weight is acts as a growth principle designed by nature. It also includes effects of environmental facts like problems of Emission, Noise, growing number of cars, and finite Resources.

VI. STRATEGIC APPROACH OF BIONICS

A. Topdown Approach:
Typical example for the top down approach of the bionic strategy, is that starting from a well defined technical problem, bionics is searching for analogous situations in nature that might provide a solution for that specific problem. The mission of bionics, in this case, is the detailed analysis of system that is providing a potential solution, in order to understand, how this proposal of nature can be transformed into a technical system with similar properties. The whole process of development and optimization can be seen as a dialog between the worlds of technology and biology, there may be some early results, which appear very similar to the original proposal of nature, but the shape of the final technical solution will in many cases not being traced back to its natural origin.

Table I
Top Down Approach

<table>
<thead>
<tr>
<th>S.N.</th>
<th>Basic Stages</th>
<th>Domain</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Technical Problem</td>
<td>Technology</td>
</tr>
<tr>
<td>2</td>
<td>Searching for Feasible Solutions in Nature</td>
<td>Bionics</td>
</tr>
</tbody>
</table>

2. Bottom up Approach:
The bottom-up approach of bionics is not starting with a well defined problem that has to be solved. It is starting with a discovery in biological research that is fully described and well understood. The recognized principle then is translated into an abstract, formal and interdisciplinary description of the phenomenon, which is opening the pathways for the transfer into different fields of technology. A well known example for this approach is the so called “Lotus-effect”, which was leading to many new applications in nano structured surface design.

Table II
Bottom Up Approach

<table>
<thead>
<tr>
<th>S.N.</th>
<th>Basic Stages</th>
<th>Domain</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fundamental Research in Biology</td>
<td>Biology</td>
</tr>
<tr>
<td>2</td>
<td>Description of Construction and Working</td>
<td>Bionics</td>
</tr>
<tr>
<td>3</td>
<td>Description of Organizing Principles</td>
<td>Bionics</td>
</tr>
<tr>
<td>4</td>
<td>Abstraction of recognized Principle</td>
<td>Bionics</td>
</tr>
<tr>
<td>5</td>
<td>Finding Problems where principle might offer solutions</td>
<td>Bionics</td>
</tr>
<tr>
<td>6</td>
<td>Transfer into Technical Solutions</td>
<td>Technology</td>
</tr>
<tr>
<td>7</td>
<td>Final Product</td>
<td>Output</td>
</tr>
</tbody>
</table>

VII. A CASE STUDY OF MERCEDES BENZ CAR BIONICS

The boxfish, the aerodynamic model for the concept car, is also a prime example of stringency and light weight. Daimler-Chrysler researchers examined this bionic structure and transferred this principle to the Mercedes-Benz bionic car study with the help of a special calculation process. The process is based on the principles of bone formation and for instance allows up to 40 percent more rigidity to be achieved in the external door paneling than would be possible with conventional designs. The total weight is reduced by around one third with undiminished strength and crash safety if the entire body shell is designed according to this bionic principle. With such a low C_d value, it’s quite normal that this car doesn’t use much petrol. In fact, this concept car consumes 4.3 liters of fuel per 100 kilometers making it 20 percent more economical than a comparable standard-production model. Still it has a maximum speed of 190 km/h [7].

Table III
Development stages of Bionic Cars by Mercedes Benz

<table>
<thead>
<tr>
<th>S. N.</th>
<th>Illustration</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><img src="image" alt="Boxfish Illustration" /></td>
<td>This is a boxfish (<em>ostracion cubicus</em>).&lt;br&gt;[1] It has its home in the coral reefs, lagoons and seaweed of the tropical seas, where it has a great deal in common with cars in many respects.  &lt;br&gt;[2] It needs to keep its strength and move with the least possible consumption of energy, which requires influential muscles and an aerodynamic shape.  &lt;br&gt;[3] It needs to stir in small spaces in its search for food, which requires good manoeuvrability.[7]</td>
</tr>
<tr>
<td>2</td>
<td><img src="image" alt="Wind Tunnel Illustration" /></td>
<td>[1] This is a visualization of an aerodynamic calculation of the boxfish model having C(_d) value 0.06.  &lt;br&gt;[2] Though it has bony structure, the boxfish has almost as good reform qualities as the water drop shape which specialists consider to be the standard for the ideal aerodynamic form.  &lt;br&gt;[3] When exposed to an open flow, this streamlined shape has a C(_d) value of 0.04.</td>
</tr>
<tr>
<td>3</td>
<td><img src="image" alt="Mercedes-Benz Concept Car" /></td>
<td>[1] This is a wind tunnel model of a boxfish.  &lt;br&gt;[2] Using computer calculations and wind tunnel tests with an accurate model of the boxfish.  &lt;br&gt;[3] In this, the Mercedes engineers achieved a value which came very close to this ideal, namely 0.06.</td>
</tr>
<tr>
<td>4</td>
<td><img src="image" alt="Mercedes-Benz Concept Car" /></td>
<td>[1] This is a wind tunnel model of a car with the contours of a boxfish.  &lt;br&gt;[2] To make use of the aerodynamic potential the specialists in Stuttgart first created a 1:4 scale model car whose shape substantially corresponded to the boxfish.  &lt;br&gt;[3] In this, they were achieved the C(_d) value for the car was 0.095.</td>
</tr>
<tr>
<td>5</td>
<td><img src="image" alt="Future Bionic Concept Car" /></td>
<td>[1] Finally, here is a picture of the Mercedes-Benz bionic concept car.  &lt;br&gt;[2] Concept car still retains outstanding aerodynamic characteristics with a C(_d) value of 0.19 the fully-functioning.  &lt;br&gt;[3] Driveable Mercedes-Benz bionic car is among the aerodynamically most efficient in this size category.</td>
</tr>
</tbody>
</table>

### Table IV

Future Bionic Concept Cars

<table>
<thead>
<tr>
<th>S. N.</th>
<th>Illustration</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><img src="image" alt="Mercedes-Benz Airo Concept" /></td>
<td>The modified design of Bionic concept car provides a sustainable future, enhanced comfort and better commutation. It has come up with organic shape of plants and nature. The use of modern technology makes it correct for heavy crowded cities.[8]</td>
</tr>
<tr>
<td>2</td>
<td><img src="image" alt="BMW i8 Concept Spider" /></td>
<td>In addition to being the car to first wear BMW's eDrive emblem (the designation eDrive will identify the drive technology for all future electric energy and plug-in hybrid cars from BMW), the i8 Concept Spider carries two three-wheeled electric scooters in the back. The Light Cocoon sports car, from German design firm EDAG, is a “bionically inspired” vehicle made from ultra-lightweight materials. This Bionic concept car is a super-futuristic vehicle that draws inspiration from the organic shapes of nature and blends it with advanced eco-technologies—including advanced and optimized materials.</td>
</tr>
</tbody>
</table>

### VII. Conclusions

As earlier discussion through this paper, bionics is not to be defined by a specific set of subjects or fields of applications; it is defined by a methodological approach that uses two strategies, in order to transfer inventions of nature into technical solutions. In order to conclude this review of bionics we have summarize this paper as below: Bionic design needs design space, requirements and loads, experience and offers weight savings, innovative shapes. Lightweight Bionic design has to be used more intensely for future vehicles due to looked at comprehensively and affordable. Bionic design can help to find efficient concepts in product development, identify new light weight solutions, reduce development time, and minimize development costs. It also has to be emphasized, that there are growing and solid requests from various industries for bionic expertise in future engineers. It is more and more recognized that future technologies in automobiles will gain at least a part of their innovative potential out of inspirations and ideas that are coming from Nature. As an example for this Bionic trend, the brief case study of a bionic concept car by Mercedes Benz can be mentioned above.

### References

[1] Colani Luigi, “Bio-Design of Tomorrow”, Part 3, Publisher Car styling, Volume 46 1/2; Japan