HOW TO STEAL FROM NATURE

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### How To Steal From Nature

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<table>
<thead>
<tr>
<th>a. REPORT</th>
<th>b. ABSTRACT</th>
<th>c. THIS PAGE</th>
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<td>unclassified</td>
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</table>

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**17. NUMBER OF RESPONSIBLE PERSON**

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*Standard Form 298 (Rev. 8-98)*
Prescribed by ANSI Std Z39-18
Start from here . . .

• The abilities of ‘living machines’ can exceed those of man-made ones
• Nature’s solutions survive
• Physics rules, so we can copy and adapt

HOW CAN WE TRANSFER THE TECHNOLOGY?
Solutions from biology

• Competition selects and optimises - but for what?
• Optimisations are local - organisms are multifunctional, have to work while they grow, and are derived from earlier designs
• Optimisation means ‘good enough’
• Nature may be solving different problems - minimum energy or maximum competitiveness?
<table>
<thead>
<tr>
<th>Biology</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet, flexible</td>
<td>Dry, rigid</td>
</tr>
<tr>
<td>Heterogeneous</td>
<td>Homogeneous</td>
</tr>
<tr>
<td>Anisotropic</td>
<td>Isotropic</td>
</tr>
<tr>
<td>Curved</td>
<td>Rectilinear</td>
</tr>
<tr>
<td>Non-metallic</td>
<td>Metallic</td>
</tr>
<tr>
<td>Factory &lt;&lt;&lt;&lt; product</td>
<td>Factory &gt;&gt;&gt;&gt; product</td>
</tr>
<tr>
<td>Multifunctional</td>
<td>Limited functionality</td>
</tr>
<tr>
<td>Self-repairing</td>
<td>Repair or replace</td>
</tr>
</tbody>
</table>
Sections through the wing of a tipulid (crane fly)
A bee’s wing
Framework for a lightweight wing
(What’s wrong with it?!)
Vortices in a wing cycle of a hovering hawk moth *Manduca*
The power problem

Continual flight needs continual power
Intermittent flight could use low grade energy
and store it . . .
. . . then release it suddenly.

power amplification

Jump-and-glide
Robots sense something going past, all jump together to detect what it is and communicate with each other.
Height of a jump

Kinetic energy on leaving the ground:

\[ E_k = \frac{1}{2} m v^2 \]

Potential energy at the top of the jump:

\[ E_p = mgh \]

\[ \therefore mgh = \frac{1}{2} m v^2 \]

Height of the jump:

\[ h = \frac{v^2}{2g} \]

The height of the jump depends linearly on the power available.
100 g JumpBot
jumps to 1 metre
(assumes 10% spring efficiency)

Computer   >>>>>>  30 g
Spring      >>>>>>  5 g
Energy in   >>>>>>  40 g
Chassis    >>>>>>  25 g

n.b. - the chassis will store some of the strain energy
Femur of jumping leg
Bennet-Clarke HC (1975). *J. Exp. Biol.* 63, 53-83
### Mechanical properties of skeletal materials

<table>
<thead>
<tr>
<th></th>
<th>Locust tendon</th>
<th>Mammalian tendon</th>
<th>Resilin</th>
<th>Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength (MN/m²)</td>
<td>600</td>
<td>100</td>
<td>3</td>
<td>450 - 2700</td>
</tr>
<tr>
<td>Stiffness (MN/m²)</td>
<td>20000</td>
<td>2000</td>
<td>2</td>
<td>210000</td>
</tr>
<tr>
<td>Elastic strain (%)</td>
<td>3</td>
<td>&gt; 10</td>
<td>&gt; 140</td>
<td>0.45 – 1.3</td>
</tr>
<tr>
<td>Energy storage (J/g)</td>
<td>9</td>
<td>&gt; 5</td>
<td>&gt; 2.1</td>
<td>0.125 – 1.4</td>
</tr>
</tbody>
</table>
TRIZ

Teoriya Resheniya Izobreatatelskikh Zadatch

Теория Решения Изобретательских Задач
Has your problem already been solved by someone else?
Increasing Ideality

- Invent the system
- Make it work
- Modify the system to make it better
- Increase performance
- Optimise resources
- Get the most out of the mature system by decreasing costs and harm
Space segmentation

- Monolithic system
- System with a cavity
- System with multiple cavities
- Capillary and porous system
- System with active capillaries

- Solid
- Hollow
- Multiple-hollow
- Porous
- With an additive

With permission from Invention Machine- Trends  example from TechOptimizer Software
Dynamisation
increasing degrees of freedom

<table>
<thead>
<tr>
<th>Immobile System</th>
<th>Joint</th>
<th>Many Joints</th>
<th>Completely flexible</th>
<th>Fluid</th>
<th>Field</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rigid System</td>
<td>Articulated shaft</td>
<td>Multi-joint steering</td>
<td>Flexible steering</td>
<td>Hydraulic steering</td>
<td>Electrical steering</td>
</tr>
</tbody>
</table>

- Rigid System
- Partially Mobile Objects
- Maximum Mobility of Objects
- Multiple Mobile Objects
Principal TRIZ Tools

TRIZ offers a comprehensive series of creativity and innovation tools, methods and strategies. The main tools include:-

* **Contradictions**/40 Inventive Principles
* **Ideal Final Result**
* **Trends of Evolution**
* **Function/Process Analysis**
* **Use of Resources**
* **Scientific Effects/Knowledge**
* **S-Field Analysis**/76 Standard Inventive Solutions
* **Feature Transfer**
* **Subversion Analysis**
* **STC/SLP/System Operators**
* **ARIZ** (Algorithm for Inventive Problem Solving)

The tools shown in red can use information from nature. Hence TRIZ can drive biomimetics by organising and targeting information. Biomimetics can drive TRIZ with new “patents”.
Lessons

• It’s possible to learn from nature
• Huge changes in context are possible
• Most of nature’s design can be (carefully!) dumped
• Biologists are essential to differentiate functions
• A virtuous circle exists between bio- and tech-
• Bio-solutions have control built in to the material
  and the design
Successful biomimetics

Biologist required who must be able to . . .

. . . identify essential functions
. . . recognise evolutionary baggage
. . . recognise developmental baggage
. . . recognise metabolic baggage
. . . talk to non-biologists
Recommendations

• True interdisciplinary team needed
• The biologist must be there at all times
• Expect unexpected solutions
• Recognise that many solutions are not used by nature . . .
• . . . and that natural solutions may be used non-optimally
• Frame problems as FUNCTIONS