

HOW TO STEAL FROM NATURE

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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

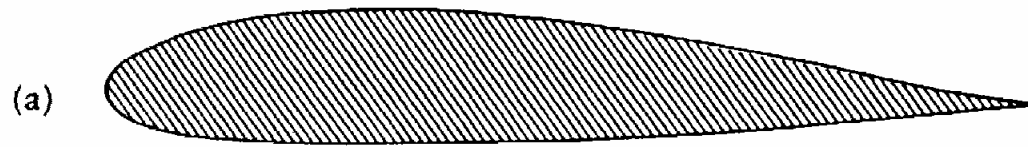
? ? ? ? ? ? ? ? ? ? ? ? ? ?

- 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?

Biology | Technology

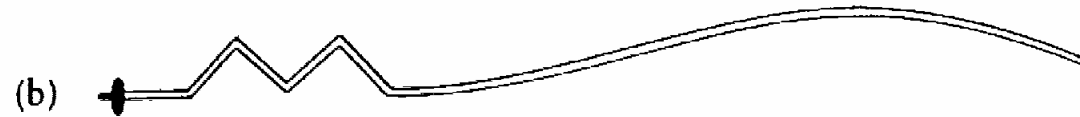
Wet, flexible	Dry, rigid
Heterogeneous	Homogeneous
Anisotropic	Isotropic
Curved	Rectilinear
Non-metallic	Metallic
Factory <<< product	Factory >>> product
Multifunctional	Limited functionality
Self-repairing	Repair or replace

1.0 meter



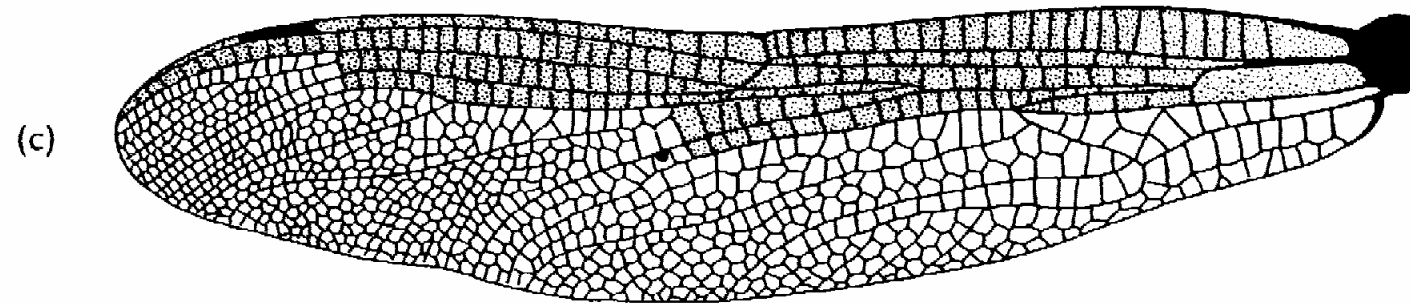
Aircraft

1.0 centimeter

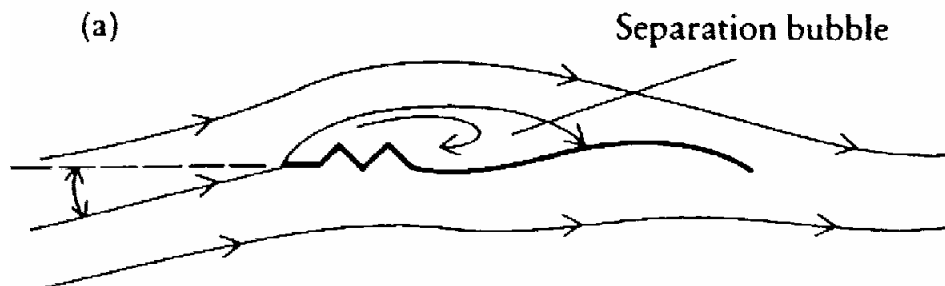


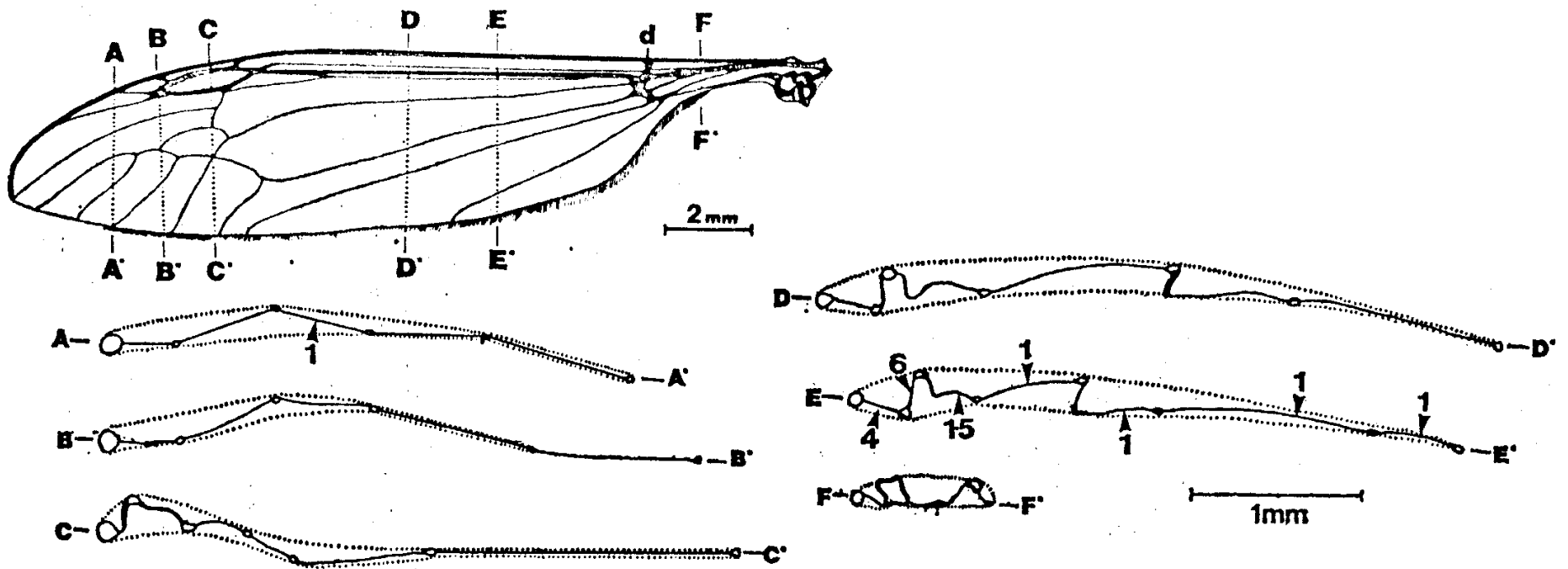
Dragonfly

5.0 centimeters



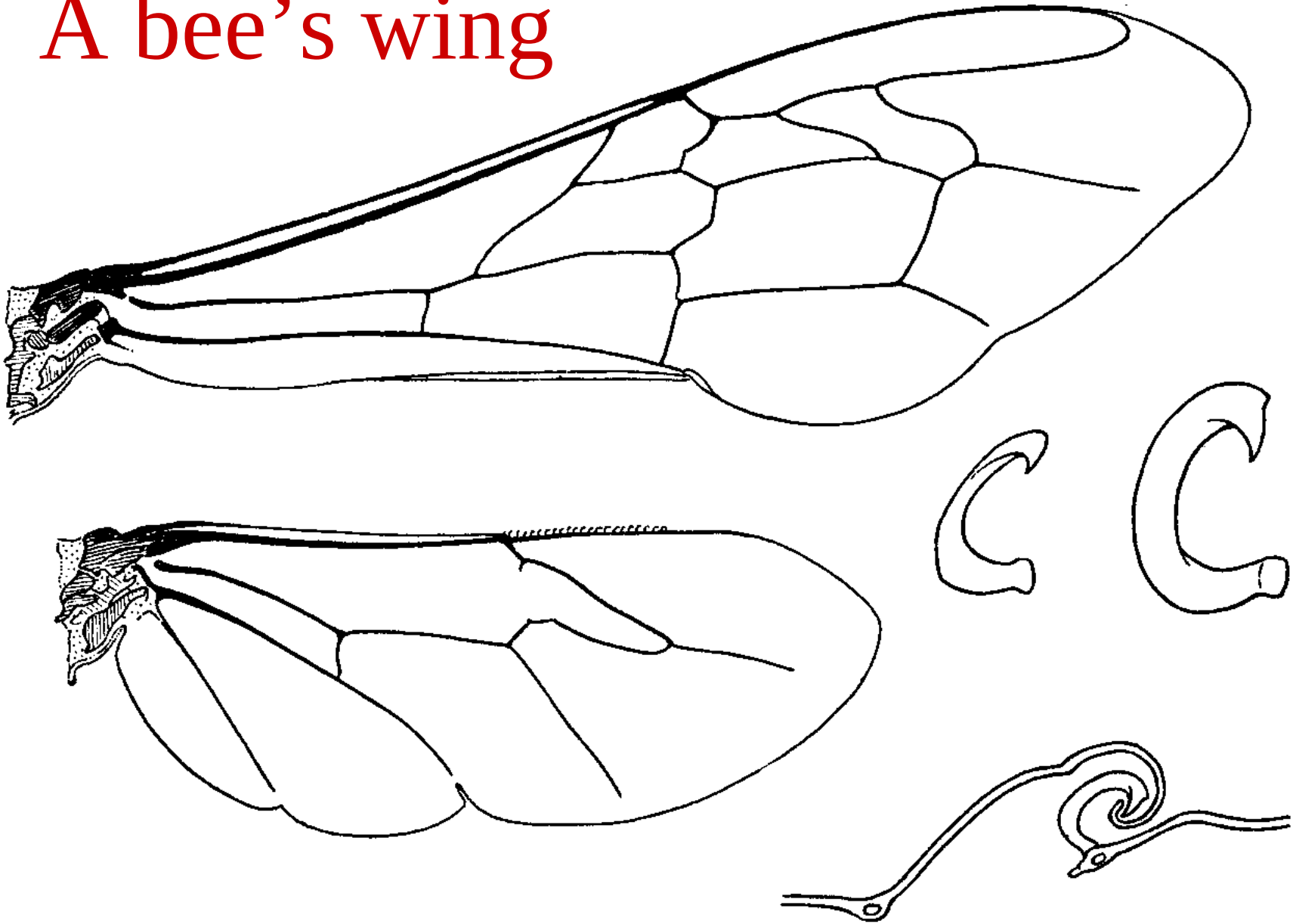
(a)

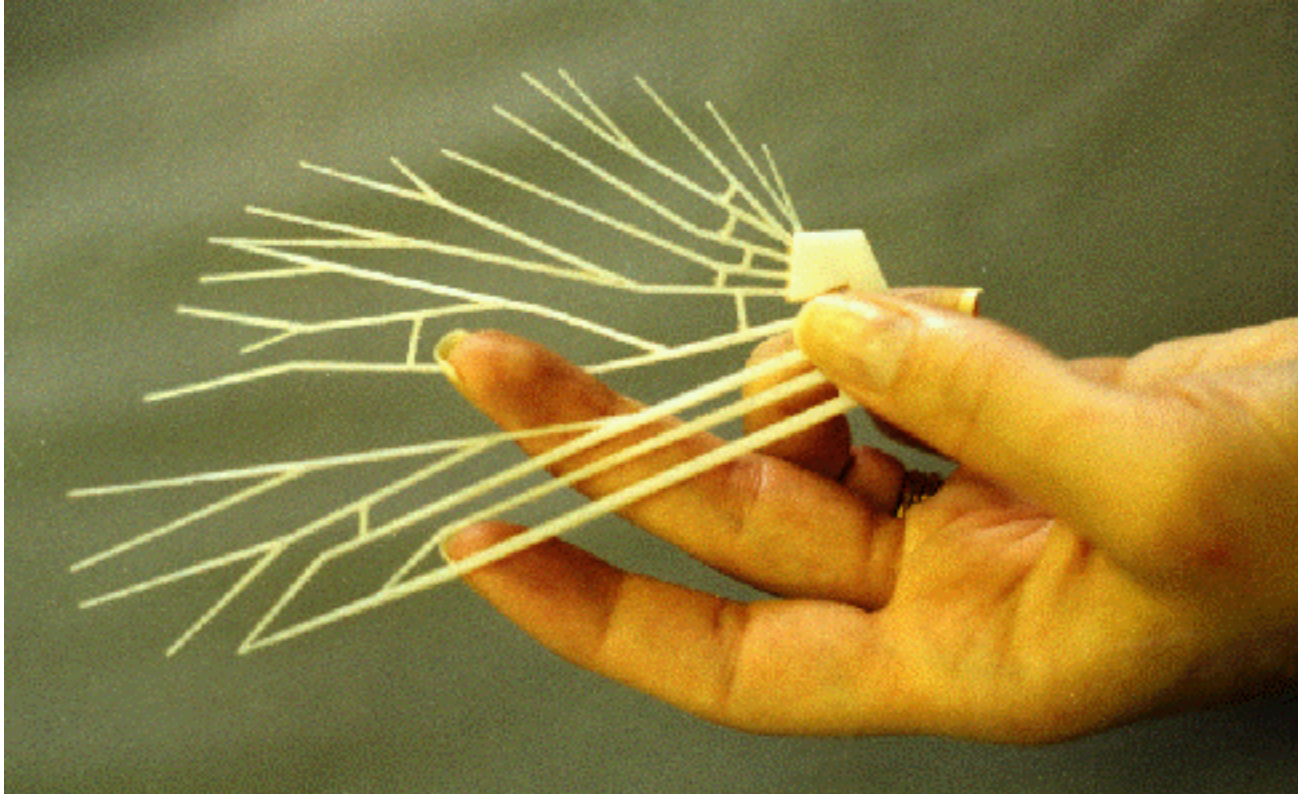




Sections through the wing of a tipulid (crane fly)

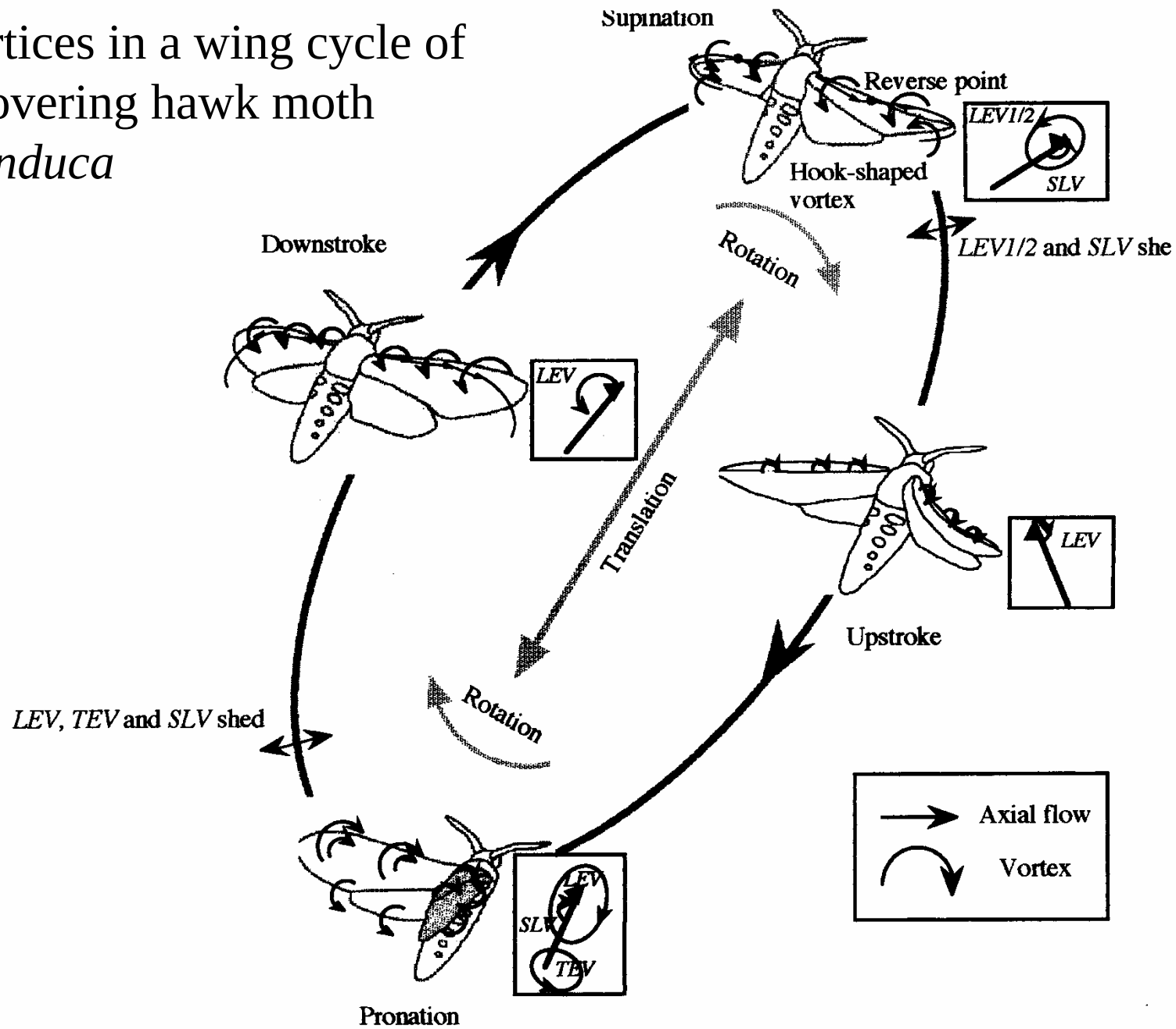
A bee's wing





Framework for a lightweight wing
(What's wrong with it?!)

Vortices in a wing cycle of a hovering hawk moth *Manduca*



The power problem

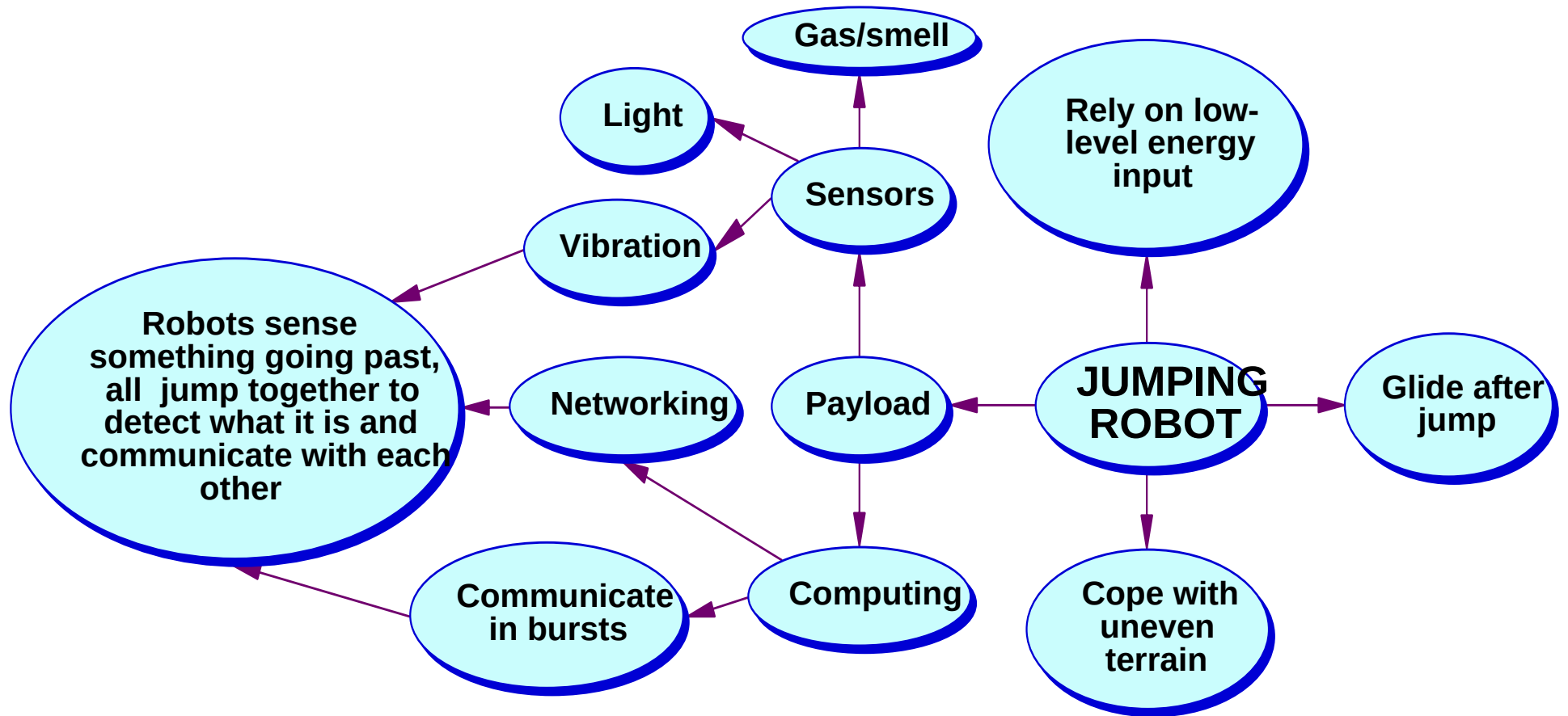
Continual flight needs continual power

Intermittent flight could use low grade energy
and store it . . .

. . . then release it suddenly.

power amplification

Jump-and-glide



Height of a jump

Kinetic energy on leaving the ground: $E_k = \frac{1}{2}mv^2$

Potential energy at the top of the jump: $E_p = mgh$

$$\therefore mgh = \frac{1}{2}mv^2$$

Height of the jump: $h = \frac{v^2}{2g}$

The height of the jump depends linearly on the power available

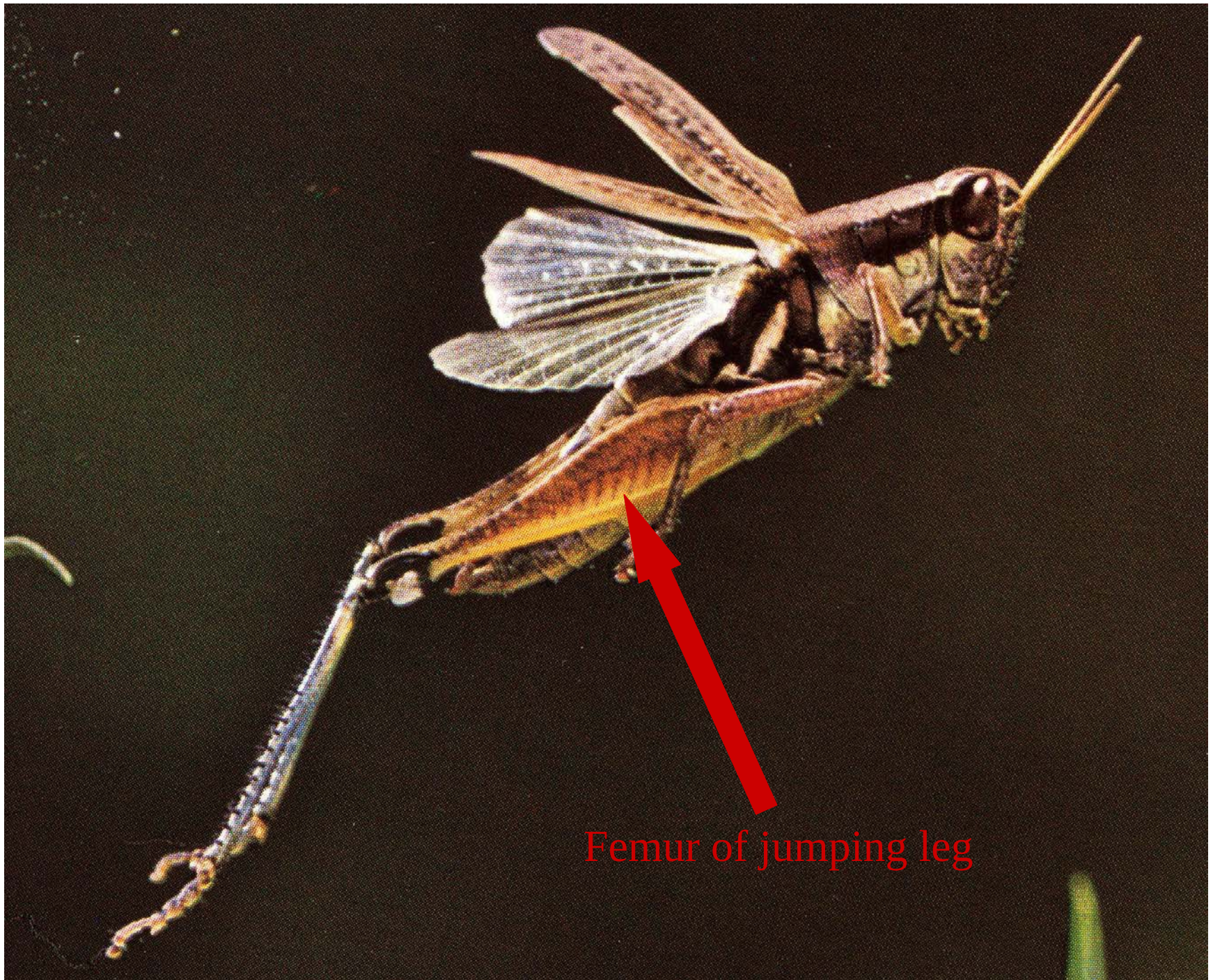
100 g JumpBot

jumps to 1 metre

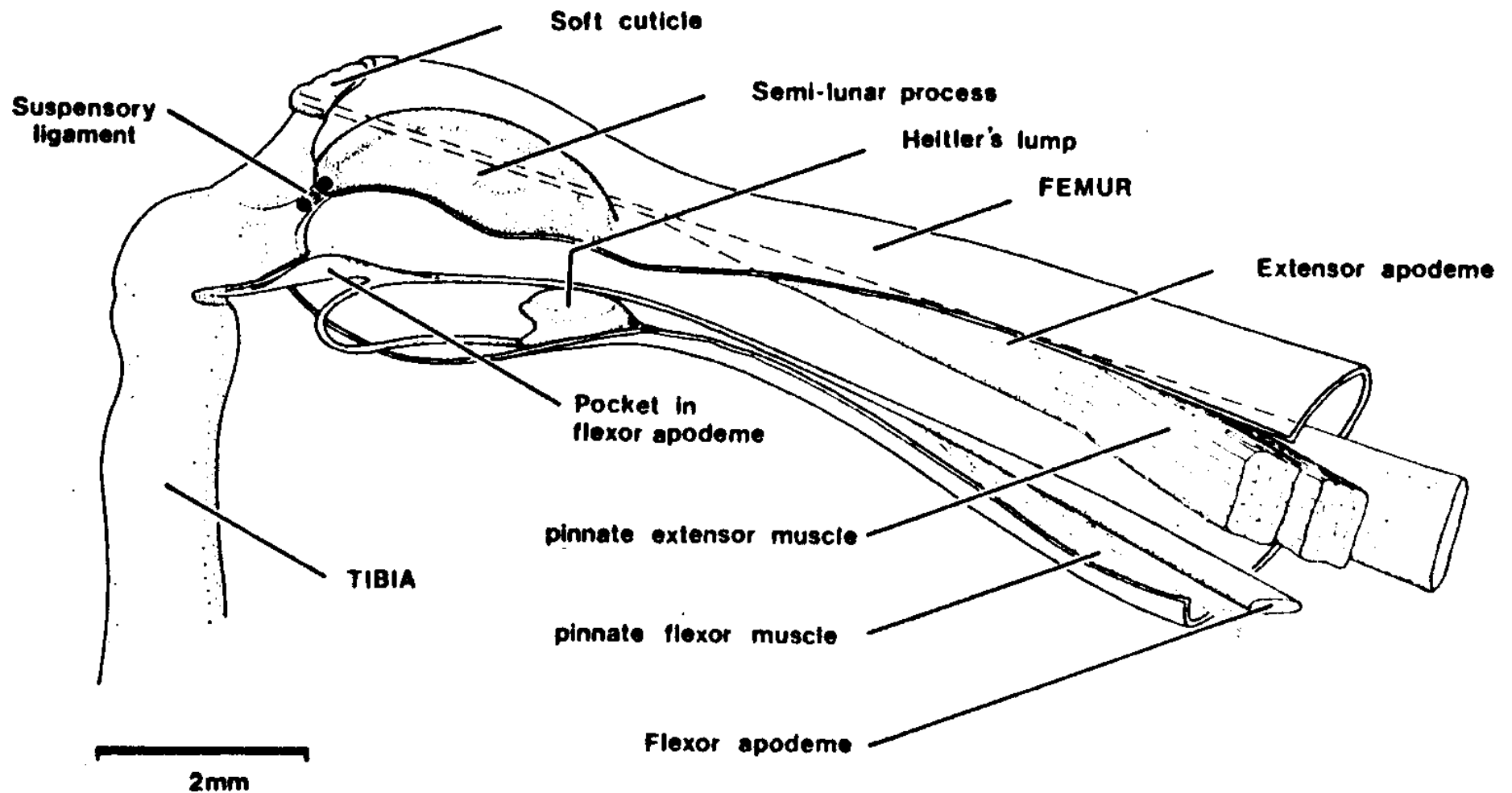
(assumes 10% spring efficiency)

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

n.b. - the chassis will store some of the strain energy



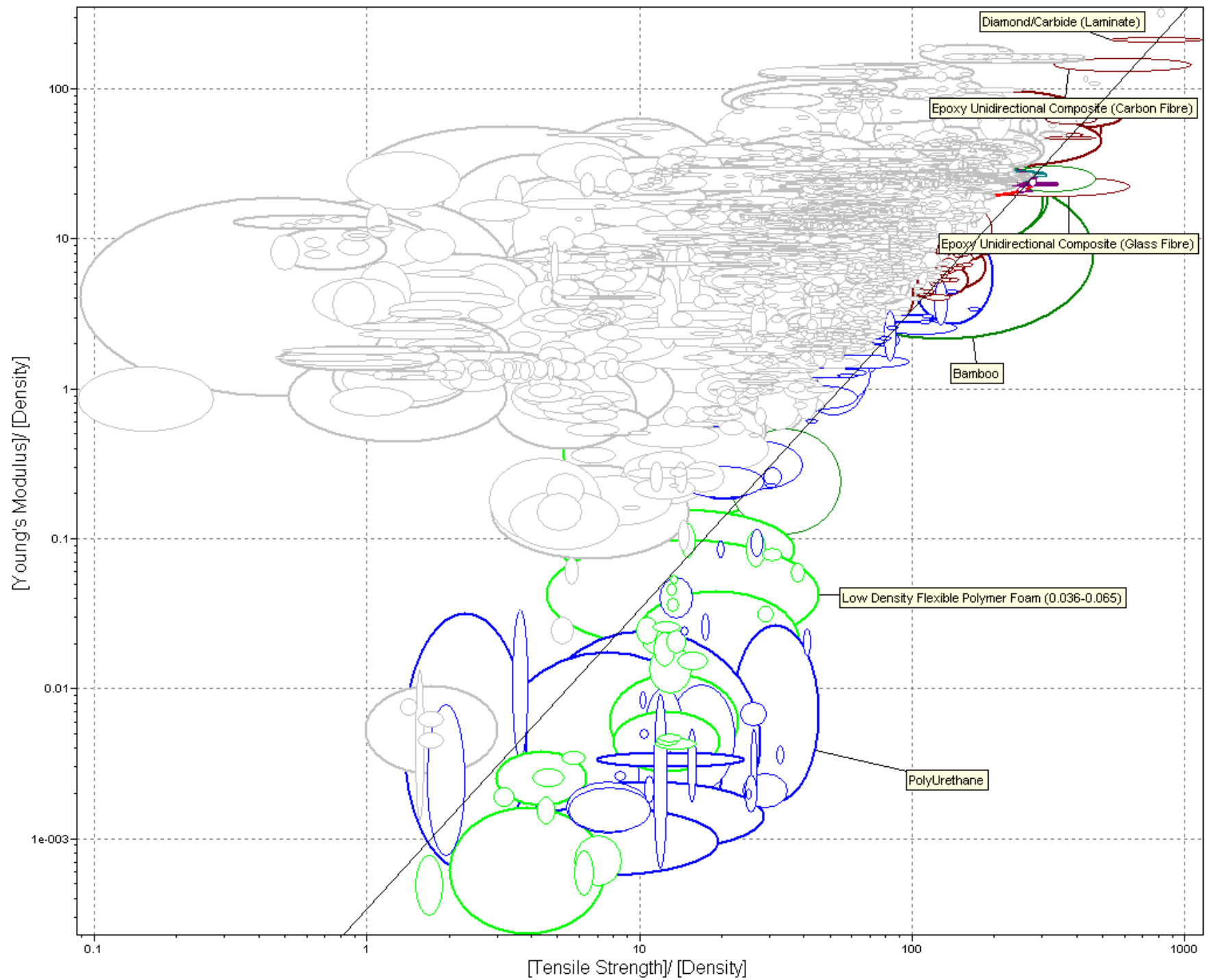
Femur of jumping leg



Bennet-Clarke HC (1975). *J. Exp. Biol.* **63**, 53-83

Mechanical properties of skeletal materials

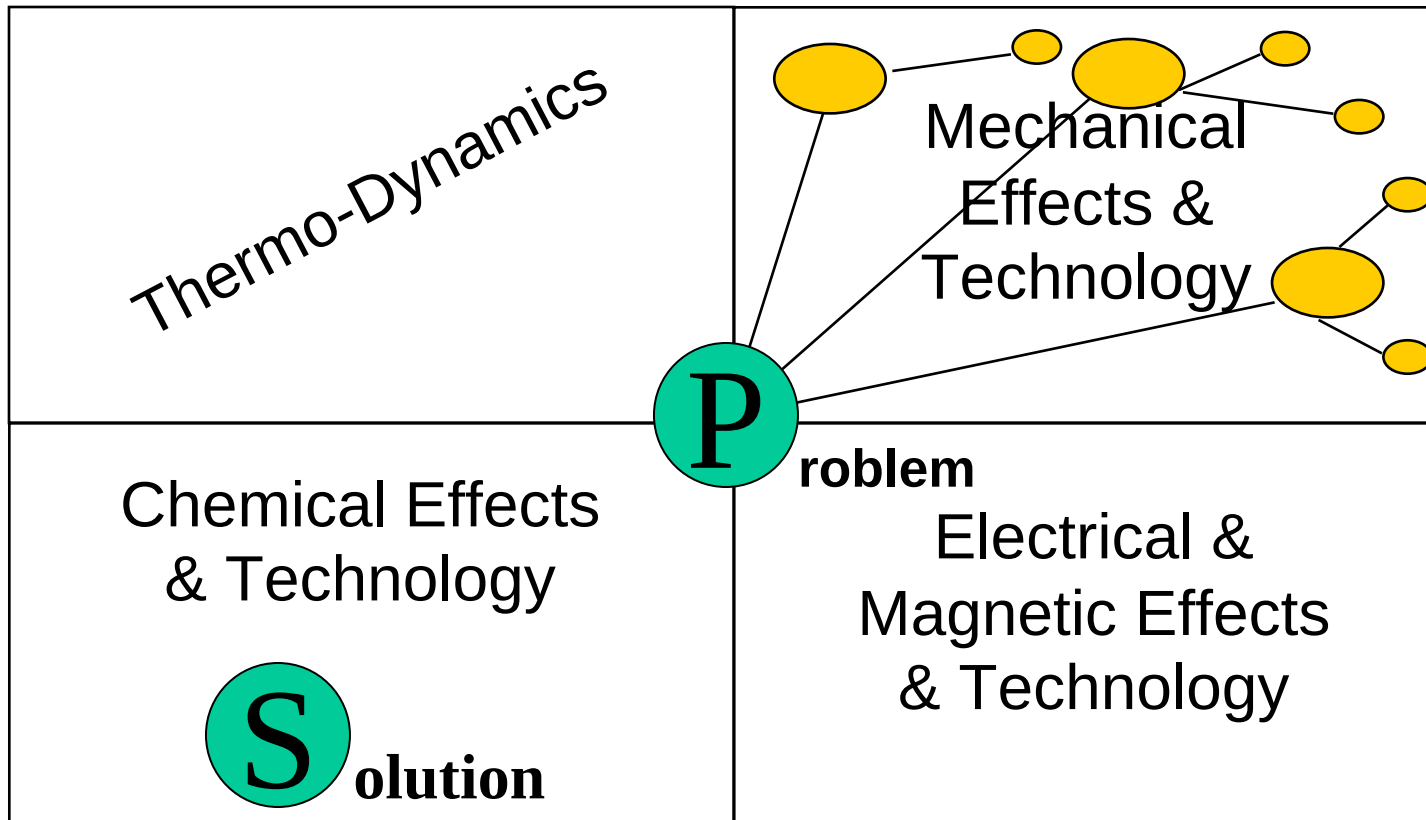
	Locust tendon	Mammalian tendon	Resilin	Steel
Strength (MN/m ²)	600	100	3	450 - 2700
Stiffness (MN/m ²)	20000	2000	2	210000
Elastic strain (%)	3	> 10	> 140	0.45 – 1.3
Energy storage (J/g)	9	> 5	> 2.1	0.125 – 1.4



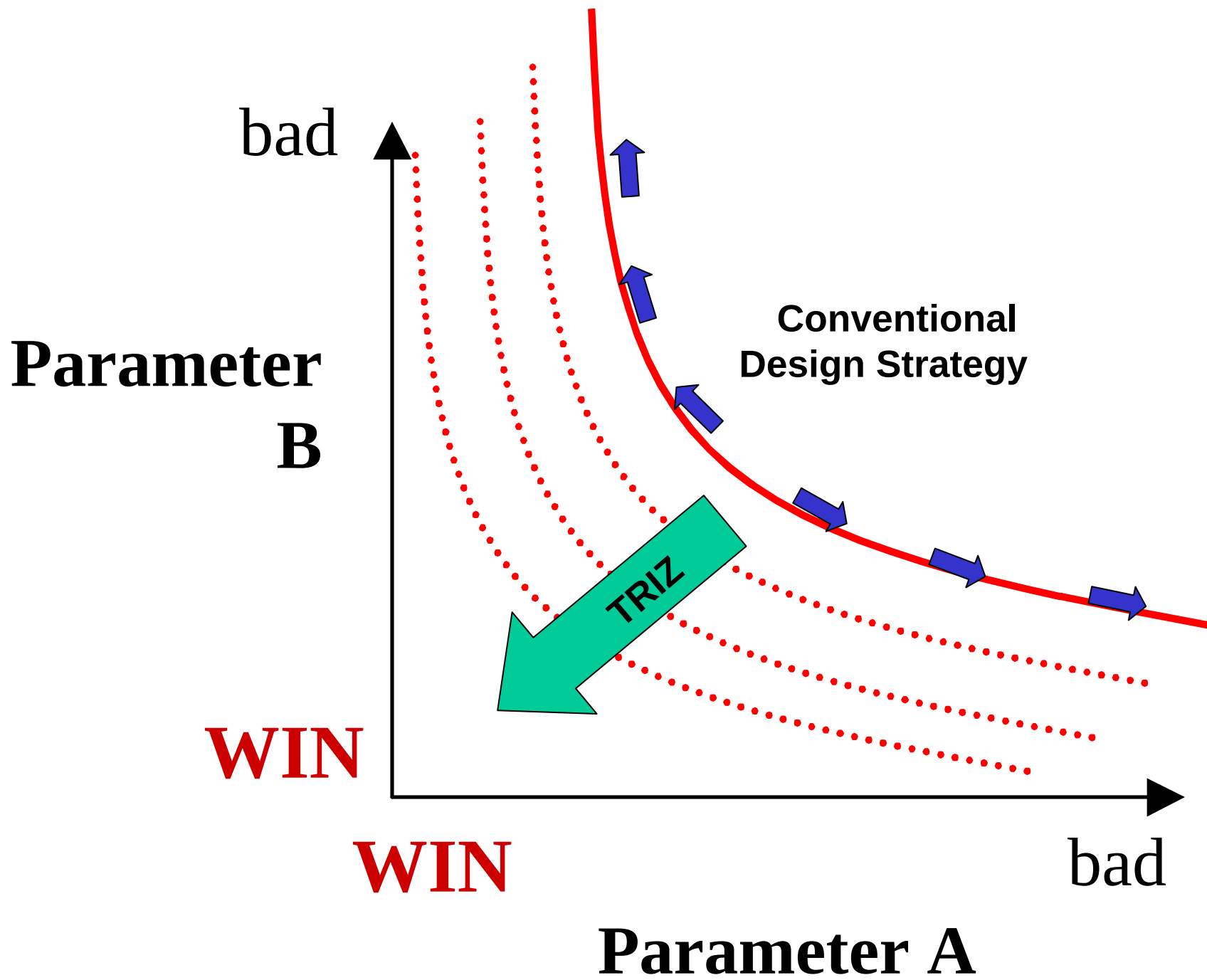
TRIZ

Teoriya Resheniya Izobreatatelskikh Zadatch

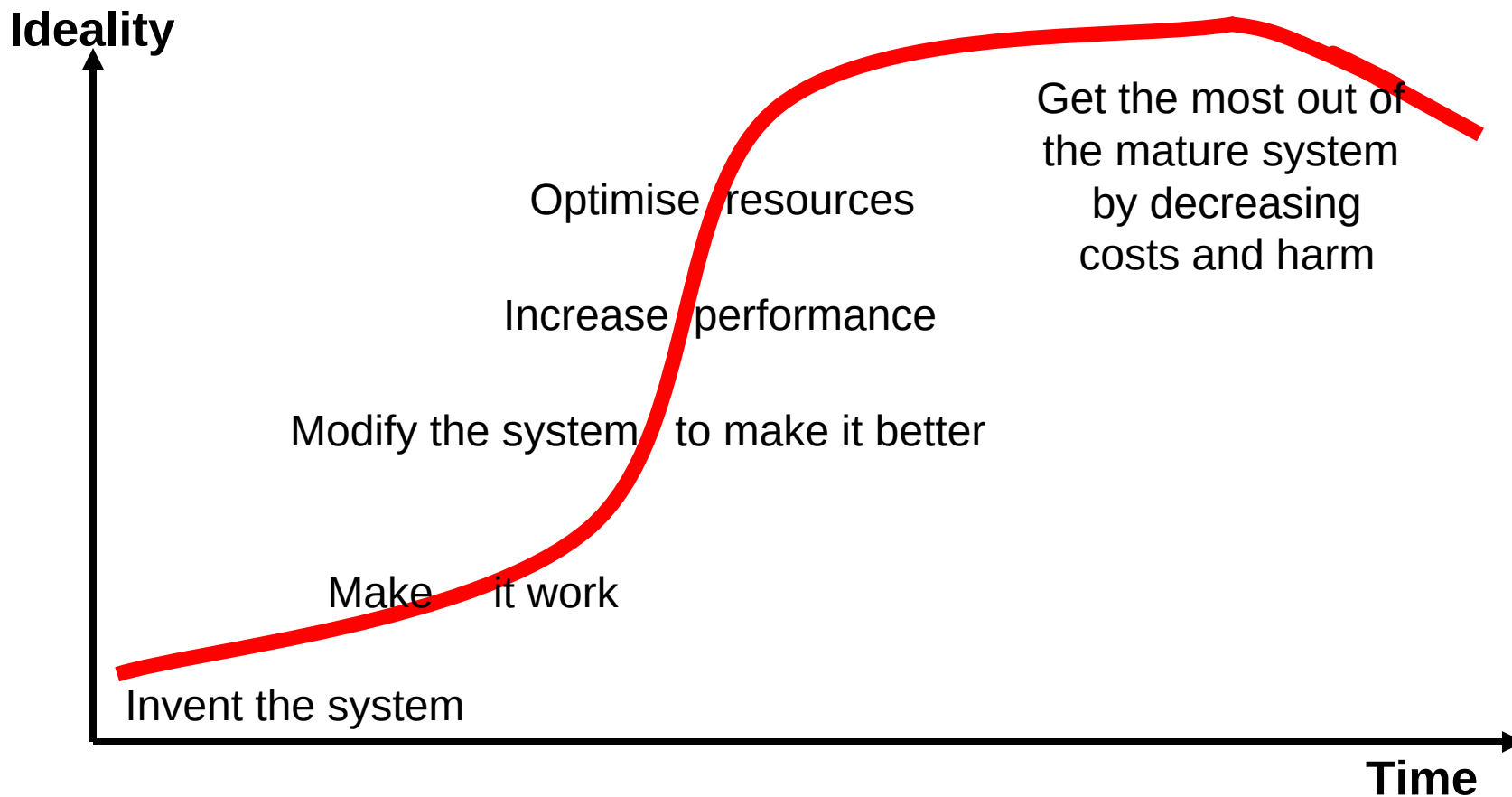
Теория Решения Изобретательских Задач



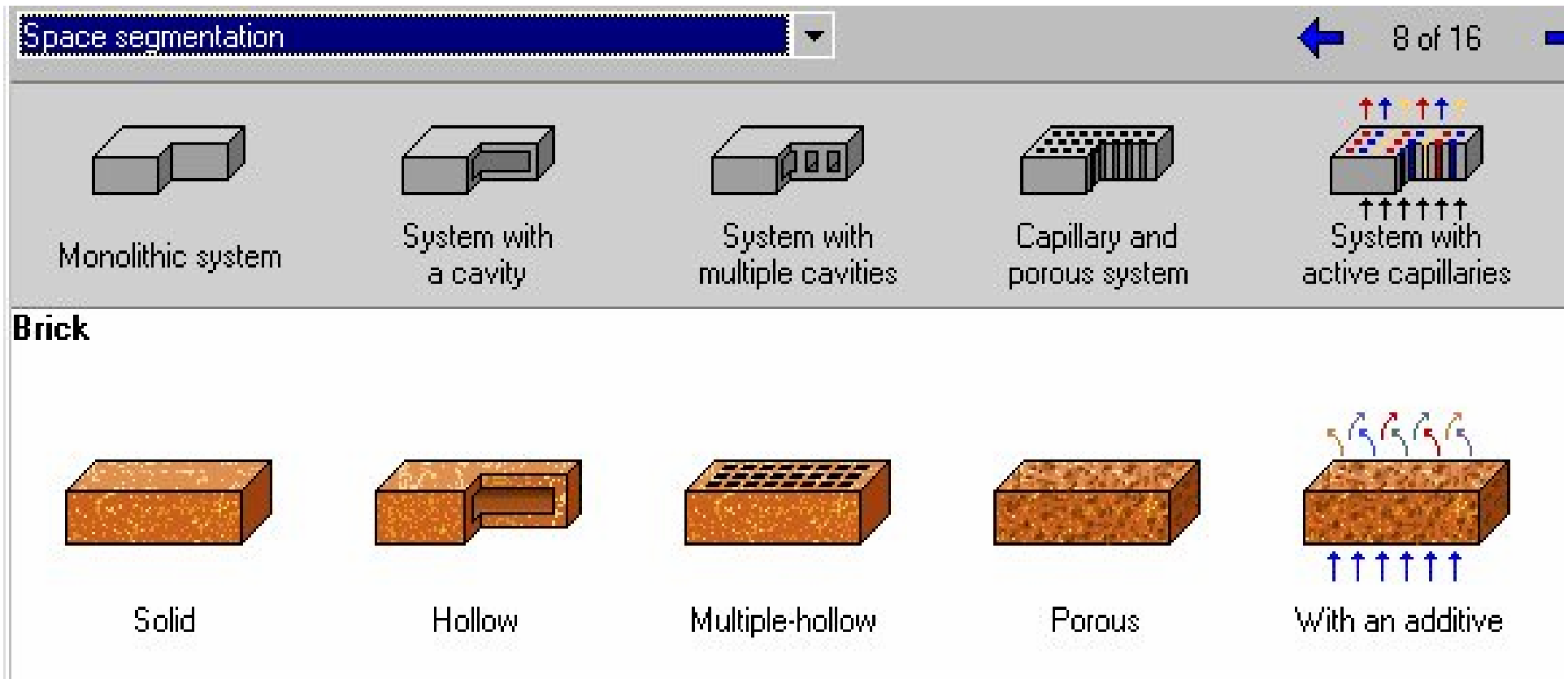
Has your problem already been solved by someone else?



Increasing Ideality



Space segmentation



With permission from Invention Machine- Trends example from TechOptimizer Software

Dynamisation

increasing degrees of freedom

Immobile
System

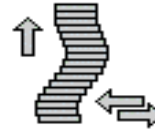
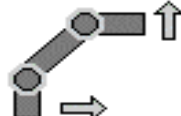
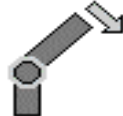
Joint

Many
Joints

Completely
flexible

Fluid

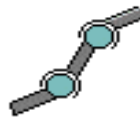
Field



Rigid



Articulated shaft



Multi-joint steering



Flexible steering



Hydraulic steering



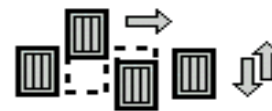
Electrical steering

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**