Nature as Inventor.

Billions of years of freely available innovation

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Efficiency versus Waste

General principles in Biological technology:

1. Assumes shortages and strives for efficiency
2. Works cyclic, recycles everything, thus no waste only raw materials
3. Uses only small amounts of energy, tolerates no extremes and thus operates within small bandwidth's
4. Organisms and their manufacturing are optimised for energy efficiency
5. Direct and indirect use of readily available energy like sunlight or chemical energy
6. Uses clean, renewable and sustainable energy sources
7. Uses only small amounts of material through lightweight materials and integrated constructions
8. Everything has a function, form follows function
9. Organisms of sufficient quality with a function in the ecosystem

Evaluating versus Planning

General principles in Biological technology:

1. No deliberate development of organisms. The only goals is "survival of life".
2. Evolution by natural selection
3. Errors are beautifull accidents
4. Shit happens
5. Organisms use a lot of feedback and feedforward
6. Only small changes (sometimes leading to big changes)
7. Slow development
8. New biological systems not necessarily replace old systems, both systems coincide.
9. Technology is about evolving species
10. Good is good enough
11. Organism have to function adequately, or else they cannot survive
12. No deadlines, it is never completed

Flexibility versus Rigidity

General principles in Biological technology:

1. Organism are adaptive to changing conditions
2. Organisms are self-repairing and thus have a long lifespan
3. Organisms are self-cleaning
4. Organism can learn
5. Organisms are unpredictable
6. Organisms are fault-tolerant
7. Diversity and redundancy are desired and guarantee resilience
8. Changes the environment but also adapts to the environment
9. Flexible
10. Cannot re-engineer

Local versus Global

General principles in Biological technology:

1. Uses only locally available materials
2. Local transport
3. Organisms are not independent they are part of an ecosystem in which they operate
4. Keeps its own environment clean
5. Does not use toxics (except sometimes as a weapon)
6. Each organism has a clear niche of its own. Possible changes are slow.

Recipes versus Ingredïents

General principles in Biological technology:

1. Uses a very limited number, readily available materials, using many recipes
2. Uses only a few metals in low quantities
3. Creates from simple parts , using simple rules, very complicated fractal structures using hierarchical construction and self-assembly
4. Technological challenges are solved using structures and information.
5. Biological factories build products larger than the factory itself
6. Easily scalable
7. Relatively easy to combine/merge different properties
8. Relatively easy to reconcile contradicting demands
9. Integrated parts
10. Multifunctional parts reduce material usage

Recipes versus Ingrediënts cont.

1. The whole is more than the sum of its parts
2. Operates at environment temperature and pressure
3. Mostly slow processes
4. Chemical reactions take place in water
5. Water is the main raw material
6. Optimises the whole
7. Designs for strength and toughness
8. No finishing operations thus less waste
9. Distributed systems, many small ones make a big one. Resilience of the whole system.

Nature's Design rules

1. Be efficient
2. Be flexible
3. Ensure adequate quality
4. Take care of the environment
5. Generate smart structures

Be efficient

1. Use low energy consuming manufacturing processes
2. While producing use clean, readily available and renewable energy sources
3. The product should use as less as possible energy
4. Use as less as possible materials while manufacturing, use lightweight constructions
5. Make the product easy to recycle
6. Produce no waste or reuse it as raw material
7. Produce only useful products

Be flexible

1. Make the product adaptive, such that it adapts to changing circumstances
2. Make the product self-learning, self-repairing and self-cleaning for a long lifetime.
3. Make the product fault-tolerant such that it keeps functioning
4. Follow relevant developments and adapt the product/process to them
5. Errors are beautiful accidents
6. Diversity leads to resilience

Ensure adequate quality

1. Do not produce messes
2. Prevent finishing operations and thus waste
3. Good is good enough
4. Form follows function
5. It is never finished, thus keep developing.

Take care of the environment

1. Use locally available materials
2. Produce and distribute locally
3. Do not use harmful materials
4. Keep the environment clean

Generate smart structures

1. Use smart structures to give materials the desired properties
2. Limit the number of used materials
3. Use often occurring materials
4. Build integrated multifunctional parts
5. Let chemical reactions take place in water
6. Optimise the whole not the parts
7. Distributed systems are sometimes easier to realise and give more resilience

Animal behavior as inspiration

1. In complex societies of social insects many tasks exist
2. None of these tasks is centrally controlled. Coordination and decision making is decentrally. There are no inspectors.
3. The result is more than the sum of its parts
4. Remarkably the behaviour can be described bij a small set of simple rules.
5. A small set of simple rules can generate complex behaviour.

Optimalisation strategies for networks, logistics and planning

Strategies for big groups of self-organising insects have two successful characteristics:

- Flexibility by changing its behaviour fast when circumstances change and
- Robustness, because the target is met even when errors are made or individuals drop out

Wisdom of the crowd

Studies show that ants, when choosing their nest location, almost always chose the most optimal location. Individual ants might be irrational, ant colonies are rational.
Decentralised decision making gives robustness: optimal decision making (although individuals might be mistaken),

Wisdom of the crowd cont.

Wisdom of the crowd also functions for groups of people. For instance when estimating the weight of a cow. On average the group comes up with a reasonable number although some individuals present very unrealistic numbers.

Cooperating robots

Swarm intelligence and self-organising social insects are interesting study objects. Many small and cheap robots working together can achieve more than a few large and expensive robots. Decentralised self-organisation is, especially for large numbers of robots, more suited and delivers flexibility and robustness.

Insights for cooperating teams, corporate strategies and organisation types

1. Cooperating in innovation teams
2. Corporate strategies
3. Control stress

Cooperating in (innovation) teams

Desert ants are a nice metaphor for teamwork. Innovations are mostly performed in multidisciplinary teams. Each has its own role to perform, for instance:

1. Inspirator (creative)
2. Curator (systematical)
3. Thinker (analytical)
4. Tinkerer (do)
5. Entrepreneur (deciding)
6. Supporter (social)

Because these roles are performed by different characters, frustrations are always present. A meaningful intervention is to let the participants acknowledge the roles of others as being very valuable. They need each other to achieve the goals.

Corporate strategies

Biological species and companies have one similarity the will to survive ("survival of the fittest"). Only species which (accidentally) adapt to new circumstances or which are so flexible that they can operate in different circumstances will survive. Lessons for companies desiring a long life are:

- Innovate continuously and
- Detect upcoming relevant changes early
- Respect adequatly to upcoming changes
- Flexibility and adaptivity, to execute the needed changes fast
- A vision to not only survive in the short term but also in the long term

Corporate strategies cont.

Organisms have developed many survival strategies. An inspiring question is which strategy fits a company best.

- Generalist,
- An opportunistic predator ,
- Cooperating wolves ,
- A niche player. A panda bear continuously living on the edge.

Control pressure

A swarm of starlings does not have a centralised control. A group only following a leader is vulnerable for bird of preys. Only if the leader reacts does the group react.
In a self-organising swarm everyone looks for danger and after each other. When a starling sees a bird of prey it will react and because its neighbours watch it, they will react too. This response will propagate through the swarm although most of the starlings will never see the bird of prey.