The evolution of a design

genes, combinations, mutations and a selective environment

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1 THE TASK OF DESIGN

Introduction

A design process stretching over days, weeks or months does have something in common with the evolution of life we think to know from the remains of the past 3 billion years.
That is valid for design processes taught at the Faculty of Architecture UTDelft (where, as a professor Technical Ecology and Methods I already for ample 20 years I found an inspiring job), but it is probably also valid in any other design process.
Evolution biology may be an inspiration for effective phasing the design process.[a]
And for me designing is the crucial characteristic distinguishing humans from animals.

Probability (the genetic material)

The title of this lecture is its summary. So, it does not concern a supposed design of evolution but the reverse, the genes, combinatorics, mutations and the environment of a design process.
How did humans after 3 billion years of evolution, since 3 million years of their existence after 3 thousand years appear to be able to develop so fast and so many new possibilities? 'Developing new possibilities' is my definition of design here. So, it does not deal with developing truths or probabilities, but possibilities. Formulating truths and probabilities following or simulating the existing reality

[a] See also Steadman, Philip (1979, 2008) *The evolution of designs* (New York) Routledge

accurately is the task of science. And, anything true is also probable, but not anything probable is also true. Truth is a subset of probability. Probability *contains* truth.

Improbable possibilities
Subsequently, what is true or probable is per definition possible, but not everything being possible is also probable, let alone 'true'. Probability on its turn is a subset of anything possible. Possibility *contains* probability. Therefore, science is a part of designing by which people distinguish themselves from animals. Science itself is designed by humans after all. So, science supposes design, not the reverse. From the standpoint of a scientist a designer is even a liar, because what (s)he draws is not true or probable. However, it is *possible (see Fig. 2)*.

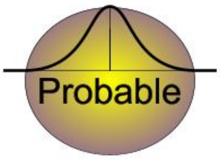

Fig. 1 The task of empirical research

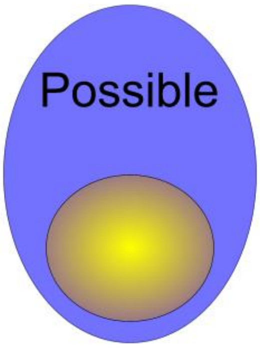

Fig. 2 The task of technical design

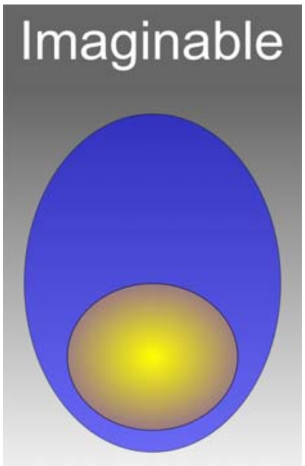

Fig. 3 Art's task

Imaginable possibilities
What is not possible still may be imaginable (see *Fig. 3*). Think of the drawings of Escher, science fiction films or stories about travelling in time. I concern exploring and extending the imaginable as a task of art.[a] That impact of art on science may be underestimated.
In his anatomic drawings, Leonardo da Vinci had to make an imagination of the heart's function before a century later Harvey could imagine the blood circulation, then investigate and demonstrate it.
And, there are also more abstract imaginations that could open our eyes.


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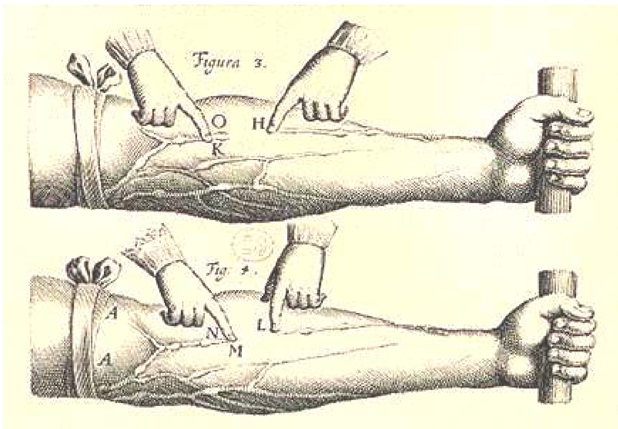
Fig. 4 The heart, drawn by Leonardo da Vinci in 1509

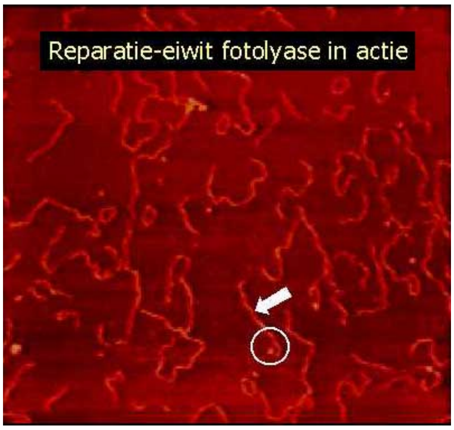


Exercitatio Anatomica de Motu Cordis et Sanguinis in Animalibus.
Fig. 5 The proof of blood circulation Harvey in 1628

Making imaginable
Visualising a process makes processes imaginable. We become aware of them. Imaginations subsequently invite to aimed further investigation. For example, there is a spectacular cinematic

[a] Jong, Taeke M. de (2008) *Art's task for science* (Zoetermeer) Opening course Art Science 2008-2009 http://team.bk.tudelft.nl/ > Publications 2008

representation of the way genes are repaired by inspection-proteins (fotolyase). They walk along the strands and call on helpers (cutters, copiers, fitters) if necessary (see *Fig. 6*). I became aware of that amazing process by the film shown at the farewell speech in 2002 of cell biologist prof. Bootsma in Rotterdam.



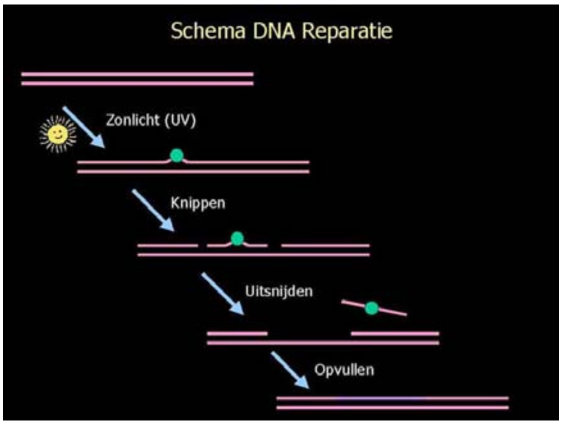


Fig. 6 Repairing proteins …

Fig. 7... their global working

In the mean time we can all the time better understand how it works (see *Fig. 7*).
The transfer of that genetic code into structures and processes further on in the living cell requires subsequently more imagination and investigation.

Unthinkable possibilities?
The question if anything possible is also imaginable is more difficult to answer. And, if they are thinkable, are our languages or drawings sufficient to communicate them? According to Wittgenstein, the question if there are unthinkable possibilities at all can not be answered. We only can determine that boundary of imagination if we can imagine the unimaginable at the other side of the boundary. And, that seems absurd.

Imaginable possibilities
However, more and more becomes imaginable. So, the boundary of imagination seems to shift outwards. At the 2nd of March 2009 I had the honour to chair Wouter Lems'[a] defence of his doctoral thesis supervised by Prof. Schoonman about the still inconceivable efficient energy conversions in the living cell. From that we could learn how energy losses disappearing as heat in artificial conversions could be utilised anyhow (exergy).
We may know much about the living cell, but relatively little of its complex reactions we can imitate in a test tube. After all, the living cell (isolated from the entropic outside world) creates ideal conditions for every single step of these complex reactions. In higher organised cells the ever different conditions required for these reactions (particularly eukaryotes) are separated and selectively connected (as rooms with doors in a house) by membranes.

Ever more becomes imaginable
How the genes with their messengers put these membranes on place, get the components of the reactions with their catalysts in time at the optimal place of their reaction and transfer the results into the next step has become in the mean time roughly imaginable.[b] The building stones of membranes (phospholipids) do have a great affinity to each other. If you shake them together in a test tube, you can see how they form membranes spontaneously.
The proteins embedded in the membranes mainly have an extra piece of approximately 20 amino acids, the address by which the visiting protein finds its proper location in a specific membrane. Complex reactions are often executed by complexes of proteins within the membrane or outside of it. Chaperone-proteins help the amino acid chains to fold up in the right spatial way. But, as said before: we know too little the details to imitate that in a test tube. Imitating outside the cell requires ongoing detailed investigation and that would still be too expensive for an industrial process.

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[a] Lems (2009) *Thermodynamic explorations into sustainable energy* conversion (Delft) DUT thesis
[b] With gratitude to Prof. Kuenen. He corrected my outdated image of microbiology in this and the next paragraph. Some passages contain his proposed text.

To let nature work may be cheaper than doing it yourself
So, in the factory we let intact fungi (for instance to produce penicillin) or bacteria (for example anammox, see below) do the work by shaping the right external conditions.
For example, nature found in the millions of years of its evolution numerous solutions for recycling. Many of them we still do not know. However, sometimes a new natural solution is discovered. The Delft research group of prof. Kuenen[a] identified the anammox bacteria[b]. These bacteria appeared to be able to remove very environmental friendly nitrogen in ammonia from polluted water. This seemed to be impossible for a long time, but after this discovery it is applied more and more in the industry. That discovery has outdated a part of what we learned at high school and thought to understand about the nitrogen circulation. We did not yet have a proper image of it.

The task of designing
However, mainly this is still more a matter of discovery than of invention, though genetic modification (an artificial mutation, for example to produce insulin) comes close to invention. What is designed anyway is shaping the right conditions. The rest is chiefly applying the existing possibilities of nature. However, the wheel-with-axis is an invention because it did not occur in nature before humans appeared. The role of electricity in our society is also different (higher tensions, current intensities) than what we discovered in nature in the mean time.
The task of designing, and thus of a University of Technology, is exploring new possibilities or more limited: executable possibilities. That limitation occurs by selection in an economic, cultural and administrative environment.

2 COMBINATIONS, MUTATIONS AND SELECTION IN SCIENCE AND DESIGN

Science as a design
So, the task of design is formulating possibilities just different from what is probable, otherwise it would be empirical prediction. For a matter of fact, that implies designing *contains* science and not the reverse. Science can not contain design completely, because it is itself one of the designs humans have produced.
However, designing *uses* scientific results (the transferred and selected ‘genetic material’ within which the experience of preceding generations is stored), but that is not its core task.

Difference in selection
Designing does not produce predictions. It produces improbable combinations and mutations extending empirical material with artefacts. These are selected by the market or the government.
In science however, the selecting public is further limited to colleagues (peers). There, combinations are restricted to comparable quantities (with common denominators) or qualities. The mutations are shifting paradigms doing more justice to existing empirical material.

Combinatorics
Architects and urban designers that are too much bound to examples (precedents, the genetic material of architecture and urbanism), will not produce other new ideas than combinations of what already exists. And, designing is more than combining. However, combining well-known categories and types on itself may produce a ‘combinatory explosion’ of new possibilities from which the public could choose if it would have time enough to do so.

Possible variants to distribute building materials over locations
For example, if one divides an architectural design in locations where matter or space could be placed, than the number of imaginable variants depends primarily on the number of different materials available (m) and the number of locations (l) one would like to distinguish, according to the simple formula m^l.
With a great number of materials and in particular locations, that produces very many imaginable variants.

[a] Kuenen (2005) Microbiologie is mijn hobby (Delft) TU-Delft, Faculteit Technische Natuurwetenschappen, farewell speech.
[b] Caulil (2006) Anammox the cleaning creature that could not exist (Delft) Outlook1

More categories distributed over locations

However, material (m) is just one of the categories ($c \supset m$) one can think of and distribute over locations. That becomes particularly clear at another level of scale (for example urbanism). Then, it does not only concern materials, but many other categories (c) drawn on different maps (layers). There are categories of form (for example building height), structure (connections and separations for example embedded in material and its working) or function (use). These categories combined multiply the number of alternatives another time until c^l.

A combinatory explosion of variants

The number of combining legend-units of an urban plan varies from a minimum of 2 (for example built-up and non-built surfaces see *Fig. 8*) until ca. 80. The number of locations over which these can be distributed is very large. Suppose there are 10 000 square meters (one hectare) and all of them could get a different destination. That number of variants (80^{10000}) I could not depict here or even write down (see *Fig. 9* for a moderate beginning).
Balancing that number of variants goes beyond our imagination, though we can summarise that number itself in a formula (multiply 80 ten thousand times with itself''). How could we ever make an aimed selection from such a great number of variants? Nature does so by millions of years of trial and error.

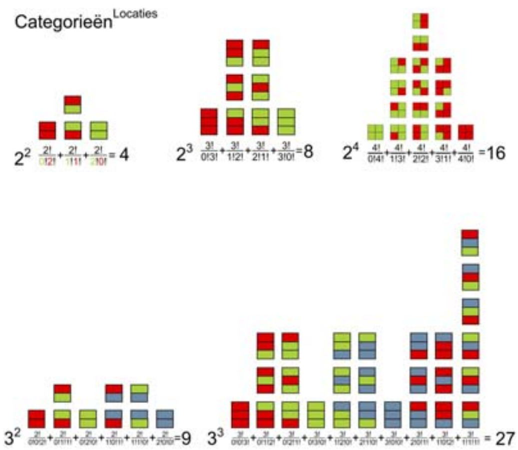


Fig. 8 Possible variants form 2 or 3 categories (for example built-up, greenery and water) at 2, 3 or 4 locations

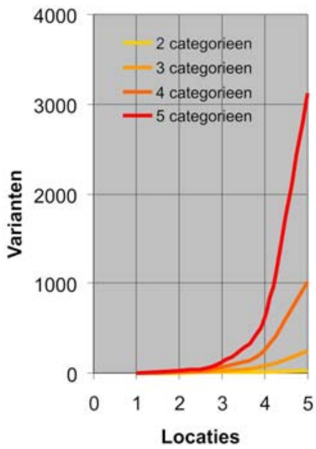


Fig. 9 Combinatory explosion of possibilities until 5 categories and locations

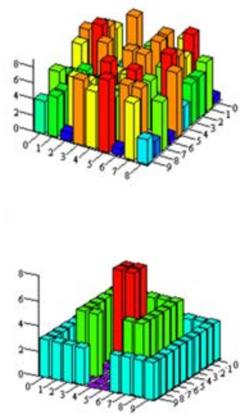


Fig. 10 Two of 8^{100} variants: 'Wild living' and 'Soviet complex', based on 1 until 8 stories

Selection of variants

However, most of the variants (for example an arbitrary heap of bricks) are clearly useless.
But, even after deduction of these useless variants very many useful variants remain between which a balanced choice might take years.
So, before the public may select, the designer makes (conscious or not) a selection based on her or his experience: the repertoire and portfolio on which (s)he is selected herself or himself.
That experience concerns examples and hidden suppositions transferred to her or him in the education (with its own necessary selections).
Before I go into my doubts about these usual suppositions and the necessity of mutations, I firstly would like to make some remarks about a difference of categorisation in design and science.

Incomparable categories in design

The architectural or urban design namely has to combine also scientifically incomparable categories such as 'useful', 'durable' and 'beautiful', as the oldest known architectural writing from before our Christian era, the one of Vitruvius, already stated. Something can not be 'more useful than durable', 'more durable than beautiful' or more 'beautiful than useful'. These are scientifically incomparable categories not to be balanced by measuring or calculating. Such comparisons are rather the domain of poetry. Poièsis is for a matter of fact Old Greek for 'the work of making', a beautiful word for 'design'.

Combinations of genetic material
If you cross a horse and a donkey you get a mule not able to reproduce itself.
The genetic material is not fertile, not durable in a longer term than one single lifetime. It shapes the end point of a short line of evolution. But, a mule is more useful than durable and in the short term more durable than beautiful. It is mainly a human product using genetic material and aimed combination. However, it is not yet a design, though it is a combinatory unique event not to be generalised into great probability.

Combinations of incomparable categories
The discipline of design combines more scientific incomparable categories, not relatable by measurements and calculations to reach an optimum. 'Blue houses' is a category 'square houses' as well, but a house can not be bluer than square, let alone more blue-square than red-round. In architecture we do not name blue, square houses a category; we call it at type, a combination of incomparable categories, for example colour and form. Typology is an important craft in architecture. In the same way an amphitheatre is a type. It is a theatre and it is half-round. It is a not necessary combination of function and form. After all, there are theatres not being half-round and there are half-round buildings not being a theatre. So, these two do not belong to the type 'amphitheatre'.

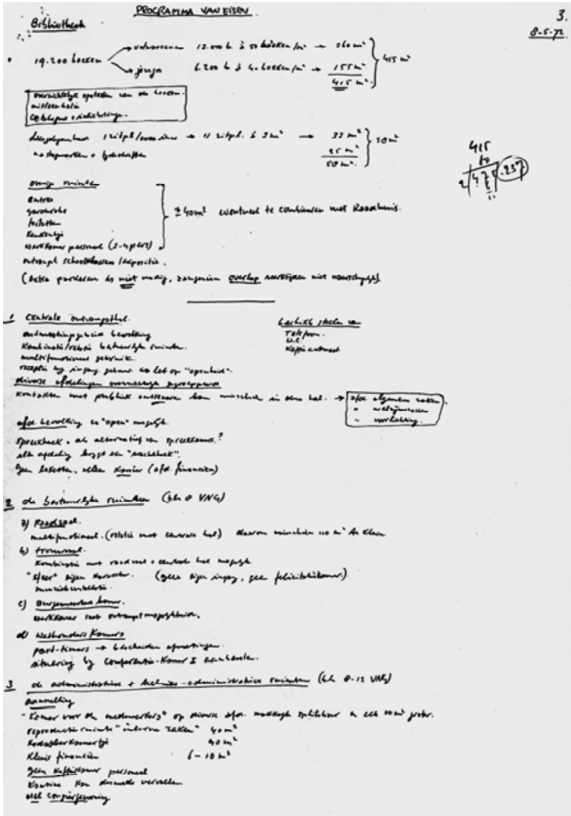
Mutations
"Creativity is omitting at least one usual supposition." one of my PhD-candidates said. Creativity going beyond smart combining requires a mutation within the genetic material of common suppositions. If a designer hearing the word 'theatre' immediately thinks of an amphitheatre, (s)he uses an unspoken supposition limiting the possibilities beforehand. And, we do have many of these 'self evident' suppositions we are not aware of. Culture is the set of shared and consequently unspoken suppositions during communication. These hidden suppositions shape the context, the text silently supplied next to the message. These suppositions are accepted as self-evident so that we do not have to build up every discourse from the axioms. But really new designs require a mutation of just these suppositions. They 'put us on another leg', producing a field of newly emerging possibilities.
That most of them will disappear by environmental selection we have to take for granted.

3 EXAMPLES OF DESIGN PROCESSES

Urban and architectural design processes are context sensitive, bound to personal style and therefore always different. It is difficult to generalise from such case studies. That demotivates proper documentation and that is why design processes not often have been documented properly. So, I take some examples from a book I edited in 2002.[a]
All examples start with genetic material; combine it into a train of thought that more than once arrive at an impasse forcing to change suppositions, while the entire process and its result experience the pressure of selection by an administrative, cultural, economic and physical environment.

Starting with a programme of requirements
The first example is a design of Carel Weeber for the town hall of the Dutch village Berkel en Rodenrijs. That design is never executed, but the process is a good example of a design primarily starting with the programme of requirements as genetic material given by the client.
The client mainly asks a management advisor to formulate the programme of requirements and in that programme the experience of earlier examples is stored.
Weeber claims he learns that programme by heart for any assignment.

[a] Jong, T.M. de and Voordt, D.J.M. van der, Eds. (2002) *Ways to study and research urban, architectural and technical design.* (Delft) DUP Science



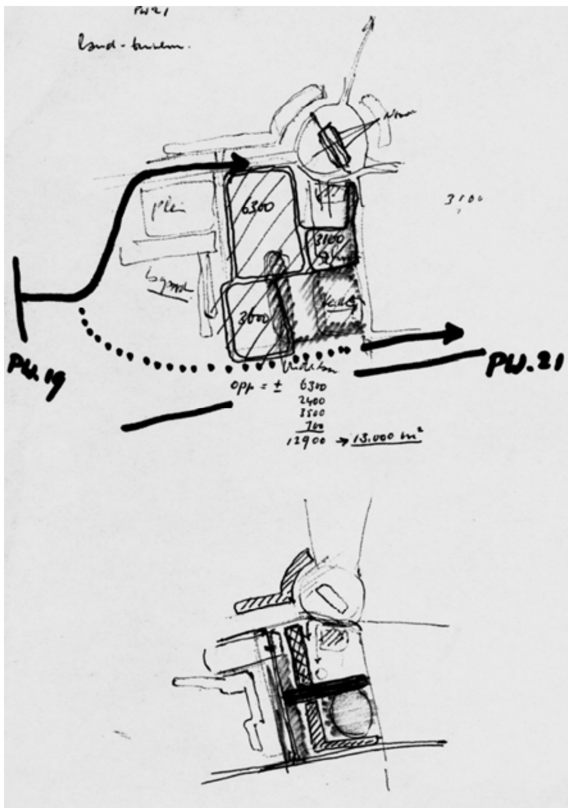
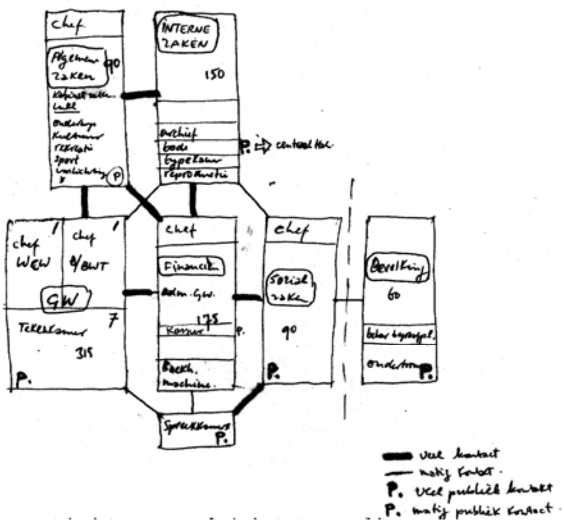


Fig. 11 Genetic material *Fig. 12 Selectivity of the environment*

He explores the location, the environment, to get acquainted with its selectivity and starts combining the components of the programme.



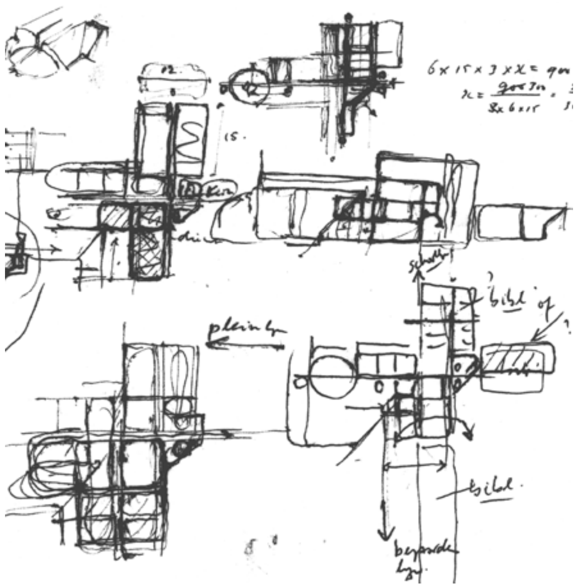
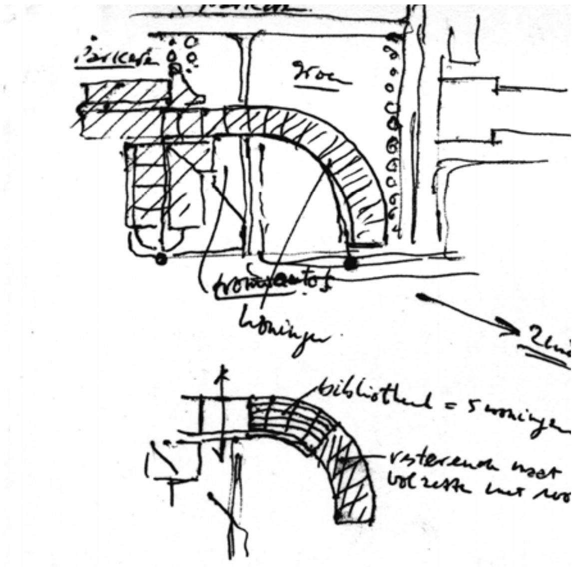


Fig. 13 Combining *Fig. 14 Variants*

Different variants come to a dead end until the mutation takes place: combine the town hall with the municipal library also nominated to be replaced.



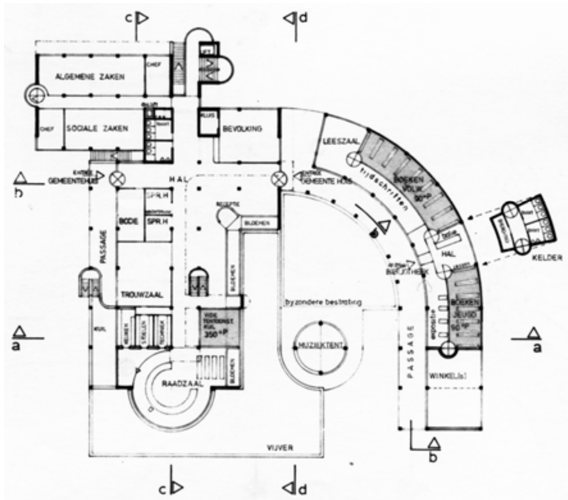
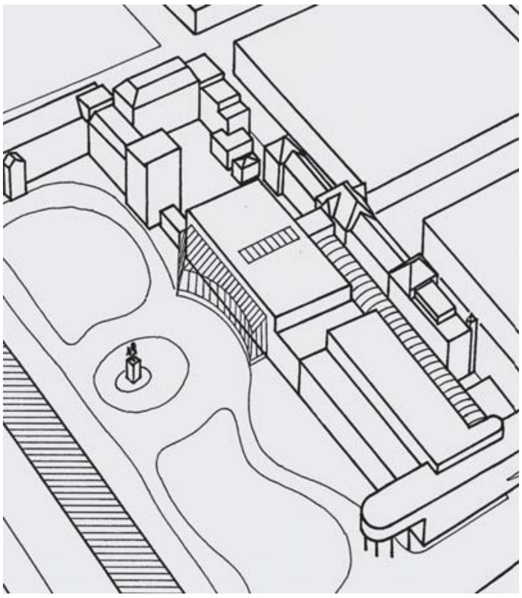


Fig. 15 Mutation *Fig. 16 Fit!*

By doing so, the genetic material is changed so that a solution emerges utilising the susceptibility of the location.

Starting with the possibilities of the location
The museum Naturalis in Leiden is designed by Fons Verheijen. His approach is primarily equal to that of Weeber: environment, programme, combinations, mutations, design. However, the most important mutation here has been the environment. The scientific department of the museum with collections should primarily be housed by renewal and extension of old buildings at the Van der Werfpark in the inner city of Leiden. A separate exhibition room would be realised outside the inner city within an isolated monument (Pesthuis).



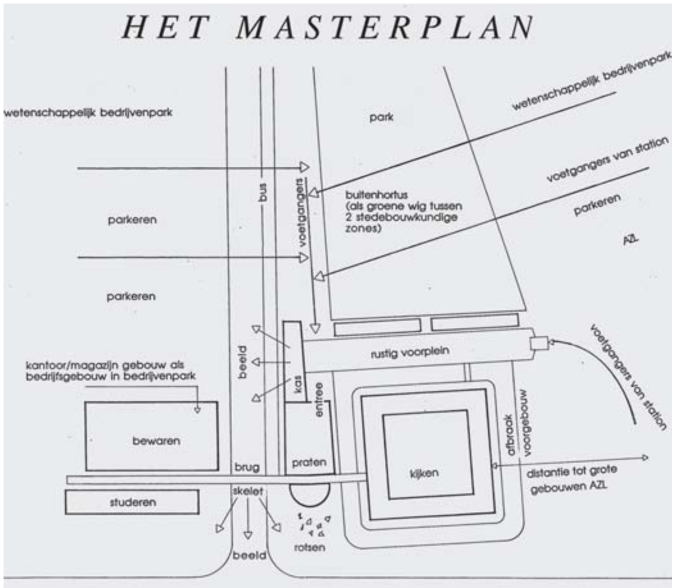


Fig. 17 Design extension Van der Werfpark *Fig. 18 New location adjacent to the Pesthuis*

The first mutation consisted of finding a new location adjacent to the Pesthuis at the other side of a road. Now the programme could be changed also by new combinations and extending the exposition space. The permanent exposition moved to the new building, while in the Pesthuis amongst others the room ‘Dutch Nature’, the museum café, the wardrobe, the studio, the shop and the auditorium could be situated.

With this, the idea for the new building developed in close dialogue with the clients: the collections in a tower, flexible expositions accessible by a footbridge from the Pesthuis across the road through the scientific department (see *Fig. 19*).

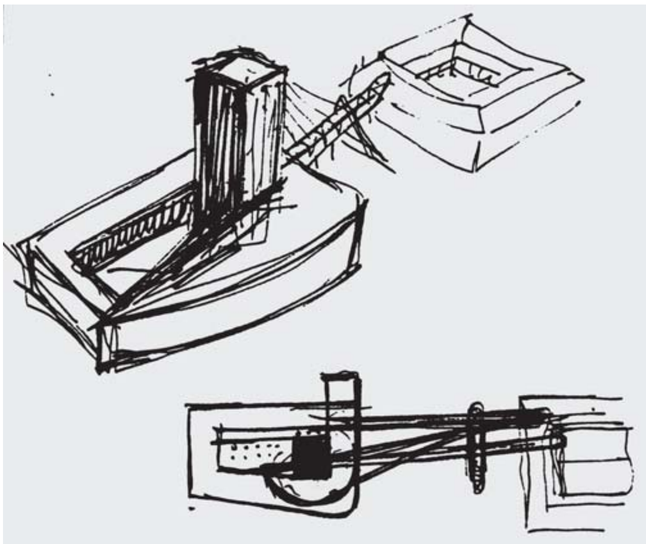


Fig. 19 Dialogue with the users

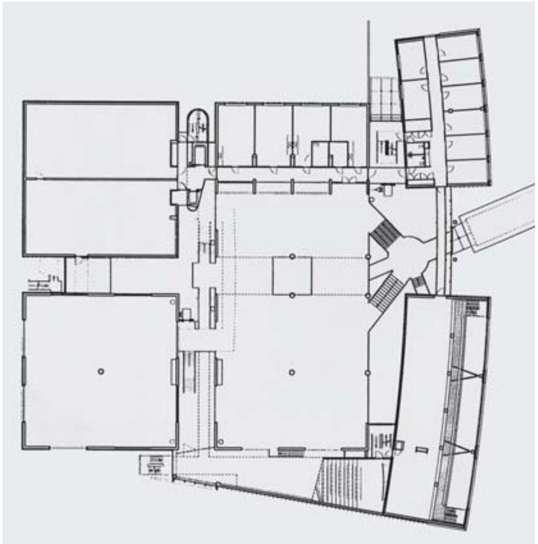


Fig. 20 Definitive design

Then, the plan could be simplified affordably into the definitive design (see *Fig. 20*).

Starting with design means
From Hertzberger I will not raise a particular design, because he has described his formula for creativity crystal clear in appealing texts and images.[a]
The first operation he proposes is a mutation in your own genetic material: break off the clichés in your own ideas and suppositions (see *Fig. 21*) to make space for another genetic source. That is comparable with the old Greek 'catharsis' or 'epochè'.

Fig. 21 Robert Delaunay (1913): Destroy the clichés

Fig. 22 Marcel Duchamps (1917): Change the context

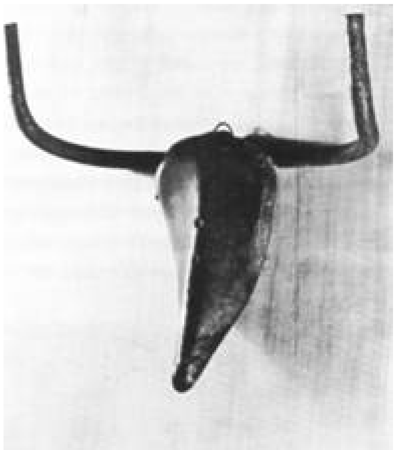


Fig. 23 Pablo Picasso (1942): Combine, leave out, adapt

Hertzberger finds the substitute genetic material (in contrast to Weeber) not primarily in a programme of requirements, but in collecting as much images as possible from all parts of the world. These images should be set free from their environment and located in another context (see *Fig. 22*). By

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Hertzberger, H. (2000) *Space and the architect: Lessons in architecture 2* (Rotterdam) 010 Publishers
Hertzberger, H. (2002) *Creating space of thought.* in: *Ways to research and study urban, architectural and technological design.* T. M. d. Jong and D. J. M. v. d. Voordt (Delft) Delft University Press

doing so, these images are cleaned from their contextual suppositions (‘silently supplied text’). Others would call that ‘montage’. Next, their adaptive possibilities can be explored designerly by combinating, leaving out and adapting (see *Fig. 23*).

Combine, leave out, adapt
The recommendation to tidy up your prejudices first to make space for a set of genetic material available in the rest of the world is in fact an educational model. The design process itself consists of combining, leaving out (mutation) and adapting (answering the environmental pressure of selection). My most convincing image of these three I borrow from Lefaivre and historian of architecture Tzonis.[a] They describe the works of Aldo van Eyck, our great architect and kindred spirit of Hertzberger. Therein they offer the image of two genetic sources (see *Fig. 24* and *Fig. 25*) combined and adapted in Van Eyck’s famous Burgerweeshuis in Amsterdam (see *Fig. 26*).

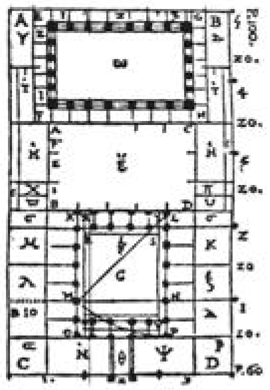

Fig. 24 The Renaissance scheme for a large dwelling house

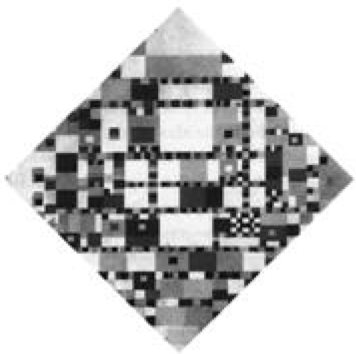

Fig. 25 Piet Mondriaan (1944) Victory Boogy Woogy

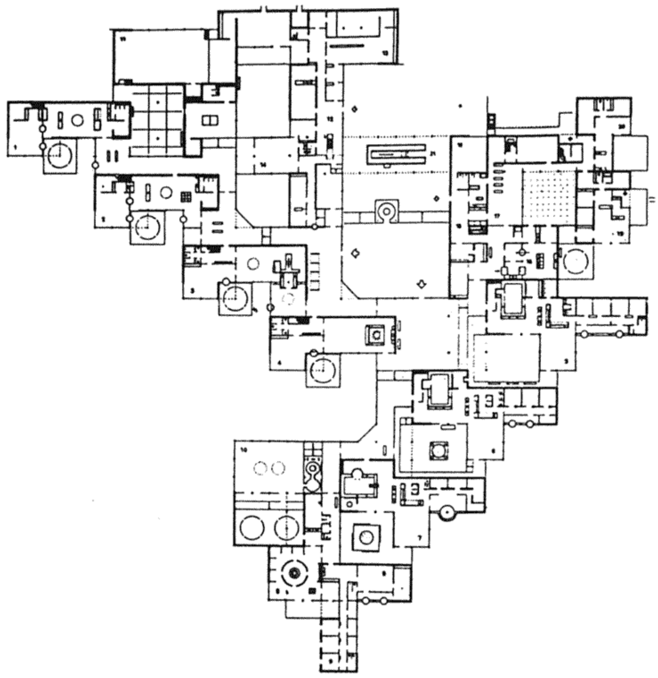

Fig. 26 Aldo van Eyck (1961) Burger Weeshuis Amsterdam, according Lefaivre en Tzonis a combination of Fig. 24 en Fig. 25

Concluding propositions about the evolution of a design
Based on these considerations and examples I would like to posit the propositions below.

1. Any design combines acquired suppositions and references comparable with the genetic material transferred in the evolution of life.
2. That experience has to be distrusted continuously, because the administrative, cultural, economic, technical, ecological and spatial environment changes continuously and substantially.
3. These changes occur faster than ever in the evolution of life.
4. These changes can not be kept up otherwise than by creative design.
5. Designing should be more than combining existing solutions.

[a] Lefaivre, Liane and Tzonis, Alexander (1999) *Aldo van Eyck, humanist rebel inbetweening in a postwar world* (Rotterdam) 010 Publishers

6. Any design process experiences dead ends where the designer has to return to change her or his suppositions kept up until then.
7. Such a change of suppositions is comparable with a mutation of genetic material.
8. Salient and bifurcated suppositions should be clarified until their trunk to cut them back if they can not resist the environmental pressure.
9. That operation is the foundation of creativity.
10. The social environment is not sufficiently equipped to fulfil its selecting task in relation to designs determining the future.
11. Positing propositions is an example of designing. It is a necessary supplement on a thesis only proving empirical ability.
12. A botanical garden for technical plants at a University of Technology is indispensable to keep engineers humble realising what nature made possible without design in 3 billion years by transferring genetic material, combining, mutating and selecting.