Facilitating change

Biomimicry as a way to create adaptable urban environments
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PREFACE

This master thesis is the final result in obtaining the master degree in Urbanism at the Technical University of Delft. The project took place in the studio Urban Regeneration at the department of Urbanism, at the faculty of Architecture. One year of research and design is presented in this thesis, about the application of biomimicry in urban redesign, in order to facilitate change in adaptable urban environments.

Biomimicry is a recently upcoming theory and was completely new for me when I started this research. Throughout the year I learned a lot about the field of research of biology, and created bridges between this field and the field of urban design. It was a challenging but above all exciting topic; bridging between fields of research, adding knowledge to different disciplines, influence the action of others and thinking about shaping our future living environment. Diving into this interesting topic made me realise that so much knowledge is present in human society but that at the same time there is so much to discover. Curiosity is a key property for urban designers shaping the future in my opinion. Using my curiosity for creating solutions for tomorrow resulted in the creation of a design strategy to apply biomimicry in urban redesign and many solutions for the ever changing future. Hopefully many more will come after this research.

My acknowledgements go to my mentors in this research. Arjan van Timmeren, thank you for your guidance, for always seeing possibilities in my ideas and stimulating me to dive into new questions. Nico Til, thank you for you clear words, analytical eye and pragmatic view on this research. Also I want to thank everyone who I interviewed for their time and thoughts about the topic of this research. Each interviews and conversations helped me with growing in the research and resulted in interesting ideas and questions. And finally Bastiaan, my consulted biologist; thank you for being an inexhaustible source of knowledge, your critical eye to keep me sharp and your time and efforts.

Behind the scenes there are many people to give my thanks to. Yannick: for utterly supporting me, for the thrust in my ideas and keeping me on the right track. Cor & Ruth for your support, attention and believe. And all other friends, roommates and fellow students who accompanied me this year; you were a great support!

Enjoy reading and exploring,

Verali von Meijenfeldt,
June 2014, Delft
ABSTRACT

Planet Earth is constantly changing, and with it our living environment. Seasonal variation in temperature and precipitation, as well as long-term climate trends, are but a few examples of change that pose challenges to a settled society. Whereas direction, magnitude, and even character of future changes may be uncertain, we can be confident that tomorrow’s Earth will be different from today’s. At the moment, urban designers respond to an ever-changing living environment by making a snapshot based on predictions about the future. Because of the inherently uncertain nature of the future, a contemporary design is hence partly based on assumptions instead of facts. However, if we can base a design merely on the fact that change will happen, we can focus on the process of change rather than on the outcome and thus better be able to deal with future changes. The goal is to create adaptable urban designs, in order to construct future-proof urban environments.

The relatively novel theory of ‘biomimicry’ might provide opportunities for the construction of adaptable designs. A biomimicry design approach tries to learn from nature’s successes in order to solve human problems. The theory proposes three levels of learning from nature: the level of form, the level of process, and the level of system. Learning on the level of form is predominantly practised in current applications of biomimicry within fields of research other than urban design. Importantly, there are also six design lessons from nature which represent the theory’s six life’s principles, one of which is ‘adapt to changing conditions’.

The theory has been widely acclaimed in other fields of expertise, such as industrial design, architecture, and organisation processes. However, till this day, the theory has not been applied often in urbanism, nor has it been evaluated scientifically in this field.

The main research question posed in this report is:

How can biomimicry be applied in urban redesign and facilitate change in urban environments?

The research evaluates biomimicry: is it just a hype or does it provide a solution for designing our uncertain future? The final result is a general strategy for applying biomimicry in urban redesign. This adds knowledge both to the field of urban design strategies and to the field of biomimicry. It is suggested that the strategy can also be applied in other disciplines.

Starting with a literature study, a strategy is developed and tested on two pilot cases in different contexts. These cases both contain an analysis and design of an urban regeneration area: Strijp S in Eindhoven and the Agniesbuurt in Rotterdam. Based on the design results, the strategy is further developed and reflected in order to improve and strengthen the strategy.

The strategy consists of eight steps that together form the design strategy (see Figure 1). However, some steps can also be used solely and implemented in other strategies. Different actors can be involved in different steps. In this design strategy, a biologist is consulted in order to understand processes, systems, and forms of nature which could be translated into design implementations. A linkage is created between the disciplines of biology and urban design.

Strategies of nature are examined in order to find solutions for the specific problems that are faced in both Eindhoven and Rotterdam. In Eindhoven, the challenge is the transformation of a partly empty former industrial area into a regenerated area. Other problems in Eindhoven that were encountered are the scarce water quantity and temperature changes. This poses future threats to the area. Rotterdam, and specifically the Agniesbuurt also faces problems of future changes in water quantity, water quality and in temperature. These problems formed the starting points for the search for solutions in nature.

Human society and natural systems experience similar problems of change like in and thus provides us with proven solutions for coping with unpredictable change i.e. ideas for urban interventions. The ideas are translated into various specific design solutions or abstract concepts and categorized into different scales. Moreover, they show the different consequences for the urban environment. Profound concepts arise because multiple ideas are combined into one concept.

The implementations of the nature inspired design ideas in both cases result in an improvement of the adaptability of the area. This is accomplished through two important aspects. First, by taking the topic of change as the starting point for the creation of concepts. And second, through the integration of design interventions at different scales across the urban fabric. Integrating implementations throughout scales results in a profound understanding of design interventions.

Adaptability is facilitated by the nature of the ideas derived from nature. The focus is primarily on change itself rather than on the final long-term plan of a possible fu-
ture scenario. Options are kept open to changing direc-
tions, magnitude, and character of functions and imple-
mentations. Thus through the application of biomimicry
in the field of urban redesign, the urban designer does
not create a snapshot of what the future could possibly
look like, but instead proposes a possibility for an area
to change over time. Though it is important to note that
the urban designer must remain critical about nature’s
proven lessons. The designer must not take the examples
for granted as the ultimate solution for achieving a suc-
cessful design result per definition, since human society
and nature do differ from each other.

This research explored the possible added value of the
application of biomimicry in urban redesign. The strat-
ey that was constructed through this thorough research,
supported with two design proposals, could form a valu-
able tool worth knowing when designing adaptable ur-
ban for unpredictable times to come.
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Urban design: The collaborative and multi-disciplinary process of shaping the physical setting for life in cities, towns and villages; the art of making places; design in an urban context. - Robert Cowan
Definitions in the field of urban design

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<td>Nature:</td>
<td>The species Homo sapiens, distinguished from other animals by superior mental development</td>
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<td>Human:</td>
<td>The phenomena of the physical world collectively, as opposed to humans or human creation (Oxford dictionary, 2013)</td>
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<td>Scale:</td>
<td>A graduated range of values forming a standard system for measuring or grading something</td>
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<td>Level:</td>
<td>A position on a scale of amount, quantity, extent, or quality / A position in a hierarchy</td>
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<td>Urban design:</td>
<td>The collaborative and multi-disciplinary process of shaping the physical setting for life in cities, towns and villages; the art of making places; design in an urban context (Cowan, 2005).</td>
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<td>General:</td>
<td>Concerning all cases or people.</td>
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<td>Generic:</td>
<td>Characteristic of or relating to a class or group of things.</td>
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<tr>
<td>Facilitate:</td>
<td>Make (an action or process) easy or easier:</td>
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<tr>
<td>Change:</td>
<td>An act or process through which something becomes different.</td>
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<tr>
<td>Robustness:</td>
<td>Ability to accommodate change without significant change in the physical form (Carmona, 2010).</td>
</tr>
<tr>
<td>Resilience:</td>
<td>Ability to resist change without undue deformation (Carmona, 2010).</td>
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<tr>
<td>Strategy:</td>
<td>The overall research plan or structure of the research study</td>
</tr>
<tr>
<td>Method:</td>
<td>Research processes that are common across the entire range of architectural research, including content areas from the technical fields to the humanities and from the pragmatic to the most theoretical (Groat and Wang, 2002).</td>
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Definitions in the field of biology

**Adaptation (ecology):** Adaptation (ecology): a genetically determined characteristic (behavioural, morphological, or physiological) that improves an organism’s ability to survive and reproduce under prevailing environmental conditions (Smith and Smith, 2006).

**Abiotic:** Abiotic: the non-living, the abiotic component of the environment includes soil, water, air, light, nutrients, and the like (Smith and Smith, 2006)

**Biotic:** Biotic: the living, applied to the living component of an ecosystem

**Community (nature):** Community (nature): A group of interacting plants and animals inhabiting a given area

**Ecology:** Ecology: The study of relations between organisms and their natural environment, living and non-living.

**Ecosystem:** Ecosystem: The biotic community and its abiotic environment functioning as a system.

**Evolution:** Evolution: Change in gene frequency through time resulting from natural selection and producing cumulative changes in characteristics of a population.

**Open system:** Open system: system with exchanges of materials and energy to the surrounding environment.

**Population (nature):** Population (nature): A group of individuals of the same species living in a given area at a given time
Intelligence is the ability to adapt to change -

Stephen Hawking
1.1 MOTIVATION

The topic of this graduation research arises from personal interests and experiences. This can be best explained through its theme and structure;

Theme: I am fascinated by a couple of keywords that form the basis of my interest in the chosen theme: adaptation, complexity, innovation, and integration. To me, they represent the core of the key question for the future of urban design. A changing world around us and the societal response to those changes.

I am interested in the knowledge behind occurring phenomena like climate change and I started to enhance my knowledge of this topic. By understanding what is happening on our planet, we, designers and planners, can respond better to forthcoming changes. In my research, I aim to enhance understanding of possible solutions in order to try to respond to the changing world around us; do we adapt, do we accept or do we not accept the changes? And why should we change at all?

Nature for me is inextricably linked to humans, so I therefore find the theory of biomimicry very interesting: learning from nature, and using nature’s solutions to solve or own problems. In order to create a world where every species can survive, we can learn from organisms which faced millions of years of evolution. Instead of relying only on new innovation that we need to discover ourselves, we can learn from what already proved its strength and capability to survive, i.e. we can look at nature and copy the attributes that adaptation crafted to an optimum in order to solve problems comparable to our own. This strategy of biomimics interest me a lot and I am eager to find out whether these principles of mimicking existing life forms, could also play a potential key role in urban design. Could biomimicry help to move in the direction of a world that is in equilibrium for us and generations to come, or is it just a hype?

Structure: What I find interesting is adding new knowledge to the current discussion of sustainable urban design. Therefore I want to end my research with general conclusions, that represent meaningful additions to the field of urban design through biomimicry; whether it is a useable strategy which can be applied right away, or that it is not ready for direct implementation etc. Part of the research is design but my aim is to end my research with a general strategy that contains conclusions about biomimicry. My goal is to make two designs for different locations and contexts. In this way (more) general assumptions can be made.

Personal background: My personal background ensures some basic general knowledge for this research. In my internship for the engineering firm ARCADIS and the urban design studio BGVS last year, I learned about the practical side of urbanism. I also learned a lot about sustainability and how companies deal with this expression. At ARCADIS I got the idea for the topic of biomimicry and got into contact with biomimicry experts in the Netherlands. This gives me an entrance into the network of biomimicry experts. Networking and pioneering on a topic is something I am experienced in e.g. in Chile and Peru I conducted a pioneering research project for 2 months, which I enjoyed doing very much. Therefore the pioneering aspect of this research makes this the right challenging for me.
1.2 PROBLEM FIELD

A changing planet
Planet earth is bound to constant change. The planet spins in an orbit around the sun, as part of our moving solar system. This causes daily change for the human living environment. The four seasons for instance, is an example of the sun’s influence and position of the earth. This affects not only the planet on itself but also our living environment.

Change in two ways
Change like the procession of the seasons are due to processes we call ‘natural change’. The human species i.e. Homo sapiens cannot control this. We can influence aspects and ranges of it, but it is not our own decision that these changes happen. However this does not count for every change. The species Homo sapiens distinguishes itself from other species on planet earth, because of the fact that we are able to ‘design’ and make artefacts. We are able to actively choose to make changes in our living environment to a certain level and create things. We have the extraordinary skill to interpret things and materials, place them in a different context, and use this in a variety of ways (Dong, 2010). In other words we are able to create technology. Another distinction is the fact that we can communicate ideas and experience as a result of culture (Timmeren, 2013). Therefore we are able to create an environment that suits us humans.

However, both changes can have a negative effect on our living world and that of all other living species. The natural changes could form a threat for humans and their living environment. Two examples are sea-level rise or an increase of temperature (Döpp and Albers, 2008). Changes due to human technology can also turn into negative outputs. We fitted our living environment so well to our living standard that the number of individuals increased enormously over the past decade. This could cause overpopulation and food and energy shortages in the nearby future. The changes we are facing are unpredictable on many levels like scale and size of human population and climate change issues. This ensures a great uncertainty for our future on different fields.

Humans respond
It is in our nature to respond to this and look constantly for innovations and new ways to react to the change of our surroundings. We do this in order to improve our way of living and existing systems.

When talking about our living environment, there are many fields that play a role. For now, we take a look at our physical living environment, related to the field of urbanism. This field has a major impact on the human living environment and determines a large part of the way we live. The urban design field has a major impact on human society (Calthorpe, 2012).

By assuming possibilities
It is not strange that in the field of urbanism there is a constant search for how to respond to changes. At the moment urban planners and policymakers base decisions on the snapshot of the possible changes of our surroundings. We sketch possible scenarios for the future and base designs on this. But we cannot predict the future completely so we could say a design is to some extent based on possibilities and assumptions, instead of true facts.

Change itself
We do not know what will happen in the future. What we however can say about future circumstances, is
that the situation will be different from what is it now. If we can base a design on this very true fact (change), we can deal with change. This is because at this moment it is not about the content of the change, but it is about the process itself.

**Future solution?**
But how can we achieve a change based on an unknown change in the field of urban design? The emerging theory of ‘biomimicry’ might provide opportunities for solutions: Biomimicry means learning form natures success, on the level of form process or systems. Nature’s success is distinguished in six life’s principles (Biomimicry 3.8, 2013). One of these principles is ‘adapt to changing conditions’. This is interesting for our living environment; if nature is built to adapt to changing condition, could we learn from this and achieve the same for our environment? In other words; if we use this approach for the urban (re)design and take the adaptability of nature as an inspiration, could we be able to create adaptable living environments?
1.3 PROBLEM STATEMENT

The theory of biomimicry could be a serious solution to the challenge of dealing with uncertain future change. However there are some questions which arise with this theory; One of those questions is whether this strategy is applicable in urbanism because it has not yet been applied on large scale either in practice or scientific. The second question is how this strategy is related to scales, and how scales work together in ecosystems and processes and what this means for design. The third questions is whether the principles from nature can be used in a human environment or not (humans differ from that with other mammals because of the ability to create technology and culture and different level of consciousness (Timmeren, 2013, Seth et al., 2005)). So the question arises: Is this strategy useful and applicable for urban design or is biomimicry just a hype which is exaggerated by media and researchers?

1.4 RESEARCH QUESTIONS

As stated in the problem statement, there are a couple questions about the application of biomimicry in urban design:

First it is not proven that the strategy of biomimicry is applicable for urban design, and it is not clear how to use the strategy; on which scales and with what strategies. Second, the strategy raises opportunities for responding to changing circumstances like climate changing requirements of human beings. This leads to the following main question for this research:

How can biomimicry be applied in urban redesign and facilitate change in urban environments?

The sub questions which need to be answered in order to answer the main question for this research are:

1. What are the differences and similarities between biomimicry and urban redesign?
   1.1 What is biomimicry and how is it applied?
   1.2 What is urban redesign and how is it applied?

2. How could biomimicry be translated into a strategy for the field of urban redesign? Which points of attention should the strategy satisfy?

3. Which problems can be improved on two different locations in different contexts and what possible solutions arise?
   3.1 Which natural/human problems related to change can be improved at the locations?
   3.2 Which natural/human solutions can be implemented to improve these problems?

4. How can the theory of biomimicry be implemented in the urban design process of these two different locations in order to improve problems?

5. Is the strategy a biomimicry product and general applicable? Does it improve the indicated problems of change in the urban environment?
   5.1 Is a design strategy a form of biomimicry?
   5.2 Are problems (related to change) improved by this strategy?
   5.3 Can the strategy also be applied in other contexts?

The sub questions are answered in different chapters.
1.5 HYPOTHESIS

If the extent of ability to change in urban design is related to the specific design strategy, then using the strategy of Biomimicry for urban design will result in a design that contributes to an adaptable environment.

Relation between variables:

**Independent:** A design strategy. In this research the strategy of biomimicry.

In this research the variables of the strategy are attempted to be found. This should be an outcome of the research. If variables can be determined for the strategy of biomimicry, then a direct relation can be found between these variables and that of e.g. climate adaptability in a design. Conclusions can be drawn about individual parts of the theory of biomimicry.

**Dependent:** The extent to which an urban design is able to change.

The variables will be determined with in the analysis and design process. The changing variables are dependent on the specific context so need to be gathered in these design phases. After the design these variables will be measured in the design. Then a conclusion can be drawn about the extent to which a design is adaptable.

1.6 RELEVANCE

*Academic relevance:* The strategy of biomimicry has not been tested (often) in practice. It has not been researched scientifically in the field of urban design. This research will add broader knowledge to the theme of biomimicry, on a new field of application. This research will also add knowledge to the question whether the principles of life are applicable for humans.

*Social relevance:* Current issues like climate change can be an enormous threat for humans at the moment and in the future. If we live on the same way in the future as we do now, resources and materials will run out and the space we live in changes. This research might come up with a way of designing which responds to those threats. Also this research could contribute to a scientific basis in the field of biomimicry in urban design, as there is few scientific evidence present. Biomimicry is an emerging topic, that attracts interest from different stakeholders, such as the Dutch Ministry of Economic affairs, Environment and Innovation (Hopman, 2013).

Fig. 3: Newspaper-article about biomimicry (Harman, 2013)
De BV Natuur

Een van de pioniers van de biomimicry – door de natuur geïnspireerde innovatie – legt uit waarom dit het succesverhaal van de eeuw gaat worden. DOOR JAY HARMAN
A goal without a plan is just a wish -
Antoine de Saint-Exupery (1900-1944)
2.1 GOAL

The goal of this project is to find out whether biomimicry could be used for urban redesign, in the specific context of adaptation or change. If it is possible, this research shows how this is being done. Is biomimicry a hype or is it really a solution for designing our future? In order to answer this, the final goal is to conduct a general strategy, which shows general relations between the chosen strategy and a specific context, in this case adaptation. The design is in this research not the final goal, but a part of the research. Also this research is build up in a way, that it can be repeated whit in another context for further research, so it could be an example research to come.

2.2 RESEARCH STRUCTURE

Research - Design - General conclusions (Theory building)

The figure on the right shows the research structure in different phases, the used methods and time planning.

Methods: Different methods will be used during phases of the research. For the literature phase different methods will be used for different themes of the theoretical framework. This is because the topic of biomimicry is an emerging topic, with relatively few academic literatur. Instead, knowledge is spread and discussed by experts and non-experts. A lot of different stakeholders are involved in the subject, and they have different point of views on biomimicry. Networking and interviewing is therefore an important way to gain information and as well as exchanging it. Because the topic is emerging, stakeholders could also be interested in this research, as it could contribute to the knowledge base of the topic. The design locations therefore should also be actual research locations. The topics of urban regeneration and other context themes will be discussed with literature studies. Case studies will be used if examples from practise are needed for that specific topic.

In the strategy development phase a method for the further design will be developed, based on the literature study. It is important that the way the strategy is conducted is able to be validated. Therefore the structure of this research must be followed as indicated in fig 4. In the introduction a problem is observed and further defined in the problem statement. A short analysis is done. After this the hypothesis is presented. This hypothesis will be tested in the following steps: strategy generation, analysis, design.

In the design phase two pilot projects based on biomimicry will be done on existing urban regeneration areas. Different methods of analysing will be used, based on the preferred output of the method. Mapping, observing and layering are obvious methods. The layering is a desired tool, as there are different fields of interest which need to be mapped and related (natural and human systems). The reflection afterwards is an important final step. A judgement about the validation of the strategy will be given. Interviews will be done with design companies and municipalities to discuss the described strategy on e.g. usability.

Planning: The decision to make two designs might seem too ambitious, yet I think it is possible in the following way: During the literature study phase, the strategy generation and analysis phase also starts. So while deepening into the literature, I will start with the first strategy description. The strategy describes analysis and design steps, so the first analysis steps can already be performed while conducting the strategy. While analysing the first themes, the first reflection on the strategy will be done. New literature will be elaborated and new analysis steps will be made at the same time. After the first analysis, the methodology for the design with biomimicry should be fine-tuned, so the second analysis can use this as a starting point. In this way the strategy is tested in another context and the process of analysis steps is fastened. When the first analysis is done, the first design steps can be made.

Fig. 4: Research structure with method during different phases
Method description of biomimicry in urban redesign

Pilot case 1: Eindhoven, Strijp S

Pilot 2: Rotterdam

Biomimicry Definition and philosophy
Method description
References

Urban regeneration
Definition
Scales
Method description

Q: How can biomimicry be applied in urban redesign and facilitate change in urban environments?

Problem: How to respond to change, instead of responding to snapshots?

Hypothesis: Biomimicry is a solution for the described design problem

Context: Changing conditions
- Explain why this context was chosen and no others.
- General concerns
- Existing problems
- References & Existing solutions

Method development

Methods
- Literature study
- Interviews with: Government
  Public stakeholders
  Private stakeholders
- References / case study
- Networking

Biomimicry in urban design
Mapping
Observing
Layering

Test requirements
- Interviews with: Government
  Public stakeholders
  Private stakeholders

Reflect designs and method

Conclusion

Problem field

LITERATURE

METHOD

ANALYSIS

DESIGN

REFLECTION

Urban regeneration

Method description of biomimicry in urban redesign

Context:
Changing conditions

Problem:
How to respond to change, instead of responding to snapshots?

Hypothesis:
Biomimicry is a solution for the described design problem

Biomimicry
Definition and philosophy
Method description
References

Urban regeneration
Definition
Scales
Method description

Q: How can biomimicry be applied in urban redesign and facilitate change in urban environments?

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Method development

Methods
- Literature study
- Interviews with: Government
  Public stakeholders
  Private stakeholders
- References / case study
- Networking

Biomimicry in urban design
Mapping
Observing
Layering

Test requirements
- Interviews with: Government
  Public stakeholders
  Private stakeholders

Reflect designs and method

Conclusion
2.3 THESIS STRUCTURE

Figure 5 shows the structure of the research in the thesis plan. In every chapter one question will be answered in order to give an answer to the main question at the end. Figure 6 shows the planning for the research structure and thesis structure.

Main research question: How can biomimicry be applied in urban redesign and facilitate change in urban environments?

Sub question 1. What are the differences and similarities between biomimicry and urban redesign?
   1.1 What is biomimicry and how is it applied?
   1.2 What is urban redesign and how is it applied?

Sub question 2. How could biomimicry be translated into a method for the field of urban redesign? Which points of attention should the method satisfy?

Sub question 3. Which problems can be solved on two different locations in different contexts and what possible solutions arise?
   3.1 Which natural/human problems related to change can be solved at the locations?
   3.2 Which natural/human solutions can be implemented to solve these problems?

Sub question 4. How can the theory of biomimicry be implemented in the urban design process of these two different locations in order to solve problems?

Sub question 5. Is the method a biomimicry product and general applicable? Does it help solve the indicated problems of change in the urban environment?
   5.1 Is a design method a form of biomimicry?
   5.2 Are problems (related to change) solved by this method?
   5.3 Can the method also be applied in other contexts?
<table>
<thead>
<tr>
<th>P1</th>
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<td>Method 1.2</td>
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<td>Pilot 1 general info</td>
<td>Pilot 1</td>
<td>1st reflection method</td>
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<td>Pilot 1</td>
<td>Literature study</td>
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<td>Finetuning</td>
<td>General model</td>
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<td></td>
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<td>Room for improvement</td>
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</tbody>
</table>

**Thesis structure**

- Literature overview
- Pilot 1 general info
- Pilot 1
- Pilot 2 general info
- 1st ideas
- Literature study
- Method 1.0
- Method 1.1
- Method 1.2
- Method 1.3
- Analysis 2x
- 2 Designs
- General model
- Room for improvement
2.4 LOCATION

In order to conduct a general strategy, two pilot cases will be performed on different locations. Change in the locations is caused by different contexts. The first design location is the neighbourhood Strijp S in Eindhoven. This former Philips area has become vacant after the departure of the company in ‘80s and ‘90s. The neighbourhood started a huge regeneration of the area. At the moment the area is under construction, half empty but with a few early adapters. The change of the area due to human decision forms a centre point.

This location is also chosen because the mayor of the city is a supporter of biomimicry and exposes the city as a testing ground for biomimicry. Different design studio’s started already with this (e.g. West8 & Park Strijp beheer). So these designs can be compared with the outcomes of this research afterwards, and can add knowledge to the existing researches.

The second design location is neighbourhood the Agniesebuurt in Rotterdam, an area north of the central station. The change which forms a centre point in this pilot case is change due to natural processes: water. Changing water circumstance could form a threat to the inhabitants of Rotterdam in particular areas. The municipality responds to these threats and also looks in the field of nature for solutions. This context forms the second pilot location. This specific area is chosen because the design firm De Urbanisten already did a lot of research on this area. My research can be compared afterwards with the existing plans and researches.

Fig. 7: Eindhoven with Strijp S (www.maps.google.com, 2013)

Fig. 8: Plans for 2030 Strijp S (www.strijp-s.nl, 2013)

Fig. 9: Rotterdam with Agniesebuurt (www.maps.google.com, 2014)
2.5 FINAL PRODUCTS

The final product of this research will be a research strategy about how to use biomimicry in urbanism. Before this two strategic designs will be generated where the conclusions for the model will be based on. The designs will be on a strategic level, but do give insight in possible spatial qualities.

Theoretical products: literature review on the topic of biomimicry, on the topic of urban regeneration, the topic of changing conditions in urban environments.

Design products: two different designs in different contexts will be presented. Prior to the design, a design strategy is presented for the designs on different scales. After this a design is conducted on an informative level; so it must be detailed enough to show qualities of the interventions and the consequences of design decisions for the end users.

Product conclusion: general strategy and recommendations about the use of biomimicry in urban redesign.

2.6 GUIDANCE

For this research the field of sustainable design, design with nature, change in the living environment and how to respond to that in the future are important topics. Therefore Arjan van Timmeren will be the first mentor in this research, because of his knowledge and experience on these topics. The second mentor is Nico Tillie for his expertise in ecology and urban/landscape design, and experience at the municipality of Rotterdam. This forms a team of scientific knowledge combined with experience in practise.

2.7 KEYWORDS

Biomimicry, Urban design strategy, adaptable urban environment, changing conditions, adaptable design, nature inspired design.

2.8 DISCIPLINES

The disciplines that are touched and overlap in this research are:
Sustainable urban design, ecological design, circular design, urban regeneration, biomimicry, urban metabolism.
There are literally as many ideas as there are organisms –

Janine M. Benyus
In this chapter the following sub question is answered: 1. What are the differences and similarities between biomimicry and urban redesign? This can be split up in two sub questions: 1.1 What is biomimicry and how is it applied? 1.2 What is urban redesign and how is it applied?

In the first section a definition is given of humans and nature and the differences between the two. In the second section the expression and theory of biomimicry will be explained. Multiple descriptions will be given which show different point of views to interpret the term. After this the current use of biomimicry in theory will be described: there are different levels of biomimicry distinguished. Two current design methods are explained. After this the use in practise will be discussed: how has biomimicry been used so far? On what levels and with what design strategies? Finally the use of biomimicry in the field of urban design will be discussed: what has been done so far and how is this applied? In the third section urban regeneration will be described. Method and scales will be discussed. In the fourth section topics related to a changing context will be described.

### 3.1 HUMAN VS NATURE

‘Nature’ and ‘human’ differ from each other in various ways. This research handles a definition of nature and human:

**Human**

“Human: relating to or characteristic of humankind; Human being: a man, woman, or child of the species Homo sapiens, distinguished from other animals by superior mental development, power of articulate speech, and upright stance” (Oxford Dictionary, 2013).

The species Homo sapiens distinguishes itself from other living species on planet earth, because of the fact that we are able to ‘design’ and make artefacts. As human we are able to choose to make changes in our living environment to a certain level and create things. We have the extraordinary skill to interpret things and materials and place them in a different context and use it in a variety of ways (Dong, 2010). In other words we are able to create technology. Another distinction is the fact that we communicate ideas and experience as a result of culture (Timmeren, 2013). Therefore we are able to create an environment which suits us humans. ‘Human’ is interpreted as the species Homo sapience, which differs from nature on the above described points.

**Nature**

“Nature: the phenomena of the physical world collectively, including plants, animals, the landscape, and other features and products of the earth, as opposed to humans or human creation” (Oxford Dictionary, 2013). ‘Nature’ is interpreted as all other species which are no humans.

### 3.2 BIOMIMICRY

#### 3.2.1 Introduction

The word ‘biomimicry’ is a combination of the Greek bios; meaning ‘life’ and mimesis; meaning ‘imitate’ (Benyus, 1998). Related terms that are often used for it are ‘bionics’ or ‘biomimetics’. The introduction of the term ‘biomimicry’ came in 1982 but got real attention in 1997 by the book Biomimicry: Innovation inspired by nature by Janine Benyus. Since that moment a lot of different interpretations of biomimicry appeared. On the one hand the description of Janine is a starting point: ethos, re-connect and emulate are centre points. It is about understanding nature and re-connect with nature itself. It is important to understand why nature does things in order to mimic the ‘genius of nature’ for the use in our own life (Biomimicry 3.8, 2013). On the other extreme nature is seen as inspiration for clever and smart solutions. Modern technology is combined to make solutions more powerful. Nature is a starting point for innovation but it is not the goal to mimic nature on itself. In all the different point of views it is of importance that biomimicry is about what we can learn from nature, instead of what we can extract from it. In all different views this is a central point of the theory. Three elements come forward in every definition or characterisation of biomimicry:

Fig. 10: Measure of the type of concern in use biomimicry (Made by author, 2013)
“1) New (technical) possibilities for 2) innovations solving societal problems and/or fulfilling demands and 3) “learning from living nature,” or more precisely: learning, in the broadest sense, from: “biological research” “(Gleich et al., 2010).

Figure 9 shows the types of concern people have when using biomimicry. To further understand the philosophy behind biomimicry the reasons behind it are now explained. The reason to do this comprises three angles (Schumer-Huurman, 2012);

1. Ethos: the essence of our aesthetics, our intentions and the under lying philosophy in the choice of using biomimicry in a design process. It puts humans into our place on the earth: we are one of the many organisms living on earth. Each species has its own right to survival. And the survival of humans cannot be seen separated from its surrounding and the survival of other organisms. We are dependent on their survival.
2. (Re)connect: Nature and humans are deeply connected with each other. There is no ‘we’ and ‘they’. We are nature. This part is about (re)discovering of biology, and the (re)discovery of patterns of the generality of nature’s techniques, principles and solutions.
3. Emulate: the active part of biomimicry. The designs which end up as a result are inspired by nature and have minimal negative impact on earth. Nature will be used as model, measure and mentor. The goal is to develop new ideas, technical point of views and technologies.

3.2.2 Two design methods
Two general design methods are developed by Janine Benyus and the organization Biomimicry3.8 (Schumer-Huurman, 2012). The steps of the design methods are the same but are used in a different order.

1. From biology to design (figure 10): Biologic research forms a starting point. An organism is studied and an idea arises on how to use a principle from this organism for human life.
   -The first step to do is discover natural models. Find an inspiring organism or ecosystem and learn about its unique strategies for survival.
   -Abstract biological strategies and translate them into a design principle.
   -Identify what function this is.

   1. From biology to design (figure 10): Biologic research forms a starting point. An organism is studied and an idea arises on how to use a principle from this organism for human life.
   -The first step to do is discover natural models. Find an inspiring organism or ecosystem and learn about its unique strategies for survival.
   -Abstract biological strategies and translate them into a design principle.
   -Identify what function this is.

   -Define the context and circumstances where this function is needed.
   -Brainstorm about how to combine function, context and a design principle to solve a challenge.
   -Integrate life’s principles in the solution
   -Pick the best ideas of the brainstorm and emulate design principles to develop a design concept. Consider scale aspects and all 3 levels of biomimicry.
   -Measure your design using life’s principles as a check list on what the design should satisfy.

2. From design to biology (Figure 11): The integration of biology into the design process forms a central point in this method. If a design challenge is established, then biology will be used for finding a solution.
   -The first step is to define the context: specify the challenge and it’s operating conditions.
   -Brainstorm about how to combine function, context and a design principle to solve a challenge.
   -Integrate life’s principles in the solution
   -Pick the best ideas of the brainstorm and emulate design principles to develop a design concept. Consider scale aspects and all 3 levels of biomimicry.
   -Measure your design using life’s principles as a check list on what the design should satisfy.

Fig. 11: Design spiral biology to design (Baumeister, 2012)

Fig. 12: Design spiral challenge to biology (Baumeister, 2012)
-Identify what key functions the design must perform.
-Integrate life’s principles into the design requirements
-Discover natural models that have strategies to solve the needed function.
-Abstract biological strategies: determine the mechanism behind an organism and translate that into a design principle.
-Brainstorm about ideas for how to apply the design principles to solve the challenge.
-Emulate the best design principles. Take scale and level of biomimicry into account
-Measure your design using life’s principles as a check list on what the design should satisfy.

3.2.3 Levels of biomimicry
The strategy distinguishes three levels of the use of biomimicry from shallow biomimicry to deep biomimicry (Benyus, 2011);

The first level is mimicking of natural forms (shallow biomimicry). For example the mimicking of the boxfish, as inspiration for a streamlined car with less construction material showed in figure 12. The best known example of this level is Velcro: hook and loop fastener.

The second level is mimicking of natural processes, or how something is made. Studied examples from practice are swarm intelligence and ant patterns.

The third level is mimicking of natural ecosystems (deep biomimicry). In this level, we must look at the bigger scale of an example from nature. We should include the larger economy an organism works in, so that what the organism takes can be restored. To reach this level of biomimicry, the question of how each product fits in a bigger context is necessary. If all three levels can be mimicked, we start doing what nature does according to Benyus: “create conditions to conduct life” (Benyus, 2011, p.18). This is not an option but is a necessary fact if we want to keep our living environment liveable in the future.

Gleich e.a also describe this as three different levels of learning from nature (Gleich et al., 2010). The first level is described as learning from the results of evolution. Until now the most used form in practise. Form-function relations are the most obvious used ways in which this level of biomimicry is applied. The second level is learning from the process of evolution. In this level mostly optimisation issues are improved. The third level of biomimicry is learning from (success) principles of evolution. “The third level of learning form nature is based on an abstraction of the generalizable principles of evolutionary success” (Gleich et al., 2010, p.26). With the use of this level the result is two dimensional: on the one hand guiding principles and smart ideas can be used in models or design. On the other hand the solution forms the ‘promise’ that the solution has more respect to ecology and ensures lower risk for solutions, as nature already ‘proved’ the concept. Gleich describes six principles of nature’s success:
1. Solar energy and raw material opportunism
2. Modularity, hierarchical structuring and multi-functionality
3. Resource efficiency and recycling
4. Resilient (adaptability, diversity, redundancy)
5. Self-organisation and self-healing
6. Multi-dimensional optimisation

Fig. 13: Car inspired on the form of the boxfish (Clark, 2008)
Janine Benyus also set up a six principles of life that are seen as the basics for nature’s success, and form a basic for the approach (Biomimicry 3.8, 2013); 1. Be locally attuned and responsive 2. Adapt to changing conditions 3. Evolve to survive 4. Be resource efficient (material and energy) 5. Integrate development with growth 6. Use life-friendly chemistry

When all these principles can be performed, we start doing what nature does: create conditions to conduct life in.

3.2.4 What is biomimicry not?
The big difference between the biomimicry design process and traditional design processes is the fact that biomimicry uses biology and ecology in the process. This could ensure a design that requires sustainable measures.

Other related strategies but not biomimicry (Benyus, 2011):
- Bio–utilized: harvesting a product or producer
- Bio–assisted: domesticating an organism to accomplish a function
- Learning about nature

Next to the ‘bio…’ related strategies there are more strategies which overlap with the theory of biomimicry.
- Cradle 2 cradle: but mostly used in industrial systems, focus on product level.
- Industrial ecology: focussed on large industrial systems with multiple actors.
- Regenerative system design: process oriented approach for design based on systems theory. Regenerative refers to the processes that restore, renew or...
revitalize their own sources of energy and materials. In this way sustainable systems are created which integrate the needs of society with the integrity of nature.

- Metabolism: the sum total of the technical and socio-economic process that occur in cities, resulting in growth, production of energy and elimination of waste (Kennedy et al., 2007).

### 3.2.5 Biomimicry in practise

At the moment the main field of developments are form and function morphology (Velcro) related fields, biocybernetics (genetic algorithms), sensor technology, robotics (sensor technology) and nanobimimetics (research on spider silk) (Gleich et al., 2010). Different levels of biomimicry are used. Biomimicry also appears in architectural design (Wise et al., 2013). Different stakeholder/actor groups are involved with the subject of biomimicry in the Netherlands. The stakeholders can be divided in clusters; Universities, government, architects, municipalities, foundations and engineering firms. The clusters have mutual contact with each other. Different actors approach biomimicry on a different way. For example at the faculty of 3ME Paul Breedveld looks to the level form, while at the faculty of TBM Jaco Appelman looks to the level of processes (Appelman, 2013, Breedveld, 2013). See appendix 1 for the complete overview of spoken actors.

Biomimicry has not been used much in the field of urban design. In Germany there are a few pilot project of biomimicry in urban design. HOK, Arup and AE.COM and Draaijer + Partners are companies which are working on this topic. To gain understanding in the current applications of biomimicry, a case study is performed. The goal is to give insight in the fields of application and the used levels of biomimicry and scales. The focus of the case study lies in the field of urban design and architecture, to get inspiration and information about the existing ideas in this design field. With this overview, relations can be found between the used levels of biomimicry, scales and field of application. The case study is presented in image .... The case studies are connected with the level of biomimicry: form, process and system. Also generic principles from nature are added, as it is not always a specific level that is used. The scale of the example from nature is indicated according to Odem (detailed explanation can be found in chapter 4) and the field of application is indicated according to Gleich.

![Fig. 15: Overview of the used categories in the case study](image)

**Level of biomimicry:**

- General principles
- Form
- Process
- System

**Scales in a natural system (Odum, 2005)**

- Landscape
- Ecosystem
- Community
- Population
- Organism
- Organ system
- Organ
- Tissue
- Cell

**Fields of application (Gleich et al., 2010)**

- Industrial Design & Architecture & Urban Planning
- Construction and structures
- Medical technology
- Materials and surfaces
- Process optimisation
- Sensing (not mentioned)
- Communication & information processing
- Movement and locomotion
- Organisation & self organisation
When looking at all the project the conclusion can be drawn that the most used level of biomimicry is the form, in the most projects examples from plants are used on the organism scale in nature. In the field of urbanism this is different. Two projects are found in this research field and they both use the same scales and levels of biomimicry: the level of systems, on the scale of ecosystems and with this both plants and animals function as inspiration. The application is on varying urban levels; form building ensemble up to city scale. In architecture this is different: the level of form is used most often, plants function as inspiration almost in all the cases and the organism scale is the most used one. The application is on the urban scale of a buildings or building ensembles.

So there are some existing examples of biomimicry in an urban design or architecture. But both examples of urban designs show a design for a completely new city or neighbourhood of an area. There is no existing urban context and the projects are disconnected from the existing urban tissue. For further research it is not a requirement to only use the indicated levels and scales in urban design from the case examples. Other options (of levels and scales) should be let open, because the existing urban transformation and context is not taken into account in the case examples.

Fig. 16: Conclusions casestudy

**Overall used levels and scales**

**Architecture:**
- Form
- Plants
- Organism

**Urban design:**
- Process
- System
- Plants and animals
- Ecosystem
CASE STUDY: BIOMIMICRY IN PRACTICE

CASE 1: Water Wall, Brazil
Urban commercial center
HOK Architects

Description
This project had a glass building facade outfitted with slanted blades offering shade from the sun. We wanted to develop a system that, like the Brazilian rainforest, would reject heat while returning water to the atmosphere. When we realized that changing the horizontal blades to spirals would atomize cascading water, sending it back into the surrounding environment, it dawned on me: the building could reject heat and conserve water. This multifunctional capability is ever-present in nature but often ignored or even rejected in our compartmentalized world.

Consulted organism/system
Rainforest, Ferns

Strategy
Transpiration of a leaf:
Water stays in the ecosystem (rainforest). The leaves of plants transpire water from their storage, to cool the organism. The water evaporates into the air.

Case Study: Biome in Practice

CASE 2: Lavasa India
Masterplan
HOK

Description
The key for the designers was to identify the most important ecosystem services in Lavasa’s biome. Water collection, storage and filtration are crucial, as the city sees 30 feet of rainfall during monsoon season, followed by a period of drought.

Lavasa experiences limited runoff and erosion because its trees engage in hydraulic distribution, which is one strategy we explored. Wide, shallow roots collect water, driving the excess deep into the soil for storage. Our team worked with engineers at Buro Happold to develop a building foundation capable of hydraulic redistribution.

We planned green roofs designed to prevent soil erosion and to create wind turbulence to aid evaporation. Already, 20 to 30 percent of the monsoon season water evaporates due to Lavasa’s tree canopy. The design also restores 70 percent of deforested land, reviving a variety of ecosystem services.

Consulted organism/system
Local ecosystem
Bromeliad

Strategy
- Commuting: Most things are within a 10 minute radius from home or work
- Connectivity: A network of streets, boulevards and alleys to easily disperse traffic
- Mixed Use and Diversity: A melting pot of inhabitants from all walks of life and a mix of commercial and residential premises within neighborhoods, blocks and apartments
- Mixed Housing: A range of living spaces based on a variety of factors - size, proximity to the town centre, type, price and income groups
- Quality Architecture and Urban Design: Detailed attention to aesthetics and human comfort
- Traditional Neighbourhood Structure: A discernable city centre and more open public spaces that encompass a range of uses and densities
- Planned Increased Density: Transect Planning, wherein population density decreases progressively as it moves away from the town centre
- Smarter Transportation: An advanced and cost-effective commuting network for enhanced efficiency
- Sustainability: Minimal impact on the environment
- Quality: A better life and soul space
### CASE 3: Meixi Lake, China
Masterplanning a new residential district
HOK

**Description**
We took a similar approach when master planning a new residential district around Meixi Lake in Wuhan, China. Inspired by the local ecosystem, we designed buildings of varying sizes and forms, arranging them like trees in a forest to permit at least two hours of daylight to penetrate into each dwelling. We left half the landscape open for parkland and to promote water movement, and designed pathways leading to public transportation options.

**Consulted organism/system**
Local ecosystem

**Strategy**
- Buildings of varying sizes and forms
- Arranging the buildings like trees in a forest to permit at least two hours of daylight to penetrate into each dwelling
- Half the landscape is left open for parkland and to promote water movement
- Pathways designed, leading to public transportation options

More information
http://www.hok.com/thought-leadership/natural-inspiration-through-biomimicry

### CASE 4: Port-Au-Pince, Haiti
William Jefferson Clinton Children's Centre
HOK

**Description**
HOK's Thomas Knittel took inspiration from the kapok tree, a native Caribbean species that stores water internally and sheds its leaves in times of drought. The kapok tree has spiritual significance to Haitian culture – an earth-to-sky mentality that is imparted into the branching support of the building’s balcony system. Mother limbs are twice the mass of daughter limb pairs, and a simple, cellular structure ensures easy replication.

**Consulted organism/system**
Kapok Tree

**Strategy**
- Construction
- Water storage

More information
http://www.hok.com/thought-leadership/natural-inspiration-through-biomimicry

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- **Level of biomimicry**
  - General principles
  - Process
  - System

- **Scale**

- **Field of application**
  - Industrial Design & Architecture & Urban Planning
### CASE 5: San Francisco, USA
Renovation of the San Francisco Museum at the Mint
HOK

**Description**
To get the most from the site’s water resources, we found a long-covered cistern in the central courtyard that taps into a deep well fed by a spring. Next, we organized a biomimicry design charrette and worked with a biologist to look at how native Bay Area plants, especially ferns and succulents, use the precipitation here. This includes the few months of rain we get in the winter as well as the year-round fog that blankets the area on most mornings. We discovered that, to collect this water, many of the native plants are covered in countless tiny nodules. The surface of the nodules resembles a half-round bump. When water falls on a plain, flat surface like a sheet of glass, it immediately runs off. When water falls on a horizontal surface that has nodules, it coats the nodules. There is more area to capture water before it runs off.

Our design creates a glass canopy structure floating above the Old Mint’s existing open-air courtyard. The canopy ties the building together structurally, brings in daylight and preserves the historic courtyard facade that is currently crumbling. This canopy captures rainwater and moisture from the fog with the use of a fritted system -- a ceramic dot screen raised above the surface of the glass canopy. The frits modulate the daylight and glare and the surface provides 100 percent more area for moisture to collect. When it drains off the glass, the water is captured by cisterns sitting on the roof. The roof becomes a living museum exhibit that relates to the site’s wetland past.

**Consulted organism/system**
Native bay area plants

**Strategy**
- Construction
- Water storage

**Level of biomimicry**

**Form**

**Scale**

**Field of application**
Industrial Design & Architecture & Urban Planning

---

### CASE 6: Swiss Re Insurance Tower, London
Norman Foster

**Description**
The design of the iconic Swiss Re Insurance Tower in London by Norman Foster, known as “the gherkin” for its unique shape, was actually based on the form of the glass sea sponge. These deep sea organisms survive despite the absence of light, thanks to multi-tiered structures comprised of silicates (glass). The strands wrap and layer in seven different directions, resulting in a structure that is as incredibly strong as it is beautiful, allowing the sponge to filter water and sequester food. In the Swiss Re Tower, floors are staggered around an inner core that serves as a ventilation chamber, resulting in a 40% reduction in energy use to heat and cool the building.

**Consulted organism/system**
Glass sea sponge

**Strategy**
Construction: less material, optimal strength

**Level of biomimicry**

**Form**

**Scale**

**Field of application**
Industrial Design & Architecture & Urban Planning
Construction and structures
Architect Mick Pearce collaborated with engineers at Arup Associates to build a mid-rise building in Harare, Zimbabwe that has no air-conditioning, yet stays cool thanks to a termite-inspired ventilation system. The Eastgate building is modeled on the self-cooling mounds of Macrotermes michaelseni, termites that maintain the temperature inside their nest to within one degree of 31 °C, day and night, while the external temperature varies between 3 °C and 42 °C. Eastgate uses only 10 percent of the energy of a conventional building its size, saved 3.5 million in air conditioning costs in the first five years, and has rents that are 20% lower than a newer building next door.

The TERMES project, organized by Rupert Soar of Loughborough University, is digitally scanning termite mounds to map the three dimensional architecture in a level of detail never achieved before. This computer model will help scientists understand exactly how the tunnels and air conduits manage to exchange gases, maintain temperature, and regulate humidities. The designs may provide a blueprint for self-regulating human buildings.


CASE 7: Eastgate, Harare, Zimbabwe
Mick Pearce

<table>
<thead>
<tr>
<th>Description</th>
<th>Consulted organism/system</th>
<th>Strategy</th>
<th>Level of biomimicry</th>
</tr>
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<td>Architect Mick Pearce collaborated with engineers at Arup Associates to build a mid-rise building in Harare, Zimbabwe that has no air-conditioning, yet stays cool thanks to a termite-inspired ventilation system. The Eastgate building is modeled on the self-cooling mounds of Macrotermes michaelseni, termites that maintain the temperature inside their nest to within one degree of 31 °C, day and night, while the external temperature varies between 3 °C and 42 °C. Eastgate uses only 10 percent of the energy of a conventional building its size, saved 3.5 million in air conditioning costs in the first five years, and has rents that are 20% lower than a newer building next door.</td>
<td>Termite nest</td>
<td>Natural cooling system</td>
<td>Form</td>
</tr>
</tbody>
</table>

CASE 8: High Speed train, Japan
Eiji Nakatsu

<table>
<thead>
<tr>
<th>Description</th>
<th>Consulted organism/system</th>
<th>Strategy</th>
<th>Level of biomimicry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning Efficiency from Kingfishers The Shinkansen Bullet Train of the West Japan Railway Company is the fastest train in the world, traveling 200 miles per hour. The problem? Noise. Air pressure changes produced large thunder claps every time the train emerged from a tunnel, causing residents one-quarter a mile away to complain. Eiji Nakatsu, the train’s chief engineer and an avid bird-watcher, asked himself, “Is there something in Nature that travels quickly and smoothly between two very different mediums?” Modeling the front-end of the train after the beak of kingfishers, which dive from the air into bodies of water with very little splash to catch fish, resulted not only in a quieter train, but 15% less electricity use even while the train travels 10% faster.</td>
<td>King fisher</td>
<td></td>
<td>Form</td>
</tr>
</tbody>
</table>

More information
http://www.hok.com/thought-leadership/natural-inspiration-through-biomimicry

Field of application
Industrial Design & Architecture

CASE 9: Wind turbine blades

Description
Learning from Humpback Whales How to Create Efficient Wind Power
Like a school bus pirouetting under water, a humpback whale (Megaptera novaeangliae) – 40-50 feet long and weighing nearly 80,000 pounds – swims in circles tight enough to produce nets of bubbles only 5 feet across while corralling and catching krill, its shrimp-like prey. It turns out that the whale’s surprising dexterity is due mainly to its flippers, which have large, irregular looking bumps called tubercules across their leading edges. Whereas sheets of water flowing over smooth flippers break up into myriad turbulent vortices as they cross the flipper, sheets of water passing through a humpback’s tubercules maintain even channels of fast-moving water, allowing humpbacks to keep their ‘grip’ on the water at sharper angles and turn tighter corners, even at low speeds. Wind tunnel tests of model humpback fins with and without tubercules have demonstrated the aerodynamic improvements tubercules make, such as an 8% improvement in lift and 32% reduction in drag, as well as allowing for a 40% increase in angle of attack over smooth flippers before stalling. A company called WhalePower is applying the lessons learned from humpback whales to the design of wind turbines to increase their efficiency, while this natural technology also has enormous potential to improve the safety and performance of airplanes, fans, and more.

Consulted organism/system
Whale

Strategy
Change airflow with blade form

Level of biomimicry
Form

Scale

Field of application
Construction and structures

CASE 10: Surface structure
Clean without cleaners: water-repellent surface

Description
Learning from Lotus Plants How to Clean without Cleaners
Ask any school child or adult how leaves keep water from sticking to them, and they’ll almost certainly say, “Because they are so smooth.” Yet one of the most water-repellent leaves in the world, that of the Lotus (Nelumbo nucifera), isn’t smooth at all. The myriad crevices of its microscopically rough leaf surface trap a maze of air upon which water droplets float, so that the slightest breeze or tilt in the leaf causes balls of water to roll cleanly off, taking attached dirt particles with them. Now, microscopically rough surface additives have been introduced into a new generation of paint, glass, and fabric finishes, greatly reducing the need for chemical or laborious cleaning. For example, GreenShield, a fabric finish made by G3i based on the “lotus effect”, achieves the same water and stain repellency as conventional fabric finishes while using 8 times less harmful fluorinated chemicals.

Consulted organism/system
Lotus

Strategy
Lotus plants have superhydrophobic surfaces: water droplets falling onto them bead up and, if the surface slopes slightly, will roll off. As a result, the surfaces stay dry even during a heavy shower. What’s more, the droplets pick up small particles of dirt as they roll, so that the lotus leaves are self-cleaning.

Level of biomimicry
Form

Scale

Field of application
Materials and surfaces
### CASE 11: Agriculture

**Description**
Learning from Prairies How to Grow Food Sustainably

Take a look at any natural ecosystem, such as a prairie, and you will see a remarkable system of food production: productive, resilient, self-enriching, and ultimately sustainable. The modern agricultural practices of humankind are also enormously productive, but only in the short term: the irrigation, fertilizer, and pesticide inputs upon which modern food crops depend both deplete and pollute increasingly rare water and soil resources. The Land Institute has been working successfully to revolutionize the conceptual foundations of modern agriculture by using natural prairies as a model: they have been demonstrating that using deep-rooted plants which survive year-to-year (perennials) in agricultural systems which mimic stable natural ecosystems – rather than the weedy crops common to many modern agricultural systems – can produce equivalent yields of grain and maintain and even improve the water and soil resources upon which all future agriculture depends.

### CASE 12: Industrial design

**Description**
Learning from Trees and Bones How to Optimize Strength and Materials

The next time you drive through a forest, go ahead and thank the trees out your window for helping on your car’s crash safety and gas mileage. Trees engineer themselves in a number of ways to maximize their strength, such as arranging their fibers to minimize stress and adding material where strength is needed (take a look at the extra material beneath a heavy branch, for instance). Bones – unlike trees in that they must carry moving loads – go a step further by removing material where it’s not needed, optimizing their structure for their dynamic workloads. Engineers have incorporated these and other lessons learned from how trees and bones optimize their strength and minimize their use of materials into software design programs, such as Claus Matteck’s “Soft Kill Option” software, which are revolutionizing industrial design. Using these programs to design cars, for example, has resulted in new vehicle designs that are as crash-safe as conventional cars, yet up to 30% lighter.
### CASE 13: Interface floor

**Description**
We combined the ideas and characteristics of the natural world with our tufting technology to produce totally random tiles, each slightly different in pattern and colour. With no repeat pattern the tiles don’t have to be installed in the same direction, and if an individual tile or area of tiles is damaged, they can be replaced without disturbing the overall look of the floor.

Random tiles can also reduce waste, with off-cuts being used to fill in any perimeter area. This has always been possible with traditional carpet tiles, but with random products you don’t have to find the correct piece of the pattern in the right size or direction.

Benefits of random tiles and non-directional installations:
- Increased flexibility
- Quick to install
- Less waste
- Longer life cycle
- Easy to maintain and repair

**Consulted organism/system**
Nature’s principles

**Strategy**

### CASE 14: Bioinspired medical instruments

**Paul Breedveld**

**Description**
“Gebruikmakend van de anatomie van inktvistentakels, maken we op dit moment de dunste (diameter 0,9 en kleiner) en meest beweeglijke stuurbare instrumenten ter wereld.”

Inktvistentakels zijn opgebouwd uit ingenieuze samenstellingen van spieren die met elkaar samenwerken in verschillende lagen, ringen, bundels en pakketjes. De eerste instrumenten die Breedveld maakte, waren gebaseerd op een enkele ring van stalen kabeltjes omringd door springveren; de nieuwe instrumenten zijn gebaseerd op een zogenoemd dendritisch mechanisme, dus met vertakkingen. Ze bestaan uit een flexibele stam die uitloopt in diverse manoeuvreerbare armen. Iedere arm bestaat uit een dicht gestructureerd pakket van flexibele stuurelementen. De instrumenten beschikken tevens over vormgeheugen; ze ‘weten’ dus waar we geweest zijn.

**Consulted organism/system**
Octopus

**Strategy**

### More information

CASE 15: Business inspired by nature

<table>
<thead>
<tr>
<th>Description</th>
<th>Consulted organism/system</th>
<th>Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Firm of the Future brings the values of sustainability to its core and, in doing so, generates value for itself, its communities and the ecosystems in which it operates. The Firm of the Future is a Business Inspired by Nature, functioning like an adaptive living organism, thriving within ever-changing business and socio-economic systems, resilient to disruptions and interdependent within the largest ecosystem of all – Earth.</td>
<td>Nature’s principles</td>
<td>Organism &amp; self organisation</td>
</tr>
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<td></td>
<td></td>
<td>Communication &amp; information processing</td>
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</tbody>
</table>

Using computational modeling, we design colonies of biomimetic microcapsules that exploit chemical mechanisms to communicate and alter their local environment. As a result, these synthetic objects can self-organize into various autonomously moving structures and exhibit ant-like tracking behavior. In the simulations, signaling microcapsules release agonist particles, whereas target microcapsules release antagonist particles and the permeabilities of both capsule types depend on the local particle concentration in the surrounding solution. Additionally, the released nanoscopic particles can bind to the underlying substrate and thereby create adhesion gradients that propel the microcapsules to move. Hydrodynamic interactions and the feedback mechanism provided by the dissolved particles are both necessary to achieve the collective dynamics exhibited by these colonies. | Ant colonies | Process optimalisation |
| | | Field of application |

More information
Biomimicry for creative innovation. The firm of the future. A business inspired by nature. Guidelines for sustaining organizations towards 2020


CASE 16: Organisation Strategies for automated guided vehicles / Robotics

<table>
<thead>
<tr>
<th>Description</th>
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<th>Strategy</th>
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<tr>
<td>Using computational modeling, we design colonies of biomimetic microcapsules that exploit chemical mechanisms to communicate and alter their local environment. As a result, these synthetic objects can self-organize into various autonomously moving structures and exhibit ant-like tracking behavior. In the simulations, signaling microcapsules release agonist particles, whereas target microcapsules release antagonist particles and the permeabilities of both capsule types depend on the local particle concentration in the surrounding solution. Additionally, the released nanoscopic particles can bind to the underlying substrate and thereby create adhesion gradients that propel the microcapsules to move. Hydrodynamic interactions and the feedback mechanism provided by the dissolved particles are both necessary to achieve the collective dynamics exhibited by these colonies.</td>
<td>Ant colonies</td>
<td>Communication: Adaptive and Natural Computing Algorithms</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Field of application</td>
</tr>
</tbody>
</table>

More information
Communication & information processing Organisation & self organisation

MEASUREMENT 1: Photovoltaic “leaves”
SMIT’s Solar Ivy

Description
Imagine a building covered in ivy. Now imagine that the leaves can harvest energy from the sun and wind to power the building. That’s exactly what SMIT’s Solar Ivy product does: these photovoltaic leaves cover the facade while collecting solar energy. SMIT has also researched using photovoltaic electric crystals on the “stems” to generate electrical energy as wind blows across the facade. The result is a facade that is both aesthetically pleasing and functional — much like nature itself.

Consulted organism/system
Plant leaves

Strategy
Energy collection by solar energy and wind energy.

More information
http://solarivy.com/the_idea

Level of biomimicry

Form

Scale

Field of application
Industrial Design & Architecture & Urban Planning
3.2.6 Threats and driving forces
There are still a couple threats for biomimicry, which
are questionable when applying the theory into prac-
tice. There are things which have to be taken into ac-
count in this research, and further research. It is an
important task of the urban designer to see biomim-
icry as a possible solution for designing, but not as
the definite right answer for a problem. These are the
following things;
First of all Gleich et al. (2010) are pointing to the fact
that it is hard to adjust complex systems into human
problems. Easy problems can be applied more eas-
ily, but when a natural system get more complex, it is
hard to apply in other contexts. Secondly there lies a
difficulty in isolating and transfer only some aspects of
a system. It is questionable whether this part will func-
tion on the same way in another system. So are na-
ture’s solutions directly accessible for us (Ball, 2001)?
Next to the substantive questions there are also practi-
cal obstacles for biomimicry;
- A small community and individuals are performing
biomimicry at the moment
- Limited institutional resources to give information
over the expanded strategy of learning from nature.
- The implementation in practise only to a limited ex-
tent
- Discipline based traditions and strategies make it
more difficult to apply biomimicry.
- Scepticism among researchers and businessman
to fascination with biomimetic ideas (Gleich et al.,
2010).
But luckily there are also driving forces behind bio-
mimicry which ensure the emerging of the theory: First
the field of inquiry is expanding. Secondly it gives a
positive image of new technologies for the appliers
of biomimicry. Thirdly the fact of self-organisation
or self-growth is something which is happening. Fi-
nally the current questions raise opportunities for bio-
mimicry: “The increased demand for addictiveness
of technical systems and the capability to cope with
complexity have, at least in part, paved the way for
the biomimetic” (Gleich et al., 2010, p. 183). At the
moment we also have lab techniques to understand
how nature works. This makes us able to mimic parts
on small scale.
3.3 URBAN REGENERATION

3.3.1 Introduction
In this paragraph an explanation is given about the urban regeneration design field. First a definition of urban regeneration is given. The focus on one of these forms is chosen for this research, based on the context of change. This is elaborated. After this examples of existing project are elaborated. These designs will later be compared with the design outcomes of this research. The differences between current design strategies and the biomimicry design strategy can be mapped in this way. The focus lies on regeneration as people are central and use of space in human environment: city / village context.

The issue of scales in urbanism is an important factor for this research. It is questionable on which scales interventions based on biomimicry should be performed. In order to express an opinion about the application of scales, the theme scales is further elaborated. Also the difference between level and scale is presented. This is important for a later bridge from urban design to biomimicry and the other way around.

**Definition**

Urban regeneration is described by Roberts and Sykes as follows:

“comprehensive and integrated vision and action which leads to the resolution of urban problems and which seeks to bring about a lasting improvement in the economic, physical, social and environmental condition of an area that has been subject to change” (Roberts and Sykes, 1999). This definition is used for further research.

3.3.2 Scales in urbanism
In the urban design field there are different scales distinguished by different experts. An overview of these combined scales is given, to include all possible strategies on what an urban scale is. The question of scale and proportion in the field of urban design is important, states Moughtin. “the correct scaling of the urban landscape from the intimate human scale of the housing cluster to the extra human scale of the metropolitan area is of great importance for the way we appreciate our surroundings” (Moughtin, 2003 p.38).

The first scale is the temporal scale. Urban decisions can have a short-term effect and/or a long-term effect (Sassen, 2012, Hallegatte, 2009). The second scale is the spatial or structural scale which is subdivided into three themes or triggers.

The first subtheme is the physical boundary. These boundaries are described as geographical or geopolitical boundaries (Read, 2013). Other call these same boundaries political or economic boundaries (Sassen, 2012). Different scales can be distinguished: world, continental, country, region, city, neighbourhood, building and human.

There are structural and functional limits to the size of buildings. So too are there thresholds for the support of urban services, as well as physical limits which determine the ways in which we perceive and appreciate the urban landscape.

The second subtheme is functional boundary or distributational boundary. This functional boundary also includes the structural limits of building structures. But more important, on the scale of the human. Urban interventions are all based on the proportion of human, so in a way human determine the proportions of urban systems (Moughtin, 2003).

The third subtheme is the scale of urban conditions and dynamics, described by Sassen as “cycles of the built environment, of the economy, the life of infrastructures, and of certain types of investment instruments” (Sassen, 2012).

What is important is the link between the temporal and the spatial scale (between the first and the second scale). A spatial scale should be linked to the timescale, because in some situations the effect of a design on short term differs from the effect on the long term.

Then there is the difference between scale and level. A scale has a different entity. A change of scale results in new interactions and relationships. A new organisation is set up. A level is a change in quantity. A relative position in a hierarchal organised system. A change of level can however ensure a change in scale (Sassen, 2012).

An extra complexity arises because of the interaction of different scales. It is not precisely clear what the effect on the one scale is on another. There may be other factors which influence one scale, so a direct cause-consequence link between scales is not directly possible. For example we look at a road with traffic jams is broadened to solve this problem. When the traffic jams vanish, this could also be an effect of people taking the public transport instead of their car, and not a direct consequence of the broadening of the
This section is about changes in our living environment, which are central themes in the pilot cases. The contexts of the changes are described for a better understanding of this.

The first point of change is the one due to human demands and requirements, which ensure a change in the urban environment.

The second point of change is due to natural processes. The most relevant example for urban design is climate change. This is the most relevant because climate change could have a direct impact on our living environment (Calthorpe, 2012). Climate change: is defined by the IPCC as: “a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity” (Pachauri and Reisinger, 2007). Climate change affects the Netherlands according to the KNMI (Döpp and Albers, 2008). Global climate change will affect the Netherlands on the following ways: Increasing temperature; Change in precipitation pattern and wind directions; Extreme weather conditions; Sea level rise. These changes will affect our living environment on the topics of: Safety; Economy; Ecology; Social structures; Societal structures; Health; Quality of the living environment. We can respond to this in different ways: mitigation and adaptation.

Adaptation: the adaptability of an area. Adaptation can consist of behaviours and of structures (Pickett, 2013).

For a better understand of the scientific field of biology a few definitions are important:

Ecosystem: a system of organisms which forms a whole in a territory, easily said. The term can be defined in various ways. An ecosystem is an entity in which organisms interact with the physical environment in a certain area, where a flow of energy ensures the creation of clearly defined structures and cycles between living and non-living parts. The systems are open which means that a system could stay the same, while sub functions change.

Ecology: This term with a very broad scope is centred around interactions of organisms and the processes and structures they generate or are involved in. The science refers to two things: “(1) the activity that leads to discoveries about organisms, environmental interactions, and the structures and processes that result; and (2) the body of knowledge, in all its forms, that summarizes those discoveries” (Pickett, 2013, p.28).

To understand the possible effects of the application of biomimicry in urban design a couple definitions are important:

Sustainable development: The transition strategy for handling the needs of the present without compromising the well-being of future generations (Timmeren, 2013, p. 14). Sustainable development is divided in three aspects: social sustainable development (peo-
3.5 STRATEGY GENERATING

What exactly will be composed? Is it a method, a strategy, an approach, are it guidelines or principles etc.? Different interpretation can be given to those terms. A definition is given of each term and with those definitions, a choice is made about what will be conducted in this research.

Method: Research processes that are common across the entire range of architectural research, including content areas from the technical fields to the humanities and from the pragmatic to the most theoretical (Groat and Wang., 2002).
Strategy: The overall research plan or structure of the research study’ (Groat and Wang., 2002), p.10).
Vision: The ability to think about or plan the future with imagination or wisdom.
Approach: A way of dealing with a situation or problem.
Framework: An essential supporting structure of a building, vehicle, or object.
Structure: way in which a composite is constructed or made up.
Guidelines: A general rule, principle, or piece of advice.
Principles: A fundamental truth or proposition that serves as the foundation for a system of belief or behaviour or for a chain of reasoning.
Plan: An intention or decision about what one is going to do.
Scheme: A large-scale systematic plan or arrangement for attaining some particular object or putting a particular idea into effect.

Pattern: A regular and intelligible form or sequence discernible in the way in which something happens or is done.

The design steps that are developed show HOW a design can be performed. It is not about the why or the what, but the ‘how’ step in between. Therefore the strategy will be conducted for the application of biomimicry in urban redesign.

Fig. 17: Why-How-What
3.6 CONCLUSIONS THEORETICAL FRAMEWORK

The sub question about the literature study answered in this chapter is the following:
What are the differences and similarities between biomimicry and urban redesign?

The differences and similarities are imbedded in the following conclusions. These conclusions should be taken into account for further research:
- Two existing design spirals: they could both be used in the process of an urban design. But the spiral from biology to design must not be used on itself. This could only be used if the other way around (from human to biology) is also used. Using only the first would not be sufficient enough to base an urban design on. This is because more functions and systems should be integrated in an urban design. An urban design cannot be changed only based on an idea out of nature. A cause of a change and a problem related to that should first be investigated before implementing design solutions.

There are three levels of learning from biomimicry. The chances for urbanism lay on the level of process and especially on the level of systems. This is because the level of form brings most likely a small-scale solution, and does not respond to interactions of different layers. The level of system and process are the most important focus points, as the urban living environments exist out of many processes and systems itself.

These systems are the most complex ones, where learning from nature could form a good solution to improve this.

- One of life’s principles is ‘adapt to changing conditions’. If the final step of both the design spirals is also taken into account in the strategy, this should be a condition for the resulting designs.

- There is a difference between the species Homo sapiens and other species. A critical view is needed about the use of knowledge of other species to solve human problems.

- Urban regeneration is place/location specific. For the strategy it must be ensured that the location forms at least one starting point to select urban problems.

- In urbanism the timescale of an intervention or action is very important. The timescale should be included when looking at examples from nature.

- In urbanism most of our surroundings are tuned or based on human proportions. In the further research a critical view against non-human scale interventions should be taken. The design method should include a human starting point, as this forms the number one cause of urban regeneration.

Fig. 18-23: Conclusions of theoretical framework
Change brings opportunity –

Nido Qubein
4.1 THE STRATEGY

Introduction
A design strategy for the use of biomimicry in urban (re)design is presented in this chapter. This strategy is conducted with the conclusions of the theoretical framework and by undergoing the proposed strategy. While executing the steps, additions and omissions were made which resulted in this final strategy.

The questions that will be answered in this chapter are: 2. How could biomimicry be translated into a strategy for the field of urban redesign? Which points of attention should the strategy satisfy?

Description
Analysis and idea generation
Step 1: Analyse natural systems on location
Goal: the rise of design requirements or ideas and understanding the context of the design location
Step 2: Analyse human systems on location and understanding the context of the design location
Goal: the rise of design requirements or ideas
Step 3: Search for ideas and inspiration in nature
Goal: the rise of ideas and/or requirements for design interventions, strategies or measurements

Elaboration and bridge between fields of research
Step 4: Places analyses and ideas in scales of natural and human systems and in timelines
Goal: Understand the natural and human systems and understand comparisons between them. Create a link between analyses and ideas and create a link between natural and human systems.

Step 5: Express ideas and analyses in urban aspects
Goal: make ideas and analyses tangible for the urban designer and other actors. Create a link between analyses and ideas, and create a link between natural and human systems.

Design and reflect
Step 6: Select ideas
Goal: pick ideas generated in step 3 for solving the indicated issues in step 1 and 2. The ideas can be compared with each other by step 4 and 5.

Step 7: Implement ideas and create concepts
Goal: translate ideas into a design.

Step 8: Reflect the design on requirements of step 1 and 2, and on the biomimicry life’s principles.
Goal: Find out whether the design follows the principles of nature and meets the requirements of biomimicry.

Existing biomimicry spirals
with logo’s Verali
Biomimicry spiral Verali
Summary spiral Verali

Fig 24: Design spiral of biomimicry in urban redesign
The leave indicates that the step is going about the field of research of biology. The human means that this step is going about the field of research of urban design.
1. Analyse natural systems on location
   
   Rise of design requirements or ideas

2. Analyse human systems on location
   
   Rise of design requirements (or ideas)

3. Search for ideas in nature
   
   Rise of design ideas (or requirements?)

4. Place ideas and requirements in scales and time lines

   ![Day scale](image1)
   ![Year scale](image2)

   Understand comparison nature and human systems

5. Express ideas in urban aspects

   Making urban aspects tangible in the ideas of nature

   - Added values
   - Actors for implementation
   - Rate of adaptability
   - Type of space
   - Resiliency
   - Profit
   - Lifespan of idea
   - Sustainability profile

6. Select ideas

7. Implement concepts and ideas on location
   
   Based on requirements step 2.

8. Reflect design on life’s principles & design requirements step 1 & step 2.

   Does the design follow the principles of nature and biomimicry?
   The design can be tested on sustainable values.
4.2 PHASE 1 ANALYSIS AND IDEA GENERATION

Fig 25: Design strategy biomimicry in urban redesign.

1. Analyse natural systems on location
   \[ \text{Rise of design requirements or ideas} \]

2. Analyse human systems on location
   \[ \text{Rise of design requirements (or ideas)} \]

3. Search for ideas in nature
   \[ \text{Rise of design ideas (or requirements?)} \]

Step 1. Analyse natural systems on location (biology to design): Analyse the existing or past ecosystems on the location. What would have happened if no human interventions took place? Translate these into functions. Critical question which can help in the analysis process: How does nature facilitate change at the location? In this step design requirements or ideas can rise.

Step 2. Analyse human systems on location (challenge to biology): Perform urban analysis of location. Critical question which can help in the analysis process: How do humans facilitate change at the location? In this step the urban problems and requirements or ideas are collected.

Step 3. Search for solutions of the human problems in nature. Start by converting the problem into function and search for similar functions of this problem in biology.

The following question for nature could be asked: How does nature facilitate change in general / independent on the location?

These three steps are conducted with the current method of biomimicry taken into account, in other design disciplines. However the strategy ‘biomimicry in urban design’ differs from the method of biomimicry as can be seen in figure 22 and 23. In strategy 1.0 the factor ‘location’ is taken into account. The factor ‘human’ is added in searching for solutions. The idea of biomimicry is that solutions of human problems can be found in nature. In method 1.0 this idea is included and supplemented with existing ‘human’ solutions. This is because the structure of the method is not based on only the theory of biomimicry, but is combined with urban design methods. In this way the method of biomimicry is not taken as a ‘truth’ but is a part of the design method which will be researched on usability in this research.

In figure 26 two axes divide the ‘search-field’ in four quadrants. These four quadrants are starting points for generating ideas, and for finding solutions. The upper left quadrant represents searching in solutions and problems of nature, on the specific location. The upper right quadrant represents searching solutions and problems of human aspects, on the specific location (‘human’ is interpreted as discussed in chapter 3.1). The lower left quadrant represents general solutions and problems of nature. This quadrant is more for the solution finding part than for the problem part for urban design. The lower right quadrant represents general solutions and problems of human aspects. This quadrant is also more for the solution finding part than for the problem part for urban design. The general problem of this research is a found in the lower quadrants. The focus of this research lies in the upper two and the lower left quadrants.
Fig. 26: Analysis quadrants

Fig. 27: Focus point of this research on parts of the method

Fig. 28: Existing method of biomimicry. There are two starting points for searching solutions or detecting problems: human and nature. General solutions from all over the world are used for solutions. The context is taken into account, but the geographical location is not required.
4.3 PHASE 2 ELABORATE

In this step the design requirements and ideas are made tangible for an urban designer in order to:
- understand the natural system
- understand the human system
- understand the possible application of an idea out of nature in an urban context.
- Create a link between the natural and human systems
- Create a link between the analysis and ideas

This is accomplished with the following characteristics:
- The analysis and ideas are placed in a natural and human scale. The scales are presented in image XX on page 44 and 45.
- The analysis and ideas are placed in a time scale of the lifespan of an organism.
- The analysis and ideas are expressed in urban aspects. These aspects will be described in image XXX on page 46 and 47.

Step 4. Scales and time scales
On the next page: the scale of a natural system according to Odum (2005) is put next to the scale of an urban system (conducted by author). These two scales are holistic, which means that a sum of the one scale makes the following scale. These two scales are holistic, which means that a sum of the one scale makes the following scale. In our human living environment, a lot of different formats of scales can be identified. For example the social scale and the political management scale. These scales are not holistic. In this research these other scales are not taken into account, because the urban and the natural scale are the most important ones for the research question. However the other scales could also be very interesting to investigate for further research, and it must be taken into account that there are more formats of scales than only the human an natural scales which are described in this research.

Fig. 29: Comparison human and natural scales

Fig. 30: Human Scales and Social, Political and Natural scales (Odum, 2005)
Time scale

The life spans of the mentioned scales and levels are expressed in these infographics. 3 Scale bars are presented, in order to visualize the life spans clearly. Each scale bar can be recognised by its own color.

The filled area in the spiral indicates the amount of time.

Fig. 31: Time Scales

An example of the infills of the scale bars:

- 30-300 years
- 1 day
- 1 second - 45 minutes

Fig. 32: Example of Time Scales
5. **Express ideas in urban aspects**

Making urban aspects tangible in the ideas of nature

**Fig. 33: Express ideas in urban aspects**

**Step 5. Express ideas and analysis in urban elements**

The ideas of nature are made tangible for the urban designer with the following characteristics. The ratings are according to the experience and interpretation of the author.

**Fig. 34: Added value of measurements**

First the added value of a measurement or implementation is mapped. This classification is chosen because it is currently under attention in the design field of urbanism (IVAM, 2013).
Secondly the degree of easiness to implement the idea versus the genius of the idea is mapped. This is called the Now How Wow brainstorm technique (Byttebier, 2009):

NOW: ‘moderate’ or already existing idea but very easy to implement.

HOW?: Very strong idea but it is not completely clear how to implement it or it is very hard to implement is. More research could be necessary to implement the idea or the implementation steps need to be worked out further.

WOW!: Very strong idea and easy to implement. Act now instead of tomorrow!

Thirdly the rate of adaptability of the implementation or measurement itself is measured. This is done with two aspects; the degree of robustness and the degree of resilience based on the description Carmona gives:

Robustness: ability to accommodate change without significant change in the physical form (Carmona, 2010).

Resilience: ability to resist change without undue deformation (Carmona, 2010).

Fourthly the life span of the measurement or implementation itself is determined. This is the time it takes to change this measurement. The same life span indications are used as in the indication of life span with the scales from step 4. This rating is according to the experience and interpretation of the author.
When this is done, the ideas can be put next to each other, together with a specific column of the elaboration. For example the added value can be presented for each idea. Then the individual ideas can be compared. To make it more specific, also the scale of the idea can be added. This gives insight in the relation between different scales and ideas. When there is a problem on two different scales, it might be approached with one idea. This is made visible in this scheme. In the following chapter of the analysis an example is presented (Figure ... and ...). Different variables of the elaboration points can be put along the axes.

Fifthly the dynamic change of the measurement is indicated. It indicates how ‘fast’ the conditions of the measurement itself can change. For example the cooling of a building with water: the water could go in and out every 12 hours. The dynamic change occurs on the second scale. The lifespan of the measurement however is longer; it could be used for years.

And finally the type of space is determined. This information is about the type of space where the implementation can be done. The different distinguishes spaces are: inside a building, outside a building, on the border of inside and outside, above the ground, below the ground and on the border of above and below the ground.

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4.4 PHASE 3 DESIGN & REFLECT

Step 6. In the final phase the gained ideas are selected based on the requirements of the urban analysis (step 1.2). With the comparison of the ideas and variables of the elaboration, specific design ideas can be chosen to work out further.

Step 7. These design ideas can be combined in a concept; in this way a concept can contain multiple organisms or ideas, just like it is in natural systems. This forms a starting point for the design. With this concept, the urban designer can start designing and sketching on how to implement the ideas in the specific urban context. Different scales need to be taken into account. In this way the large scale systems are taken into account. Effects on the one scale influence another scale. By taken this into account the design can become a strong whole, with different design ideas and strategies on different scales which are working together.

Fig. 40: Design and reflect proces

6. Select ideas ➔ 7. Implement concepts and ideas on location

Based on requirements step 2.

8. Reflect design on life’s principles & design requirements step 1 & step 2.

Does the design follow the principles of nature and biomimicry?
The design can be tested on sustainable values.
Step 8. The final step is reflecting the proposed design. In this step the design is reflected on the design goals and requirements. Also the level of biomimicry can be evaluated if this is preferable. This depends on how important it is to completely mimic a specific organism, or whether it is sufficient to interpret the strategy of the organism. This can vary per project, client and user of this strategy. When the designers or clients are not content with the result, step 6 and 7 can be repeated. When this is still not satisfactory, step 3 up to step 7 can be repeated in the case that more design ideas are requested.

Fig. 41: Overview of all steps
4.5 INVOLVED ACTORS

Multiple actors can be involved in the strategy in different phases and steps. It is up to type of project which determines who is involved. This means that the involved actors do not have to change when using this strategy. In this way different kind of projects can be executed. Local residents can be involved for example in the strategy, when a bottom up strategy is required. When a top down strategy is preferable municipalities can be involved. It is also possible to combine all these actors in the strategy. This makes it flexible and diverse in use.

An overview of the possible and needed involved actors:

Step 1: Urban designer and/or possibly and landscape designer/ecologist

Step 2: Urban designer and client; analyse questions and issues stakeholders on location

Step 3: Urban designer, local residents, biologist, ecologist, client and other stakeholders: local residents can be involved in the idea generating step. The issues from the government, municipality and others from the analysis are used as input for the questions for nature. Local residents can also add questions they have, which can be discussed in a brainstorm. In this way, they can implement their own local issues and be stimulated or inspired by the ideas of nature.

Step 4: Urban designer and an ecologist or biologist when a specific strategy of nature must be implemented correctly.

Step 5: Urban designer is needed to translate the ideas of the analyses into tangible aspects of his discipline.

Step 6: Urban designer, client and local residents: Urban designers can make an overview of possible options or implementation (translate the ideas from nature to urban interventions at different scales), and local residents can choose what they prefer. The urban designer has a role of overviewing the different choices and monitoring the large scale strategy. In this way the urban designer functions as a gate keeper or filter and advisor for choosing the ‘right’ ideas on the ‘right’ location.

Step 7: An urban designer is needed to translate the ideas into concepts, principles, options or concrete design proposals. The role of the urban designer is very important in this step.

Step 8: Urban designer and client can reflect the requirements with the design. When these actors are not content with the result, step 6 and 7 can be repeated or even more steps as explained above.

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**ANALYSIS**

1. Analyse natural systems on location
2. Analyse human systems on location
3. Search for ideas in nature
4. Place ideas and requirements in scales
5. Express ideas in urban aspects
6. Select ideas
7. Implement concepts
8. Reflect design

**Legend**
- **Urban Designer** = Necessary actor
- **Client** = Optional actor

Fig. 42: Stakeholders involved
4.6 PROCESS OF STRATEGY DEVELOPMENT

During the research the method developed further and further. The development went in three steps; strategy 1.0 showed the four different ways of starting the analysis and search for ideas in nature. This is made visible in the four quadrants. This strategy existed out of an analysis phase and a design and reflection phase. In this version, a lot of different questions were asked to natural and human systems. When executing the steps, it was clear that it could be formulated more simple and easy and with less questions. So the next versions should have less steps and more simple ones (For example: the question ‘how does nature facilitate change at the location?’ could be the same as the question that is asked to nature in order to solve the existing human problems). The first analysis steps of the strategy were executed for one location. But after step 1 and 2 of the analysis, no clear conclusions could be drawn about the systems that are present at the location (in both nature and human context). So the strategy needed to be supplemented with guidelines to place the analysis into a system, in which human ‘scales’ can be compared with natural ‘scales’. Also the step of what nature could learn from human and what human could learn from nature is left out. This question is very difficult to answer, because it cannot be proven what nature could learn from human in this first place. Secondly possible approximation can be done with the conclusions of all the steps when they are performed. Then strategy 2.0 was developed: Step 4 was the added to make the feeling for scale tangible in the analyses. With this strategy step 3 was performed, and with this step 5 was brought into life: the connection of the first tangible urban aspects.

The strategy now consisted out of three phases as it is now. The analysis was connected with the scales, and the ideas were also connected with scales and with urban aspects. Then the strategy was fine-tuned with the connection between the urban aspects and the analysis steps, because the relation between the ideas and the analyses was missing. Strategy 3.0 was conducted. In this version the users or actors of the different steps were added.
05 | ANALYTICAL FRAMEWORK

Strijp – S :
The forbidden city –

New-S
5.1 INTRODUCTION

In this chapter, I present the first two steps of my strategy: the analysis and further elaboration. These are implemented on two different locations: the neighbourhood Strijp S in Eindhoven and the neighbourhood Agniesebuurt in Rotterdam. Here, only the conclusions of the performed analyses are presented. The complete analyses can be found in appendix II and III (page .. and page ...).

First, step 1 and 2 are presented for both Eindhoven and Rotterdam. Step 4 and 5 are integrated in the analyses. In this way, the information is integrated in the results of the analysis and is complete. These steps result in design goals for both locations. Secondly the questions for nature are formulated with these design goals. The used methods for gaining ideas are presented and the findings are described. The findings exist out of general principles from nature and specific inspiration from nature. The first findings are important to take into account in general or could turn into design ideas. The specific design ideas show strategies or consequences from systems which give an answer on the questions that are asked to nature. With this step 3 is performed and is integrated with step 4 and 5.

Finally the ideas from nature are made comparable in schemes. The first gives an overview of all the ideas and their added value for the urban context. This scheme can be used to choose ideas based on the added value they could deliver. Next is the scheme that also integrates the urban scale with the ideas and their added values. This scheme forms a handle for choosing ideas from nature for the application of a specific problem on a specific scale.

The following research question can be answered after this:

3. Which problems can be improved on location A and B and which possible solutions arise for these problems?

3.1 Which natural/human problems can be improved in Strijp S in Eindhoven?
3.2 Which natural/human problems can be improved in the Agniesebuurt in Rotterdam?
3.3 Which ideas can be found in nature to help solving the indicated problems?

Also the followings question will be answered: Which general principles derived from nature can be implemented in urban design?

5.2 STEP 1,2 AND 4

5.2.1 Eindhoven, Strijp S

5.2.1.1 Conclusions natural systems

Goal: Map the large context of natural systems of the location on regional scale. Natural systems can be mapped. The analyses are performed on regional/city scale. These scales were chosen at first because it takes into account the larger natural systems on the location.

Interpretation: The position of Eindhoven and Stijp S on the underlying natural systems: on a depletion of the middle terrace of the Maas and on a gentle hill slope.

Conclusion: there are no direct reasons to take natural systems as a starting point. The subsurface of the two project locations is the middle terrace of the Maas. This means that the ground exist out of fine sands, which sometimes sandy clay banks. The river the Dommel forms a predominant element in the landscape subsurface. The river deposits are not directly connected with the research location. The soil map makes clear that the parts of Eindhoven that are not build up (yet), have a loam subsurface.
Fig. 43: Concussion map of natural systems on location on region scale.

![Map with location markers and natural systems]
5.2.1.2 Conclusions human systems in

SWOT Regional scale
Goal: Map the large context of the location on regional scale. Relations with surroundings can be found.
Interpretation: Eindhoven is situated in a green region, with urban settlements in the direct surroundings. A lot of industrial areas are present.

Conclusions SWOT
Goal: map the strong points of the area to express them, the opportunities to see where chances lay for improvement, the weaknesses to improve the location and the threats to try to overcome these with interventions.
Interpretation of the most important SWOT conclusions:
Strengths: The identity of the region of Eindhoven is strong. Eindhoven is known for its creative industry, technical knowledge and innovation. Actors as the Technical University, the Design Academy, Philips and ASML play a role in this image. The economic position of the region is strong compared with other Dutch regions (Rompa, 2012). Furthermore the region has a lot of greenery.
Opportunities: the city of Eindhoven is located in a green region. Fingers of green reach into the city. These fingers could be connected. In this way the green in pulled into the city and the biodiversity in the city could improve.
CONCLUSIONS REGION SCALE

Fig. 44: Strengths

- Economic activity
- Identity
- Green

People
Neighbourhood and housing quality
Social cohesion

Prosperity
- Economic vitality
- Sustainable entrepreneurship
- Future value

Fig. 45: Opportunities

Connect green fingers

Planet
Biodiversity and green

Stock
Climate
Biodiversity and green
Nuisance
Safety
Facilities
Neighbourhood and housing quality
Social cohesion
Economic vitality
Sustainable entrepreneurship
Future value
SWOT City Scale
Goal: Map the context of the location on city scale. Relations with surroundings can be found.
Interpretation: Strijp S is situated in the urban tissue of Eindhoven. It lies between the city centre and an industrial area (of Philips). Above this industrial area, a green area is situated, also a Philips area (e.g. PSV football field). The biggest marked area is an area which will be transformed in the coming years by the municipality.

Conclusions SWOT
Goal: map the strong points of the area on city scale to express them, the opportunities to see where chances lay for improvement, the weaknesses to improve the location and the threats to try to overcome these with interventions.
Interpretation of the most important SWOT conclusions:
Strengths: the infrastructure and accessibility of the city is good. For both public and private transport and for slow and fast traffic.
Weaknesses: Eindhoven deals with the heating up of the urban fabric. Urban parts of the city show a higher temperature then the rural parts of the city. With the expectation of a changing climate the heating up of the city could form a threat for residents.
Opportunities: the project area lies close to the city centre of Eindhoven. A connection can be made between the city centre and the project area. Also the area can be linked with the high tech campus of Eindhoven. This area facilitates technical people, while at the moment the project location tries to facilitate creative industries. When those industries can be linked, it could form a strong connection.
Threats: Due to a changing climate and the geographical position of Eindhoven (on a gentle slope) water storage issues are expected in the future.
Fig. 46: Strengths

Fig. 47: Weaknesses

Fig. 48: Opportunities

Fig. 49: Threats

Accessibility

People

Future waterstorage issues

Fig. 46: Strengths

Fig. 47: Weaknesses

Fig. 48: Opportunities

Fig. 49: Threats
SWOT Neighbourhood scale
Goal: Map the context of the location on neighbourhood scale. Relations with surroundings can be found.
Interpretation: Strijp S is situated in the residential area of Eindhoven, and connects with an industrial area in the North. The neighbourhood is currently undergoing a transformation from industrial area to residential/entrepreneurial area. A lot of vacant space is present.

Conclusions SWOT
Goal: map the strong points of the area on neighbourhood scale to express them, the opportunities to see where chances lay for improvement, the weaknesses to improve the location and the threats to try to overcome these with interventions.
Interpretation of the most important SWOT conclusions:
Strengths: The project location Strijp S is surrounded by residential areas, where also facilities are present. The identity of the neighbourhood is strong at the moment. The area is known by its former industrial character and current creative and pioneering character.
Weaknesses: The public space in the area is mostly undefined. There is a lack of green and water in the area. Nuisance is caused by the railway track on east side of the location and the road in the north. These infrastructure elements function as a barrier between Strijp S and the surrounding neighbourhoods in the north and east.
Opportunities: Currently there is a lot of empty space in the area. This space could be an filled in with a diversity of facilities and uses and can be used for sustainable entrepreneurship. The present buildings are different in form, size and appearance. Through the location runs a sustainable bus connection between the city centre and the airport.
Threats: the neighbourhood Strijp S is currently undergoing a transformation process. The ground is bought by the municipality before the credit crunch. At the moment the project management is trying to facilitate the transformation in order to keep an eye on the budget and exploitation. They try to facilitate the process of different groups of people who occupy the area; from pioneers to early adapters and so on (Beernink, 2014). The question at the moment is how to pull the next stage. If this is not done at the right time, the area might not develop in a well working neighbourhood with a positive exploitation in the end.

SWot territory scale
Goal: Map the context of the location on territory scale. Relations with surroundings can be found.
Interpretation: Strijp S is situated near functions and city centre, in between housing area’s. Identity of the area

Fig. 50: Strengths
- Situated near functions and city centre, in between housing area’s
- Identity of the area

People
Neighbourhood and housing quality
Social cohesion
Facilities
**Fig. 51: Weaknesses**
- Undefined public space
- Nuisance train and road
- Train and Road function as barrier
- Lack of green and water

**Fig. 52: Opportunities**
Diversity of buildings
- Space for functions, sustainable entrepreneurship and facilities

**Fig. 53: Threats**
Social cohesion: what is the next step of the transformation?
### Summary of conclusions Eindhoven Strijp S

<table>
<thead>
<tr>
<th>Region</th>
<th>City</th>
<th>Neighbourhood</th>
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<tr>
<td>Planet</td>
<td>People</td>
<td>Prosperity</td>
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**S:** Situated near functions and city centre, in between housing area’s. Identity of the area.

**W:** Lack of green and water. Nuisance train and road. Undefined public space.

**O:** Diversity of buildings. Space for functions, entrepren., facilities. Connect with city centre. Connect with high tech campus.

**T:** Social cohesion: what is the next step of the transformation? Future waterstorage issues.
5.2.1.3 Design goals
The focus for improvement of the area lies on the possible threats and weaknesses. Strengths and opportunities are taken into account in the design phase and idea phase. But the questions for nature should be the most urgent problems of the area. In this case this is the threat future water storage issues and heat island issues. And the question of what is the next step forms an important question of the current manages of Strijp S. Therefore the focus for this design location should be on this neighbourhood level question. However in solving this question, other scales must be taken into account.

The questions for nature are:
- How does nature solve adaptation to changing temperatures?
- How does nature solve adaptation to changing water quantities?
- How does nature occupy ‘empty’ or new areas?

![Fig. 54: Design goals](image-url)
5.2.2 Rotterdam, Agniesebuurt

2.2.1 Conclusions natural systems
Goal: Map the large context of natural systems of the location on regional scale. Natural systems can be mapped. The analyses are performed on regional/city scale. These scales were chosen at first because it takes into account the larger natural systems on the location.
Interpretation: The position of Rotterdam and the Agniesebuurt on the underlying natural systems: on the clay deposition bed of the Maas. If human interventions did not happen, it would be under sea-level.

Conclusion: the geographical position is critical in Rotterdam. The water quantity and quality (brackish water) form a threat for the residents. If the human interventions (the dikes and dunes) were not developed, the area was flooded and would not look the same as the current situation. Because this situation could be critical for the human society, this must be taken into account.

2.2.2 Conclusions human systems in SWOT
The regional and city scale are combined in the maps for the SWOT. This is because the most important issues overlap between the two scales. The municipality of Rotterdam is extended towards the coastline, so this means that a part of the city definition is also the region. So to keep the SWOT concise, the maps are combined. The description is separated.

Regional scale
Goal: Map the large context of the location on regional scale. Relations with surroundings can be found.
Interpretation: Rotterdam is situated at the river Maas which has a direct connection with open sea. The city is connected to the Maasvlakte, a container and industrial harbour area. Large industrial areas and activities happen here. Rotterdam is situated in the south of the Randstad region.

Conclusions SWOT Region
Goal: map the strong points of the area to express them, the opportunities to see where chances lay for improvement, the weaknesses to improve the location and the threats to try to overcome these with interventions.
Interpretation of the most important SWOT conclusions:
Strengths: The identity of the region of Rotterdam is strong. Rotterdam is known for its harbour and industrial area. Greenhouses surround the city in the northwest of Rotterdam. This also gives identity to the area.
Opportunities: Maasvlakte 2 is under construction at the moment. This addition to the existing harbour area offers a lot of space for expansion of the harbour industry. This brings an economic impulse to the area. The airport north of the city centre of Rotterdam is handling more and more flights. Tourists are able to fly to Rotterdam directly. This could form an opportunity for the business sector and tourism sector.

City Scale
Goal: Map the context of the location on city scale. Relations with surroundings can be found.
Interpretation: The Agniesebuurt is situated in the north of the city centre of Rotterdam, just north east of the central station.

Conclusions SWOT City
Goal: map the strong points of the area on city scale to express them, the opportunities to see where chances lay for improvement, the weaknesses to improve the location and the threats to try to overcome these with interventions.
Interpretation of the most important SWOT conclusions:
Strengths: The city of Rotterdam is known for its industrial activity, is strong identity with the water and as interesting architectural city.
Weaknesses: the city centre does not have a lot of green, while the surroundings are green. The city centre could be denser. At the moment it is not so dense, this ensures empty area’s when shops are closed. Furthermore functions are sprawled over the city; it is not easy to find functions if you don’t know where to go.
Opportunities: The city knows industrial harbour area’s which are currently under transformation. On these locations, pioneers settle and there are multiple examples of sustainable initiatives at this location. It
could be an opportunity to connect with those initiatives.
Threats: Due to a changing climate and the geographical position of water quantity and quality issues are expected in the future. Safety is an important issue (Greef, 2014).

Analysis neighbourhood scale
Goal: Map the context of the location on neighbourhood scale. Relations with surroundings can be found. Interpretation: The Agniesbuurt is located in the north of Rotterdam. The area is filled with multiple functions. Through the neighbourhood runs the old rail way track ‘the Hofpleinlijn’.

Conclusions SWOT
Goal: Map the strong points of the area on neighbourhood scale to express them, the opportunities to see where chances lay for improvement, the weaknesses to improve the location and the threats to try to overcome these with interventions. Interpretation of the most important SWOT conclusions:
Strengths: The infrastructure around the neighbourhood is strong and diverse. The reachability of the area is good. The area contains multiple and diverse functions.
Weaknesses: There are a lot of closed building blocks. They make the space monotonous and not much is happening on the streets itself. Especially in the southern and next to the Hofpleinlijn there are backstreets were not much is happening. This ensures an unpleasant space. The current public space is lacking green and water and space.

Fig. 55: Rotterdam, Region scale
Fig. 58: Opportunities

Existing sustainable initiatives
Transformation former harbour areas
Transformation former harbour areas
Maasvlakte 2; growth of industry
Airport Rotterdam/The Hague

Prosperity
Economic vitality
Sustainable entrepreneurship

Fig. 59: Threats

Future water storage issues; quality & safety and quantity

Planet
Climate

People
Nuisance
Safety
Fig. 60: Strengths

Diversity of functions
Strong and diverse infrastructure

Fig. 61: Weaknesses

Lack of green and water
Nuisance roads
Weak liveability

Backstreets
A lot of closed building blocks
Fig. 62: Opportunities

- Noordsingel
- Hofpleinlijn
- Diversity of building ages

- Biodiversity and green
- Climate
- People
- Neighbourhood and housing quality

Fig. 63: Threats

- Functions sprawled
- Nuisance heat effects climate
- Water storage issues
- Climate
- People
- Neighbourhood and housing quality
- Prosperity
- Economic vitality

- Facilities
- Nuisance
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<tr>
<td>Diversity of functions</td>
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<td>Identity city &amp; architecture &amp; water city</td>
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<td>Strong and diverse infrastructure</td>
<td></td>
<td>Tourism</td>
</tr>
<tr>
<td><strong>W:</strong></td>
<td></td>
<td>City centre not dense</td>
</tr>
<tr>
<td>Lack of green and water</td>
<td></td>
<td>Not much green in centre</td>
</tr>
<tr>
<td>Nuisance roads</td>
<td></td>
<td>Sprawled functions</td>
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<tr>
<td>Weak liveability</td>
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<td>Backstreets</td>
<td></td>
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<tr>
<td>A lot of closed building blocks</td>
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<td><strong>O:</strong></td>
<td></td>
<td>Exising sustainable initiaves</td>
</tr>
<tr>
<td>Noordsingel</td>
<td></td>
<td>Transformation former harbour areas</td>
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<tr>
<td>Hofpleinlijn</td>
<td></td>
<td>Maasvlakte 2; growth of industry</td>
</tr>
<tr>
<td>Diversity of building ages</td>
<td></td>
<td>Transformation former harbour areas</td>
</tr>
<tr>
<td><strong>T:</strong></td>
<td></td>
<td>Future waterstorage issues; quality &amp; safety and quantity</td>
</tr>
<tr>
<td>Functions sprawled</td>
<td></td>
<td>Future waterstorage issues; quality &amp; safety and quantity</td>
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<tr>
<td>Nuisance heat effects climate</td>
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<td>Water storage issues</td>
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</table>
Opportunities: The Noordsingel which forms the north-east border of the area is a canal with a lot of quality. This might be an element which can be drawn in the neighbourhood. The Hofpleinlijn is a linear element which runs through the entire neighbourhood. This could form a connection element.

Threats: Climate change forms a threat for the whole city of Rotterdam and the Agniesebuurt is a neighbourhood which will experience many effects because of this (Greef, 2014). A problem is the heating up of the urban fabric. Also water storage issues are on the run.

2.2.3 Design goals
The focus for improvement of the area lies also for Rotterdam on the possible threats and weaknesses. Strengths and opportunities are taken into account in the design phase and idea phase. But the questions for nature should be the most urgent problems of the area. In this case this is the threat future water storage issues and heat island issues. This is city wide problem. Therefore the focus for this design location should be on multiple urban scales.

The questions for nature are:
- How does nature solve adaptation to changing temperatures?
- How does nature solve adaptation to changing water quantities?

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5.3 NATURE’S INSPIRATION

5.3.1 Analysis

5.3.1.1 Questions for nature
From the analysis of both Eindhoven and Rotterdam, three questions for nature were posed:
- How does nature cope with changes in temperature?
- How does nature cope with changes in water quantities?
- How does nature occupy ‘empty’ or new areas?

5.3.1.2 Methods
I searched for imitable examples from nature by means of different methods:

- Online database Asknature.org: an online database about the application of biomimicry, provided by The Biomimicry Institute in the United States (Biomimicry 3.8 institute, 2014), so far the only existing online database of this kind to the best of my knowledge. It is open sourced and recently (anno 2014) improved and supplemented with a lot of strategies and design ideas. Every strategy or idea that is mentioned is accompanied by a link to a scientific source. Ideas can be admitted by everyone, by sending it to the institute (www.asknature.org). The institute validates the incoming submissions.
- Literature: books about biology, ecology, earth’s systems, weather systems etc (Campbell and Reece, 2005, Odum and Barrett, 2005). Searches were performed specifically, because every resource offers a lot of information.
- Brainstorms with an environmental/evolutionary biologist: the questions posed above were discussed in an open brainstorm. In this brainstorm, people of various backgrounds were involved: a biologist, two urban designers (students) and a real estate expert. After the first brainstorm, a second and third consult with the biologist were undertaken in order to verify my findings from nature (Meijenfeldt, 2014).
5.3.2 Findings

During the course of this study, many ideas and principles were discovered, generated, discussed and developed. After the brainstorm and searching phase, I made a selection of suitable principles. These principles were further elaborated in step 2 of the strategy. 

After the elaboration, the principles were verified by the biologist again. This resulted in more ideas and a better understanding of the principles of nature, as mentioned above.

5.3.2.1 General principles from nature

In order to search for solutions in nature for problems in urbanism, it is important to understand the databases in which one searches for solutions. If an urban designer does not understand his source of inspiration, the translation from nature to human is difficult to make or could go wrong altogether. And some things need to be taken into account whilst searching for inspiration in nature. When trying to imitate nature, an urban designer should be critical about nature’s lessons. Not every lesson may be applicable to the current problem, though it might seem so at first sight. When translating nature’s lesson into the field of urban design, a couple of basic principles of nature need to be understood. With this knowledge of the principles behind occurring phenomena, an urban designer can look critically at a possible translation of an idea. This is an overview of the principles which were relevant for me, and helped my with understanding nature.

Principles:
- Life in nature is hard and does not know mercy (Meijenfeldt, 2014). Systems are open to invasion of other species. Individuals are selfish and it is a constant battle for the survival of the fittest. For one’s survival, another one has to die. In an urban context, this is not the case. We do look after weak individuals and try to keep them in our human system as long as possible. The natural system survives on a long term but not every part of nature. Predatory species play a role in keeping the food chain in balance and with this a system is maintained. The predatory system in human context does not work the same. As an early adapter, one does not kill the pioneer who’s occupying the place where one wants to live. Our empathy ensures a difference between nature and human systems. There are no predators.

- Dynamics occur in nature by negative and positive feedback loops. A negative feedback loop means that when a process is starting, something is occurring which ensures another process. This second process ensures the decrease of the first process. A positive feedback loops means that the one process stimulates another to stimulate the first process again. Human artefacts already use this principle in for example radiators in houses. It might be a possibility to also stimulate dynamics in an urban context. Homeostasis is the important underlying principle: Maintenance of a nearly constant internal environment in the midst of a varying external environment; more generally, the tendency of a biological system to maintain itself in a stat of stable equilibrium (Smith and Smith, 2006).

- Systems in nature do not plan ahead. Ever seen a forest follow the rules of a master plan? The job of an urban designer however is planning ahead. So when looking at systems in nature, it is important to take into account that what we see in nature is not for instance a strategy, but it is mostly an effect or incidental circumstance. So we can be inspired, but a translation is needed from nature to human context.

- There are different strategies in nature. There is a difference in the adaptation strategies (i.e. how to deal with change) between plants and animals. Animals are able to respond to change by changing their behaviour. For plants who are almost stationary, change is accomplished by a complex system of feedback loops. However animals also have those feedback loops, but they also have another option. To say it simple; an animal can run away but a plant can’t. A plan has to solve his problem on location, while the animal doesn’t.

- In the animal kingdom, different types of groups can be specified; roughly we can speak of individuals (for example: tiger) and social groups (for example: bee...
The behaviour in groups varies. In colonies some individuals are even willing to offer themselves for the group (in bee colonies, the workers offer themselves for the queen’s survival). However they do not plan this or communicate how they will do this. They are self-organising. This is very different from human. As humans make artefacts, different types of change can be found in our human context: we can change our behaviour, but we can also influence our surroundings and living area which could be adaptable to change. Though some species like beavers also do this, but on a smaller scale.

For the application of urban design we could use this principle of nature. In a concept you could say that humans are the animals which change their behaviour, and that the buildings are the plants which have complex feedback systems to change them.

Fig. 67: Differences in nature

- Organisms and systems in nature start replacing themselves at the smallest level of scale. In this way an organism integrates development with growth. For example your cells replace themselves every hour; this means that a skin tissue is replaced every couple hours or day and the level above that is changing also. While you are living, your body renews itself where this is needed. In the urban context, this process of renewing happens differently. Urban elements are more static and the replacement does not happen per definition from the lowest scale level up to the highest.

- The microclimate of an area in nature is compiled with the following aspects: Temperature, wind (the higher the wind, the higher the temperature that can be resisted), water, sunlight, rocks and soil. These principles can also be applied to an urban context.

- Surface and volume have a direct relation with each other. A relative big volume with a small surface is hard to cool down and warm up (for example an elephant. This animal has large but thin ears to cool his body). A relative big surface and a small volume is easy to cool down and warm up (for example a mouse can catches a cold very soon when temperatures drop). This principle could be used as a design element in the urban context.

- Changes can occur in nature by changing the phenotype (phenotype = a physical expression of a characteristic of an organism, determined by both genetic constitution and environment). This is called phenotypic plasticity: the ability to change form under different environmental conditions. So some organisms can change their form while not changing their genes.

- There are forms in nature which have proven themselves in the last era’s. These shapes work by definition. This is called ‘convergent evolution’: ‘Development of similar characteristics in different species living in different areas under similar environmental conditions’ (Smith and Smith, 2006). Wings are an example of convergent evolution; both bats and birds have wings, and belong to different families. An urban designer could look for this convergent evolution in the urban fabric in different cultures and places. However we must take into account that these forms have proven themselves over the last thousands of years. However humans live only for a very little while compare to nature so it is questionable if we already could speak of convergent evolution elements in urban design.

- There are multilayer safety mechanisms in nature (for example the spines of a cactus and poison in a cactus itself). It might be interesting to search for these mechanisms as an example for the urban context.

- In the field of biology and ecology, researches are trying to gain more knowledge about scales; specifically the topic of what makes a scale a next scales and what ensures the jump to another scale. The so
called ‘emergent properties’ determine the scale. When there is an emerging property, there is a new scale. This is important in biology; new characteristics are present at a new scale. It could be very interesting to find out what the emergent property is for scales in urbanism. This would help in understanding processes and systems which are happening in the urban and social context.

- Form follows flow in nature according to the constructal law (Stolk, 2014). Take a look at the example of a river or tree; the first flow is wide, and to the ends of the flow, the flow is spread of a larger area than the main stream. This is similar to the principle of physics; the Path of least resistance.
5.3.2.2 Design inspiration from nature
In the following figures the design inspirations from nature are presented. These examples are elaborated further as the strategy prescribes. Many more ideas could be generated, yet for the scope of this study, these are the ideas I worked out.
Fig 69: Ideas from nature

- Sea star
- Trees and plants
- Rain forest ecosystem
- Nature’s principles
- Leaves of Sagittaria latifolia
- Forest
- Wetlands
- Grasses en trees on the savannah
- Ecosystems
- Mammals: bear/ squirrel
- Plants
- Whale
- Climate system planet earth
- Plants
- Ecosystem
- Micro climate
- Camel
The organisms were elaborated into biomimicry characteristics (derived from the Ch3.) ideas and urban characteristics for the ideas.

<table>
<thead>
<tr>
<th>Consulted organism/system</th>
<th>Challenge</th>
<th>Level of biomimicry</th>
<th>Scale</th>
<th>Field of application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea star</td>
<td>Adapt to changing temperatures</td>
<td>D/D/D Process</td>
<td>Organism</td>
<td>Building ensemble</td>
</tr>
<tr>
<td></td>
<td>Strategy</td>
<td>Buffers cold water exposition to sun:</td>
<td></td>
<td>Building / House</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fills up with cold sea water to adapt to changing temperature above the sea. He gets more mass so he heats up slower. Then he releases the warmer water when he is under again.</td>
<td></td>
<td>Water storage in buildings</td>
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<thead>
<tr>
<th>Consulted organism/system</th>
<th>Challenge</th>
<th>Level of biomimicry</th>
<th>Scale</th>
<th>Field of application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trees and plants / mammals = strategy</td>
<td>Adapt to changing temperatures</td>
<td>D/D/D Process</td>
<td>Organism</td>
<td>Building ensemble</td>
</tr>
<tr>
<td></td>
<td>Strategy</td>
<td>Mammals</td>
<td></td>
<td>Building / House</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Release heat by sweating</td>
<td></td>
<td>‘Sweaty’ asphalt?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Effect plants</td>
<td></td>
<td>‘Sweaty’ facades: water is kept in the system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Trees and plants cool by transpiration/moisture: Water is pumped up from the ground and stored in a reservoir. Through the leaves the water moisturizes outside the plant. The wind takes the moisture away and the area around the plant cools down.</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Capitoläure pressure: water goes up because of the evaporation of water</td>
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</tbody>
</table>

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<thead>
<tr>
<th>Consulted organism/system</th>
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<th>Level of biomimicry</th>
<th>Scale</th>
<th>Field of application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plants</td>
<td>Adapt to changing resources</td>
<td>D/D/D Process</td>
<td>Organism</td>
<td>Building ensemble</td>
</tr>
<tr>
<td></td>
<td>Strategy</td>
<td>Minimize activity during droughts. For example during winter: inactive plant bulb. In spring the bulb ‘wakes up’. Or only moisturize at night in very hot periods.</td>
<td></td>
<td>Building / House</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td>Day and night rhythm of functions or performances of a building</td>
</tr>
</tbody>
</table>

5.4 Step 4 and 5
The ideas were connected with e.g. urban characteristics to make the idea tangible for the urban designer.

<table>
<thead>
<tr>
<th>Sustainable goal</th>
<th>Actors for implementation degree of easyness impl.</th>
<th>Rate of adaptability</th>
<th>Lifespan of measurement</th>
<th>Change dynamics</th>
<th>Type of space</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planet</td>
<td>Stock, Climate, Biodiversity and green, Nuisance, Safety</td>
<td>Robustness: +</td>
<td>Year scale</td>
<td>Year scale</td>
<td>ABOVE</td>
</tr>
<tr>
<td>People</td>
<td>Neighbourhood and housing quality, Social cohesion, Facilities, Economic vitality, Sustainable, entrepreneurship, Future value</td>
<td>Resiliency: ++</td>
<td>Day scale</td>
<td>Day scale</td>
<td>OUT/IN</td>
</tr>
<tr>
<td>Prosperity</td>
<td></td>
<td></td>
<td>Second scale</td>
<td>Second scale</td>
<td>UNDER</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sustainable goal</th>
<th>Actors for implementation degree of easyness impl.</th>
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<td>People</td>
<td>Neighbourhood and housing quality, Social cohesion, Facilities, Economic vitality, Sustainable, entrepreneurship, Future value</td>
<td>Resiliency: ++</td>
<td>Day scale</td>
<td>Day scale</td>
<td>OUT/IN</td>
</tr>
<tr>
<td>Prosperity</td>
<td></td>
<td></td>
<td>Second scale</td>
<td>Second scale</td>
<td>UNDER</td>
</tr>
</tbody>
</table>

5.4.1 Overview of all ideas
### Consulted organism/system: Plants
- **Challenge**: Receiving energy in changing circumstances: for example the change of the position of the sun.
- **Strategy**: Every leave some sunlight because of diversity of form.

### Consulted organism/system: Mammals: bear/ squirrel
- **Challenge**: Adapt to changing resources
- **Strategy**: Resource inactive until they are filled up. Temporary use and diversity of functions. Temporary nutrients and functions.

### Consulted organism/system: Ecosystem
- **Challenge**: Adapt to changing surroundings
- **Strategy**: Resilient species colonize newly created habitats. Species fill up new niches.

### Consulted organism/system: Forest
- **Challenge**: Adapt to changing surroundings
- **Effect (not a strategy)**: Maintain biodiversity through gaps in forest. Devide heterogeneity and ensure habitats for living organisms. We can learn from the effect.

### Consulted organism/system: Wetlands
- **Challenge**: Adapt to changing conditions
- **Effect (not a strategy)**: Different seeds with different life span are living in the system. So diversity of species which grow under different circumstances. More chance of survival: ‘one will make it’ so system is robuster.

### Level of biomimicry
- **Form**
- **Organism**
- **Ecosystem**
- **Community**

### Scale
- **Field of application**
  - **Building ensemble**
  - **Building / House**

### Field of application
- **City**
  - Pioneering social groups create conditions for next group. Expand per unit/house, not one area in total
- **Neighbourhood**
  - Gaps in the urban fabric to create niches of other functions. Take away random building.

- **Building ensemble**
  - A ‘specialty’ / special function per building
<table>
<thead>
<tr>
<th>Consulted organism/system</th>
<th>Challenge</th>
<th>Level of biomimicry</th>
<th>Scale</th>
<th>Field of application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rain forest ecosystem</td>
<td>Adapt to water fluctuations</td>
<td>Sponges</td>
<td>Ecosystem</td>
<td>Region</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>City</td>
<td>Neighbourhood</td>
</tr>
<tr>
<td>Grasses en trees on the savannah</td>
<td>Adapting to changing surroundings</td>
<td>Sponges</td>
<td>Community</td>
<td>Neighbourhood</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Building ensemble</td>
<td>Building ensemble</td>
</tr>
<tr>
<td>Micro climate</td>
<td>Adapt to resource scarcity</td>
<td>Sponges</td>
<td>Population</td>
<td>City</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Neighbourhood</td>
<td>Building ensemble</td>
</tr>
<tr>
<td>Leaves of Sagittaria latifolia</td>
<td>Adapting to changing surroundings</td>
<td>Sponges</td>
<td>Organ</td>
<td>Building ensemble</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Strategy</th>
<th>Challenge</th>
<th>Level of biomimicry</th>
<th>Scale</th>
<th>Field of application</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>City</td>
<td>Neighbourhood</td>
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<td></td>
<td></td>
<td>Building ensemble</td>
<td>Building ensemble</td>
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</table>

- **Strategy**: The water system of the forest is closed: kept in the system. Soil, water and nutrient loss is prevented by diversity. Poor ground; biomass stays in the system. The system as a sponge.
- **Challenge**: Adapt to changing surroundings.
- **Level of biomimicry**: Sponges
- **Scale**: Ecosystem
- **Field of application**: Region, City, Neighbourhood
- **Strategy**: Create microclimate by density in order to collect resources under difficult circumstances (mos op grote hoogte: ijle lucht, weinig water).
- **Challenge**: Adapting to changing surroundings.
- **Level of biomimicry**: Sponges
- **Scale**: Community
- **Field of application**: Neighbourhood, Building ensemble
- **Strategy**: Competitive exclusion: The species do not interrupt each other so can live side by side. The roots of the trees are deeper than the roots of the grasses. So they don’t use each others water. But they do use the same resource.
- **Challenge**: Adapting to water fluctuations.
- **Level of biomimicry**: Sponges
- **Scale**: Population
- **Field of application**: City, Neighbourhood, Building ensemble
- **Strategy**: Change phenotype: allow survival in fluctuating water levels by changing leaf type.
- **Challenge**: Adapt to changing surroundings.
- **Level of biomimicry**: Sponges
- **Scale**: Organ
- **Field of application**: Building ensemble
- **Strategy**: Adaptable facade to circumstances water and T. Change of surface and volume. Construction = same Form changes; building material which is able to disconnect.
- **Challenge**: Adapt to changing surroundings.
- **Level of biomimicry**: Sponges
- **Scale**: Organ
- **Field of application**: Building ensemble
- **Strategy**: Create microclimate by density in order to collect resources under difficult circumstances (mos op grote hoogte: ijle lucht, weinig water).
- **Challenge**: Adapting to changing surroundings.
- **Level of biomimicry**: Sponges
- **Scale**: Population
- **Field of application**: City, Neighbourhood, Building ensemble
Actors for implementation

Rate of adaptability
Robustness: +++
Resiliency: +++

Lifespan of measurement
Day scale
Second scale

Change dynamics
Day scale
Second scale

Type of space
ABOVE
UNDER
OUT
IN
<table>
<thead>
<tr>
<th>Consulted organism/system</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Whale</td>
<td>Protect against temperature</td>
<td>Process</td>
<td>Organ system</td>
<td>Heat exchange in road and buildings or in the road</td>
</tr>
<tr>
<td></td>
<td>Counter current: Veins and arteries of Cuvier’s beaked whales manage heat through different configurations of counter-current heat exchangers</td>
<td></td>
<td></td>
<td>Whale sewerage system</td>
</tr>
<tr>
<td>Camel</td>
<td>Protect against temperature</td>
<td>Process</td>
<td>Organ system</td>
<td></td>
</tr>
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<td></td>
<td>Furr functions as isolation. Bump stores water</td>
<td></td>
<td>Tissue</td>
<td></td>
</tr>
<tr>
<td>Ecosystem</td>
<td>Protect against temperature</td>
<td>Process</td>
<td>Ecosystem</td>
<td></td>
</tr>
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<td></td>
<td>Cooling with water</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Nature’s principles</td>
<td>Respond to change</td>
<td>Process</td>
<td>Ecosystem</td>
<td></td>
</tr>
<tr>
<td></td>
<td>With positive and negative feedbackloops, equilibriums are established or temporary needs of functions are fulfilled.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Climate system planet earth</td>
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Fig. 70: Ideas and their sustainable goal.
### 5.4.2 Elaboration

5.4.2.1 Comparing ideas and values

In order to compare the ideas, they are set up next to the added values they can achieve. This is at the moment a tangible aspect for urban designers. On the y-axis are the inspiring organisms or systems from nature. On the x-axis are the added values, which can be achieved with the design idea of that organism. The idea behind the organism is presented in the elaboration scheme of the ideas. The organism from nature is presented here, to make the link between nature and urban aspects visible.
5.4.2.2 Comparing ideas, values and scales
This scheme forms a design toolbox for the urban designer. To connect the ideas and goals with the context, they are linked with the possible scale in which they can be implemented (see images next pages). With this scheme, the designer can overthink the possible options for the design goals he wants to achieve. Also this scheme makes visible the link between different urban scales. One idea can be implemented on multiple scales. The impact of an implementation on scales varies per idea. With this scheme, suggestions can be done about the impact of one implementation on another scale. The scheme is used in the following way: from the performed analyses of a location, different scales with urban aspects (expressed in sustainable added values) or point out as design goals which should be improved. The added values can vary per scale. The designer points out the scale on the x-axis and the added value on the y-axis for this problem. The ideas from nature which overlap this box can be implemented in the design. In this way this scheme could function as an overview of the scales and problems that need to be improved. It might be the case that one organism or idea covers all the scales and problems there are. This scheme can be used as a starting point but also as a reflecting element when implementations are done. When one box is not yet fulfilled after the design, the urban designer can easily select another ideas which can be implemented. In order to compare the ideas, they are set up next to the sustainable goal they can achieve. This is at the moment a tangible aspect for urban designers.
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<th>Stock</th>
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![Diagram](image_url)
Fig. 72: Ideas in scales and goals

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<th>Stock</th>
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Design is not just what it looks like and feels like. Design is how it works. -

Steve Jobs
(1955 – 2011)
6.1 INTRODUCTION

The sub question that is answered in this chapter is:

4. How could the theory of biomimicry be implemented in the urban design process in order to solve problems?

To answer this question, the methodology described in chapter 4 will be used, together with the analysis of chapter 5 as a basis for the design. First a strategic design is presented, followed by possible design interventions. The scale must be detailed enough to show the quality of the area for the inhabitants/users.

6.2 CONCEPTS

Four general concepts are composed from the inspiration of nature. Ideas that strengthen each other or can exist next to each other are put together. These concepts form a first example of the translation from nature into an urban context.

1. The sponge: the water that is needed in a system is kept in a system. Due to diversity of species and strategies to store and release water the systems is able to adapt to change. The systems can maintains itself because it ensures the holding of the needed water.

2. The feedback loop: dynamics in the urban area are ensured by feedback loops in the urban system. For example when temperatures rise, a positive feedback is given to the amount of water in a neighbourhood which could cool the area. When the temperature drops again, the water level can be lowered again. In this concept inspiration from natures is also expressed in diversity of form and the implementation of gaps in the urban fabric. These gaps create niches. A changing phenotype.

3. Pioneering occupation: the transformation of an area based on the transformation steps of nature. In this concept different change strategies of animals and plants are used as inspiration. The replacement at from a small scale up to bigger ones is integrated.

4. Nature’s weather system: in order to reduce and prevent urban heat island effects, nature’s climate system is consulted. Principles as the ratio between surface and volume are taken into account in this concept. The heath of the city must be distributed to cooler parts in the surroundings. The cool water from outside the city can cool the warmer parts.
Fig. 73: The sponge

Fig. 74: The feedback loop

Fig. 75: Pioneering occupation

Fig. 76: Nature's weather system
6.3 EINDHOVEN STRIJP S

6.3.1 Strategy on city scale
Integrate development with growth: stimulate the processes of movement and change in the entire city.

Attract innovators/pioneers to new and raw areas. This group makes way for the next urban group.

The steps of transformation are the steps of innovation conducted by Rogers (1962)

Fig. 77: City scale strategy

Fig. 78: Steps of occupying new areas based on Rogers (1962) adjusted by author (2014).
Who: Artist
Starting entrepreneurs
Private clients

Who: Small communities
Small entrepreneurs
Commited volunteers

Who: Service orientated people
Status conscious people
Active young urban people

Who: Conservatives

Who: Sceptics

Needs: Space
Freedom
Robust real estate
Flexible facilities

Needs: Basic accessibility
Small concentration of facilities
Combination of work and living
Facilities; horeca, catering, maintenance, security and special shops

Needs: Good accessibility and parking
Attractive work, learning and leisure environment
‘Ready’ area
Good facilities and service
City wide functions

(Programmabureau Stadshavens Rotterdam, 2011)

Fig. 78: Innovation steps with needs
Different groups have different needs.

This diagram shows my interpretation of the changing indicators of different innovation groups. The project managers of Strijp S can change the demand of specific indicators in different areas of the neighbourhood. In this way, the area can transform in different stages. Also the managers can anticipate to current economic or social condition, because they can change the indicators.

With changing on the indicators (and setting rules or prices of an area), the managers can influence the change process and speed. The area stays flexible. The masterplan for the area should also be flexible.

This does not completely abandon uncertainties. The municipality keeps a risk for transforming the area.

The manager play the role of a forester! Remove or places trees to influence the growth/change process.

Fig. 79: Create conditions for groups on neighbourhood scale

Indicators:
- Freedom
- Facilities
- Parking & accessibility
- Mixed use
- Robustness real estate
- Pricing
- Own initiatives

Change over time of groups
Create conditions for different groups of innovators to settle, so the area can transform step by step. By implementing specific functions or parking facilities for example, the conditions are created for the early adapters and late adaptors to settle.

Fig. 80: Create conditions for groups on neighbourhood scale
6.3.2 Strategy on neighbourhood scale
Pull the strings of conditions which influence the change of groups. Different areas can have different rules.

Create conditions for groups on specific area’s
Design concept neighbourhood:

The strategy can be implemented in the urban context. To organise the final structure of the area, a certain final design vision is proposed. The process can go step by step.

Neighbourhood scale: facilitate growth by pulling strings. Make place for different groups: ‘slow’ or step by step transformation. Uncertainty is not eliminated! But anticipation could be faster than the current situation. Incorporate diversity and resilience (by variation, decentralisation, and redundancy). This means: ‘optimum’ can change during the process. For example when ground exploitation is set, the area can be transformed back to an earlier stage of innovation by ‘cutting away buildings and functions; random gaps in the urban fabric.

The following concept is proposed: Merge pioneering steps of nature and human in a opposite direction.

Fig. 81 & 82: Concept neighbourhood scale

Dominant wind direction is SW: don’t block direction. Sundirection: high buildings in northern parts of the area. Lower buildings in the southern and western part.

Fig. 83: Concept orientation sun and wind
To facilitate this strategy, I propose a design which is able to cope with changes on the following way:
- Fill in at the fine grain: area's can get denser of open up if requested
- Create different environments qua finance, rules, freedom, number of functions, type of functions etc. The environments are dependent on the indicators which create conditions for innovating groups.

Fig. 84: Design pioneering occupation

Fig. 85: Possible first development steps
6.3.3 Strategy on building ensemble scale

Build up from the smallest grain
Diversity of form and heights
Flexible architecture

Fig. 86: Architectural concept: flexible and detachable elements: the panels can be changed when new innovations arise on the market. The old panels can be reused in different places.
6.3.4 Reflection
The financial system behind the strategy is uncertain which could cause resistance. The municipality/land owner is bound to a certain uncertainty with this strategy. They benefit from minimal uncertainty so this issue could cause aversion to the implementation. On the other hand the owner gets a flexible and changeable situation which is an interesting possibility on the longer term view.

The proposed solutions are not completely feasible at the moment. The detachable systems of buildings and the financial uncertainty ensure this.

In Figure 75 the touched tangible urban aspects and biology aspects are presented, which are the result of two interventions of nature’s lessons. The interventions of multiple concepts have an effect on different scales with different life spans, types of spaces, change dynamics etc.
Fig. 89: Learning from the occupation process of natural systems in Eindhoven
Fig. 90: Learning from trees in Eindhoven
6.4 ROTTERDAM AGENIESEBUURT

The concept of the sponge is worked out further for the design case of the Agniesebuurt in Rotterdam, in combination with the feedback loop concept. These concepts are chosen because the inspiration from natures could fit the existing problems and questions on the location.

First a strategy is presented at multiple scales. After this a design proposal is presented by means of sketches and impressions of what the neighbourhood could look like. In chapter 7 the design is reflected on the design goals that are generated for the area.

6.4.1 Strategy on city scale

The concept of the sponge is implemented in the city of Rotterdam. The required water for the Agniesebuurt is used as a standard quantity to obtain. There are 2.285 households in the area which have the average size of 1,8 persons (Funda, 2014). The average water use of a household of two peoples is 91 m3 per year (Nibud, 2014). The average annual rain fall is 815mm per m2 in Rotterdam (www.climatedata.eu, 2014). This means that annual an amount of 208.00 m3 of water flows through the neighbourhood. Daily, this means 570m3 of water. At the Benthemplein a water square is situated which has a temporary buffer capacity of 1700 m3 of water; three times the needed amount of water per day (Boer, de 2014).

On the city scale the water network is condensed. The areas which experience the most heating issues are condensed. The most vulnerable areas are condensed with water first. Later on the water network can be condensed where this is needed in a future time. In this way the concept is able to grow further.

A water network is implemented over the existing water structures. The main and (almost all) 2nd sweet water structures are existing water structures. The 3rd water structures are added. At each branch form a water structure to a lower water structure, a lock is placed. This lock regulates the water quantity in the lower water structure. It is important that the water flows, otherwise the heat of the city cannot be disposed. The 3rd structure of water pumps up water from the 2nd structure and the water flows back to the 2nd structures if this is needed (to drain the water away). The locks can be operated with a feedback system; when the water quantity lowers to a certain point, the locks open. Or when the temperature is increasing, the pumps start with pumping around the water into the 3rd structure and out again. The specific turning point of the system can be set by humans, and this can vary per day, per season or per year etc. The system goes automatically like a feedback system, but the control over the turning point is in the hands of the local water authority or municipality or a local responsible instance or resident.

Consulted principle or strategy: Feedback system & constructal law & plants (different day night rhythm)

![Fig. 91: Sponge Concept in Rotterdam](image-url)
Fig. 92: Birds eye Rotterdam city centre, concept ▼
water network expansion
Fig. 93: Map of expanded water network in Rotterdam

Nature’s inspiration:

- Constructal law
- Feedback loops

Legend:
- Salt water
- Main sweet water structure (existing)
- 2nd sweet water structure (new)
- 3rd sweet water structure (new)
- Existing sweet water
- Neighbourhood
- Building ensemble
- Most vulnerable heat islands
- Water locks

Cover large surface in a fast way

Legend:
- Prevent heating up
- Lose warmth

Prevent heating up
- Lose warmth

City

Cover large surface in a fast way

Legend:
- Salt water
- Main sweet water structure (existing)
- 2nd sweet water structure (new)
- 3rd sweet water structure (new)
- Existing sweet water
- Neighbourhood
- Building ensemble
- Most vulnerable heat islands
- Water locks

Prevent heating up
- Lose warmth

Cover large surface in a fast way
6.4.2 Strategy neighbourhood scale
The Hofpleinlijn functions as a water spreading element. Because of the height of the railway track, it can suitably be used for this. From this linear element on, water connections are running to the building blocks in the surroundings. Inside the building blocks a specific function can be performed. The water that is used in the neighbourhood is kept in the neighbourhood itself in this way. New water flows in off course due to precipitation and the water use of residents. The precipitation is collected and a grey water system could be implemented. Different measurements can be implemented for solving water quantity and quality issues: rainwater collection, water storage, use of green, infiltration, purification, awareness, participation and integration (van Lohuizen, 2014). The expression of the measurements can be worked out by local residents or designers, but these functions should be implemented into the area in order to help solving the indicated problems. The implementations on the building ensemble scale are based on the functions described by van Lohuizen.
Consulted organism or strategy: rain forest ecosystem

6.4.3 Strategy building ensemble scale
Each building block specializes itself in a specific water function. The functions can vary over time and can also be filled in by residents itself. The functions can determine the type of space, or they can be ‘hidden’ in the buildings structures and ground. In this way, a function can express itself in a space which need a lot of attention from local residents, for example a food garden. Or the function can be expressed as part of the buildings with little attention or involvement needed from the local residents. The functions can be chosen by the local residents or in this situation by Havensteder, as this is the owner of almost buildings in this area. The function ‘giving back water to the air’ can best be implemented in the large buildings in the southern part of the neighbourhood. The large buildings are school and offices. The building on the north of the Heer Bokelweg is in need for maintenance so this could be transformed first (Boer, 2014).
Consulted organism or strategy: Wetlands & Sea star & Trees and plants (evaporation through leaves)
Fig. 94: Map of movement of water in the Agniesebuurt
Fig. 95: Isometry Agniesbuurt, diversity of water related functions
Diversity of functions

Nature’s inspiration:

Wetlands

Sea star

Trees and plants

Legend:
- Function X
- Function Y
- Collection and permanent storage
- Collection and temporal storage
- Greenery and food
- Purification of water
- Giving back water to the air

Fig. 96: Versity of functions
6.4.4 Impressions

Impression of a building block in two different situations

The functions related to water in a building can vary. In the left example the collective space functions as temporal and permanent water buffer. Water is collected on the roofs and in the pond. It shows the fluctuation of the water level inside the storage. Less maintenance is required. However a building block could also be filled in by functions showed in the right image; urban farming, green facades and an active green area inside the building block. This option requires involvement of local residents. Is it up to the local actors which option is chosen.
Impression of the Hofpleinlijn in two different circumstances
The Hofpleinlijn functions as a water divider. The water is distributed functionally under the ground. At the surface, the water level fluctuation is made visible for the residents: When there is too much water in the storage at the Hofpleinlijn, the water overflows along the facade of the Hofpleinlijn, and flows to the building blocks. In this way a visible connection is made with the water.
6.4.5 Reflection

The Hofpleinlijn is a currently hot debated topic. A lot of ideas and initiatives are present about the use of this old railway track which runs through the north or Rotterdam. The ideas are not the problem (Boer, 2014). The problem however is the maintenance condition of the roof which is in a bad condition. The owner of the roof, ProRail, does not want to invest in the restoration neither do other actors. The financial aspect causes a problem for the use of the Hofpleinlijn. A fitting business case should be set up before the design could be implemented in reality.

Fig. 99: Reflection of 2 organisms on tangible aspects
Fig. 100: Learning from the sea star in Rotterdam
Fig. 101: Learning from the tropical rain forest in Rotterdam
To improve is to change; to be perfect is to change often. - Winston Churchill
7.1 INTRODUCTION

In this chapter the following sub questions are addressed:
5. Is the strategy a biomimicry product and general useable? Does it solve the indicated problems of change in the urban environment?
5.1 Is the design strategy a form of biomimicry?
5.2 Are the problems (related to change) solved by this strategy?
5.3 Can the strategy also be applied in other contexts?

In this chapter the strategy (chapter 4) and the design (chapter 6) is reflected on the variables determined in the theoretical framework (chapter 3). With this reflection, relations are identified and general conclusions are drawn about the use of biomimicry in urban redesign. The strategy is also reflected by interviews with design firms, municipality of Rotterdam and Eindhoven, bio-inspired research group at the TU Delft and the government. Here, the strategy was presented and the usability in practice was discussed. With this step information is gathered about the practical use of the strategy.

7.2 REFLECTION ON DESIGN

7.2.1 Rotterdam

Reflection on design requirements:
Are the problems related to change improved? That is the question for this reflection. The following design goals are set and accomplished with the design:

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<thead>
<tr>
<th>Design goals Agniesbuurt</th>
<th>Meet goal Y/N</th>
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<tbody>
<tr>
<td>Improve urban heat island</td>
<td>Yes*</td>
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<tr>
<td>Improve water capacity</td>
<td>Yes</td>
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<tr>
<td>Improve public space</td>
<td>Yes</td>
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*Counting on the fact that the presence of flowing water and the decrease of surface hardening ensures a reduction of the urban heat island effect (Lenzholzer, 2013).

Questions 5.2 can be answered: Are the problems (related to change) solved by this strategy? Yes, the problems related to change are improved by the design.

Fig. 102: Used ideas from nature (grayscale)
**Fig. 103: Used ideas from nature (color)**

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<thead>
<tr>
<th>Stock</th>
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*Building/House* | *Building ensemble* | *Neighbourhood* | *City* | *Region*
Differences with current plans

There are differences between the existing designs for the locations and the designs developed in this research. At the moment there are no large scale design proposals for the neighbourhood. But there are a lot of small scale intervention proposals and ‘city initiatives’ from design firms and individuals. Recently the water square at the Bethemswaard is realised, designed by De Urbanisten. De Urbanisten also recently made a plan for the Zomerhofkwartier; the blocks situated on the north of the Heer Bokelweg. Compared to these plans, there are a couple of important differences;

- The biomimicry design takes different scales into account. Different strategies on different scales are proposed. The existing proposed projects focus only on the scale level of a building ensemble.
- Small scale initiatives are developed in collaboration with local residents. The ideas and requirements are collected bottom up. The local residents are involved in the design process. This is organised on this way because the funding for projects needs to be arranged for every design proposal individually. With the bottom up approach, local residents are encouraged to start interventions themselves.

In the performed analysis this is not incorporated, but it is possible to implement this in the strategy. The functioning of this element in the strategy could be done by a pilot case with local residents in a next research.

Are the ideas that are conducted implementable?

The presented design strategy focusses on multiple scales. The political management systems throughout these scales vary. This could make the realisation of ideas on multiple levels complex. Different stakeholders are involved on different scales which ensure this complexity. In the case of Rotterdam, the strategy on city level could be financed by the government, as they see water quantity and quality issues as their priority to solve. The water structures on neighbourhood scale should partly be funded by the government and partly by private stakeholders who can benefit from the transformation of for example the Hofpleinlijn. A possible stakeholder is the housing corporation Hofstede, which owns almost all real estate in the area. The implementation on building ensemble scale should be financed partly by Havensteder partly by local residents and party by local investors; for example an actor which want to implement food and greener interventional. The storage functions should be financed by Havensteder. Why should they do it?

1. To improve the living quality and safety of the area.
2. To transform the area to a sustainable environment for future generations.
3. For a lower water and energy bill. The initial investment can be earned back in a couple years. The implementations do not have to be executed all at once. It is a growing process. Houses or buildings block could change individually if the main water structure (at the Hofpleinlijn) is implemented.

In this way the ideas could be realised. The start could be difficult in the current financial situation.

Which scales are used, which levels of biomimicry?

The mostly used scale in nature is the ecosystem scale, on the process and system level of biomimicry. On the building ensemble scale, two ideas on organism scale are implemented. All the relevant scales of the human systems are covered with the implementations.

Reflection on life’s principles

The focus of this research was on the principle ‘adapt to changing conditions’ (See Figure 88). The principle incorporate diversity is accomplished. The principle ‘embody resilience through variation, redundancy and decentralization’ is partly accomplished; Variation is accomplished with the diversity of functions and forms in the urban fabric and the water functions are decentralized in the area. The functions are however not redundant.

The other life’s principle which weren’t the focus points of this research are also touched by the design. Most of the principles have potential to be accomplished. This means that the design has potential to accomplish these points, but that at the moment they are not. So the life’s principles could be accomplished, it is however the question if we want to accomplish all the principles.
Could the same ideas be generated without this strategy?

The same ideas could be generated without this strategy but not with the same reasoning, strength and depth as when using this strategy. The big difference between this strategy and existing ones is the multi scalar thinking and integration of the systems on scales. Some specific ideas are not completely new, which means that it could also be possible to generate without this strategy. However the system thinking is new. And the overall view over the scales and added (sustainable) values is new. It could be possible that specific design interventions could be created without the strategy, not every idea is purely innovative. However the integration of ideas is new. The ideas are based on proven concepts to the ideas which are used for concepts are well profound.

Does the design facilitate change?

The design proposal for the Agniesebuurt is more diverse and resilient than the current situating. Because of this, the area is able to cope with different possible circumstances. The neighbourhood is able to adapt more easily to a change of water quantity and changing temperature, as water and temperature influence each other.

- Accomplished
- Partly accomplished
- Potential to be accomplished
- Non accomplished

Design reflection Rotterdam Agniesebuurt
7.2.2 Eindhoven:
Reflection on design requirements
The problems related to change are partly improved in the proposed design option. The proposed measurements form a strategy for transforming the area. An optional design plan is given. However this is a flexible plan. Therefor the reflection on the requirements cannot be drawn very precisely. The proposed design plans answers the requirements, however it is not sure that the requirements are fulfilled with every possible plan. It is the task of the urban designer to pursue the design goals. Therefor the first two design goals are answered with ‘yes’ but collared orange for the uncertainty. The final design goal is accomplished.

<table>
<thead>
<tr>
<th>Design goals</th>
<th>Strip S</th>
<th>Meet goal Y/N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improve urban heat island</td>
<td>Yes*</td>
<td></td>
</tr>
<tr>
<td>Improve water capacity</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Improve occupation of empty area</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>

*Counting on the fact that the presence of flowing water and the decrease of surface hardening ensures a reduction of the urban heat island effect (Lenzholzer, 2013).

Differences with current plans
The design proposal is a strategy to occupy the area. Next to that it gives a possible land infill of a future situation. There are differences compared to the current plans:
- Able to respond to different scenarios of growth and change without quality loss
- Able to return to an earlier stage of pioneers
- Fine grain size
- Organisation is more gradually and step by step.
The organisation is executing top down but less controlling, with the stimulation of bottom up initiatives.

Are the ideas that are conducted implementable?
The financial system behind the strategy is uncertain which could cause resistance. The municipality/land owner is bound to a certain uncertainty with this strategy. They benefit from minimal uncertainty so this issue could cause aversion to the implementation. On the other hand the owner gets a flexible and changeable situation which is an interesting possibility on the longer term view.
The proposed solutions are not completely feasible at the moment. The detachable systems of buildings and the financial uncertainty ensure this.

Fig. 105: Used ideas from nature (grayscale)
Fig. 106: Used ideas from nature (color)
Which scales are used, which levels of biomimicry?
The mostly used scale in nature is the ecosystem scale, on the process and system level of biomimicry. On the building ensemble scale, again two ideas on organism scale are implemented. One of these organisms looks at the level of form.

Reflection on life’s principles
The focus of this research was on the principle ‘adapt to changing conditions’ (See Figure 107). The principles incorporate diversity and maintain integrity through self-renewal are accomplished. The principle ‘embody resilience through variation, redundancy and decentralization’ is partly accomplished; Variation is accomplished with the diversity of functions and forms in the urban fabric. Functions could be redundant. However in the proposed design, the functions and decentralisation is not refined.
The other life’s principle which weren’t the focus points of this research are also touched by the design. Most of the principles have potential to be accomplished. This means that the design has potential to accomplish these points, but that at the moment they are not accomplished.

Could the same ideas be generated without this strategy?
In the case of Eindhoven the step by step thinking is new compared to other strategies. Also letting go existing design ways is an addition to the current design. The implementation of water elements and buildings on a fine grain size are new. Park Strijp Beheer, the facilitating actor of the transformation, it already trying to facilitate a change in the area. However they want to keep control about when to expand or when to transform a building.

Does the design facilitate change?
Yes, change is facilitated by the strategy and the concept of changing the area step by step with a fine grain size and flexible and detachable buildings. On this way, a building can grow but also shrink easily. It is adaptable to the change of the moment. Strijp S will be able to cope with changing temperatures and changing water quantities better because of the space for water and green. Water can be stored temporary in the green and drained away via de channels.
Fig. 107: Reflection on Life’s Principles

Design reflection Eindhoven Strijp S

- Accomplished
- Partly accomplished
- Potential to be accomplished
- Non accomplished
7.3 REFLECTION ON STRATEGY

Biomimicry is defined by Gleich as: “1) New (technical) possibilities for 2) innovations solving societal problems and/or fulfilling demands and 3) ‘learning from living nature,’” or more precisely: learning, in the broadest sense, from: “biological research” (Gleich et al., 2010).

The given definition might not be completely true for this research. Point 1 is true: all the ideas and measurements are possibilities. They are new in a way that they have not been seen in this context or in a specific system. Point 2 is not always fulfilled. It depends on what you define as innovation. Innovation is defined as ‘introduction of a new product or a qualitative change in an existing product’ (OECD, 1997, p. 28). It is not only about ‘new’ ideas but also reusing existing ideas or placing them in a different context. Point 3 is also not completely true: I did not only learn from ‘living’ nature (biotic) but also from non-living (abiotic) principles and aspects. Also looking at abiotic principles and systems was very important for this research. Talking about systems brings you to the connection between the biotic and abiotic. When using biomimicry for urban design, I would suggest adding this to a specific definition of the abiotic part. In this research, the term biomimicry is used as: learning from biotic and abiotic systems in search for possibilities for solving societal problems and/or fulfilling demands.

*The design spirals*

The current theory of biomimicry describes two different design spirals: from human problem to nature and from nature to an idea in the human context. In the conducted strategy, the conscious focus lies on the spiral from human problems to nature. The other way around happened while searching for ideas. So I started by using the human to nature approach, and I ended up with search in both directions. Step 1 (the analysis of the natural system on the location) stimulated thinking in the ‘nature to human’ approach. This step of the analysis is not researched into depth. If this is done however, maybe more ‘nature to human’ ideas could be formulated. Note that the presented strategy is not formulated with the steps of the spiral as a starting point. The steps overlap now, but this was not the aim of the research. This was not the starting point.

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**Fig. 108: Design strategy for biomimicry in urban redesign, invented in this research**

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**Fig. 109: Design spirals from Baumeister (2012), evaluated by author**
point because I wanted to keep all options open for the new strategy.

Differences and similarities between steps
The similarities and differences between the existing design steps (spiral human to nature) and the application of biomimicry in urban design:
1: Identify. This step is performed in step 1 and 2 in the analysis phase. The 2 design spirals are merged together in the strategy for urban design. It is the intention to analyse both in the human systems as well as the natural systems on the location. This is new compared to the existing biomimicry method.
2: Define. This step is also performed at step 2 of the comparison to the existing biomimicry method.
3: Biologize: integrate life’s principles in the design requirements. This is not specifically integrated in the design strategy, because the strategies of nature behind the principles needed to be researched first. The designs turned out to meet some requirements of life’s principles, but not much. In urban design, the goal to meet all nature’s life’s principles is not realistic (technically, socially and economic) and maybe not even wanted. Human differ from nature so we cannot follow all the same principles. However the principles form a set of high standards for sustainable products. So when looking at sustainability, some points could be taken into account as requirement, but not all. This is a difference compared to the existing biomimicry design steps.
4. Discover: this step is performed in step 2 of the presented strategy.
5. Abstract: this step is performed in step 3 of the presented strategy. The abstraction of the mechanism behind an organism is performed in step 3. Also the brainstorming about the ideas are performed. When brainstorming about ideas, step 4 and 5 are combined in the presented strategy.
6. Emulate: the emulation of the ideas from nature is performed in step 6 and 7. This is the translation of the ideas from nature into concepts and a design.
7. Evaluate: this step is not performed as the biomimicry design method states. The design is measured and reflected on the design requirements, because these are the most important requirements in urban design. The principles are integrated in this research to reflect the usefulness of this step. As stated above it could be used to reflect on sustainable aspects but not only as a reflection to nature. Maybe in the future with more eyes for natural systems and the technical possibility etcetera it could be evaluation criteria for urban design. But at the moment the current urban design is not in accordance with life’s principles. In order to facilitate change is could be interesting to test what an urban design would look like, completely based on life’s principles.

What added value does it deliver?

In which fields could the strategy be applied?
The presented strategy could be used by every urban designer. However it is not obvious that everyone would use this. An urban designer who has affinity with nature is likely to apply it. Next to an urban designer, a client can also insist on applying this strategy. It is possible to apply the strategy in other fields of knowledge. In the field of architecture or landscape design the strategy could also be used. Only other tangible aspect could be required and a different human scale. For landscape design, this strategy connects with the building AS and WITH nature design approaches. The same goals might be achieved with this strategy, but the questions in the idea step might be formulated different. The structure of the strategy might also be used in different design fields in which the interaction between scales plays a role. However the content of the analyses and tangible aspect should be changed.

**Which parts can be used generic?**
The structure of the strategy could be used generic for every design field: Step 1, 2: analysis. Step 3: idea generating. Step 4 and 5: bridge between two fields of research. Step 6, 7 and 8: design & reflect. Steps can also be used separately. Step 3 and 4 and 5 could be used easily in other design strategies.

For urban design, the scales of urban design could be used generic in other design cases. Also the comparison between natural and human (urban) systems can be used generic.

**Does the strategy facilitate change?**
The problems related to change are improved by this strategy because of multiple aspects:

- By taking change as a starting point in searching nature’s solutions, the focus of solutions is based on change itself. The changing conditions in the urban environment are a starting point for the questions that are asked to inexhaustible database of nature.

- The strategies that function as inspiration are proven solutions by thousands of years of evolution. Nature is struggling with the same problems related to changing conditions as human society does. Observing those solutions gives an urban designer a secured start of a concept to work out.

- In the search for solutions three levels of looking at nature are kept open. By looking at processes and systems, insight is gained in the mechanisms behind the changing conditions. The integration of form, process and systems thinking ensures the understanding of a change. By understanding a mechanism behind change, a designer is better able to find working solutions for the problems.

- The multi-scalar approach of solutions ensures that changes can happen at different scales and on different ways. Adaptation is secured into the urban fabric because of this variety.

- Thinking in an integrated way between scales ensures that ideas are adjusted to each other and can function next to and with each other. The ideas strengthen each other.

A solution is given to help solving the problem statement which formed a starting point for this research. Adaptability is facilitated by the nature of the ideas derived from nature. The focus is about the change itself and not on a final snapshot or long term plan about a future situation. Options are kept open to changing directions, magnitude, and nature of functions and implementations.

Still unpredictable changes which influence the urban fabric cannot be eliminated with this strategy. But with the eye on facilitating change itself this is not a main point of focus any more.
Feedback from interviews
The feedback on strategy 2.0 was positively received by the Bio-inspired design chair at the faculty of Industrial Design of the TU Delft. Also graduating urbanism students and a professor from the environmental design chair of Architecture were positive. The received feedback:
- Positive about classification in scales to compare nature with humans
- Positive about the design ideas and the generic principles
- Students & Machiel van Dorst (Questionnaire: would you use it?)
- Requirement: it must be tangible for the urban designer.
- It might be time consuming, when you don’t have nature’s knowledge.
- Nobody said NO!
- Can every designer use the strategy?
- Into what extent do you need a biologist?

The strategy is presented to urban designers during interviews with:
- Alwin Beernink: Park Strijp Beheer;
- Florian Boer: de Urbanisten;
- Douwe Jan Joustra: One Planet Architecture institute/ Rau Architects;
- Saman Mohammadi & Niel Slob: PhD candidates RE&H

The reactions were positive about the strategy, especially the link between natural and human systems. Also the understandings of the differences between natural and human systems were found interesting.

Requirements
An urban designer is needed which sees opportunities in this strategy. Curiosity is desirable for this strategy, because the urban designer must look in different fields of research than his own area. A biologist is needed in order to fully understand the natural systems and strategies of organisms correctly. My own interpretation of a natural strategy was not always completely right. A system thinking biologist is preferable, because this type of biologist has knowledge in a broad knowledge field and is able to think in systems that are behind nature.

Next steps for the strategy
The strategy must be performed in practise. The steps that need to be taken are presenting the strategy to urban design studios or municipalities, and show them the strategy. Then a pilot case must be found to apply the strategy.

This research adds knowledge to the field of biomimicry by the following aspects:
- A strategy for using biomimicry in urban redesign. The integration of the field of research of biology and urban design.
- Shown the application of biomimicry in urban redesign, in an existing city while keeping the existing context intact. So no completely new master plans, but small scale intervention in an existing urban context.
- Comparison between natural and human systems.
- A toolbox or consideration tool for choosing ideas: the scheme with the ideas from nature expressed in urban scale and added value. This scheme can also be used with other variables on the y – and/or x-axis.
- Indicate the used levels of biomimicry.
- A set of idea examples, translated from nature into urban design applications.

Next to the additions there are a couple of general comments about biomimicry that arose:
- Do not forget the abiotic factors of nature. The term biomimicry might direct the user to biotic aspects, in stead of biotic and abiotic.
- The biomimicry database could be made more tangible for designers. This can be achieved when aspects of scale and type of biomimicry are added to the online database.
- Biomimicry suffers the same problems as innovation: there are always people who do not want to do it. The use is only reserved for a specific target group. People who have affinity with nature and exploring new possibilities are the designated persons. The stage of biomimicry is at the moment that of the pioneers and early adapters. Pioneers as Janine Benyus and
7.5 REFLECTION ON URBAN REDESIGN

This research adds knowledge to the field of urban redesign with the following aspects:
- A design strategy to design with biomimicry in urban redesign; nature as inspiration for solutions.
- The addition of a field of research in the field of urban design. This strengthens the solutions for urban design.
- A comparison between human and natural systems.
- Designing with taking into account the relations between scales.
- The urbanist functions as a filter for selecting ideas, and builds bridges between fields of research.

There are also some questions for the field of urban design which pop up from this research:
- Into what extent should cities be organised?
- Do we accept unpredictability in urban design? Into what extent can we accept this now and in the future?
- What is the role of the landscape in the city with this strategy? An always present source of inspiration?

7.6 REFLECTION ON PROCESS

Bob Ursem explore the possibilities, and the first early adapters are trying to apply biomimicry in practise.

The strategy developed over time
- Start with literature research and networking for information about biomimicry. The conclusions of the literature study pointed out the first aspects for the strategy:
  - Strategy 1.0 was created: focus only on the starting points for the use of biomimicry in urban design.
  - When executing strategy 1.0 on the first pilot location, it became clear that the comparison between human system and natural systems was not clear. So the strategy needed to develop. This conclusion was drawn around the P2 moment.
  - Strategy 2.0 was created: added urban aspects at the ideas of nature and scales to place analyses and ideas in.
  - Strategy 2.0 gave more direction in the comparison between nature and human. However around the P3 presentation, it became clear that the relation between the analyses and the ideas and solutions was missing. This was lacking in strategy 2.0. What was also lacking was the connection with the implementation in practise. I discovered this during an interview when we were talking about neighbourhood participation.
  - Strategy 3.0 was created: made a connection between the analyses and the ideas with the urban aspects. Added the involved actors.

Two design cases
Two pilot cases were used for developing and testing the strategy. The pilot cases have a very different context. This ensured that the strategy is tested in two very different area’s and fits diverse projects. It also means that little differences between contexts are not visible. For example the same ideas could be tested in the same area. This should be done for further research in order to find out more about the general application of the ideas and the strategy.

Taken two pilot cases for this research resulted in a lot of work and because of this I did no go completely into detail of a design. For a next research I suggest to work out one pilot case. However for this first research of creating a design strategy the two pilot cases were helpful.

Relation research and design and the used methods
The used methods were very helpful for the research project. The alternation between methods helped me getting further. During the process different methods were used with different goals. The most important methods are discussed here, in combination with a short process description of the project.

In the first weeks I tried to overthink to whole process precisely and create a structure for the research. This structure changed during the process until the P2. From the P2 on I followed the proposed structure and this helped me very much in accomplishing this final result. So my approach worked for this research. The different used methods and the choice of two pilot cases made it a success. Also the methodology of studio did help me a lot. What helped me was the structured first half year of the studio. The deadlines and consultations with the studio tutors helped me with structuring my research.

The field of research was completely new to me when I started with this research. It took a lot more effort than I expected to get familiar with the existing in-
formation and knowledge of biomimicry. The network method was very useful in this phase of ‘swimming’ in the topic. Events as a congress about biomimicry and the circular economy where interesting days to gather information about the use and application of biomimicry. On this event different views of biomimicry were presented by different people. The networking method brought me into contact with a lot of people involved – or less involved- in biomimicry. Also the people who were less involved, or involved in related research fields helped me form a clear view about biomimicry. The network of biomimicry is currently very small. I spoke to multiple people who spoke with the ‘inventor’ Janine Benyus. This ensured me that the world of biomimicry is still a pioneering research field, were a lot of knowledge can be added. In the final phases of the research I noticed that the build-up network now is an easy entrance for spreading and sharing information. While networking, I interviewed different people. Those interviews were very helpful in every step of the research. Satisfyingly every interview gave me a lot of inspiration. The positive reactions about the research and the questions everyone had, stimulated me to solve the questions and bring the strategy further to something tangible. The interviews brought me mostly to the reality in the final stages of the research. The alternation of literature research and practise was very interesting and strengthened the research in my opinion. The nice thing with the networking and interviews was that the people who are involved in biomimicry are one by one people who are pioneers or early adapters and believe in new ideas and ways to get somewhere. The ambiance around the people I spoke with was very positive. Everyone believed in this theory at his own way with an own interpretation but one by one everyone saw opportunities. That is what inspired me the most. They are all very interesting people with an interest in thinking about the future and searching for possible ideas and solutions.

The strategy development went smoothly while running through the proposed research structure. Switching between the two pilot cases fastened the development, because different findings were done in the different pilots. The feedback loops did work at the proposed phases. The only way to set a new strategy is by experiencing and testing it. In this way new information is gathered for further development.

When looking back at the process and planning, I experienced that it was difficult to focus on the specific urban design, when the strategy was not completely finished. I struggled with the alternation of research, strategy development and design. I did try to integrate the design in an early stage, but the most interventions were conceptual. For a next research I would recommend to try to express the concepts immediately into concrete design proposals. In this way the design can become more realistic and more into depth. However for this research this depth was not completely feasible, because the main goal was setting up a new design strategy. So I tried to focus on that instead of working to a detailed design. What I notice know is that other people need to see this design in order to completely see the working of the strategy. So the translation of ideas into concepts and designs is definitely required.

At this moment I am looking back on a most interesting year full of inspiration, learning new things, asking myself fundamental questions or very specific ones. I enjoyed doing this research very much. The pioneering aspect made it big challenge and adding this knowledge to the field of research is exiting. The knowledge fits very well in the research chair or Urban Metabolism. Biomimicry is for me a new fact and possible strategy for urbanism. I learned a lot of different lessons about the field of urbanism and the practical side of it. Also I experienced what it is like to be a pioneer and to work with a lot of different people. Setting up this master thesis was also a nice experience for me. The freedom of proposing and structuring your own research helped me a lot with this. However sometimes it was hard to be critical on your own work, but with a reflections and discussion with other students and my mentors this was accomplished.

I noticed that during the research the subject is brought under attention by a lot of people, people who share this knowledge of nature’s database with me. So with this research I think I influenced – even in a tiny way- my own network. Achieving this with a research is big reward !
If you change the way you look at things, the things you look at change. - Wayne Dyer
8.1 CONCLUSIONS

In this chapter the combined conclusions are presented, which are generated in chapter 3-7. First the sub questions are answered in the order they were presented. Secondly, the answer to the main research question is given. The chapter ends with a summary of the added value this research has for the field of urban redesign and the recommendations for further research.

Main Research question:
How can biomimicry be applied in urban redesign and facilitate change in urban environments?

Answers to the sub-questions
1. What are the differences and similarities between biomimicry and urban redesign? (Chapter 3)
   - 1.1 What is biomimicry and how is it applied?
     A biomimicry design approach tries to learn from nature’s successes, for innovations solving (human) societal problems (Gleich et al., 2010). The theory prescribes three levels of learning from nature: the level of form, the level of process, and the level of system. Form is mostly used in current applications of biomimicry, as practiced in fields of research other than urban design. Importantly, the six life’s principles that are described by the theory are design lessons from nature, one of which is ‘adapt to changing conditions’ (Biomimicry3.8, 2013). There are two different approaches if one is to use biomimicry: either from biology to design, or the other way around, from problem to biology. There are to date only few examples of the application of biomimicry in urban design. These examples are on a city scale and show plans for a completely new city.

   - 1.2 What is urban redesign and how is it applied?
     Urban redesign is about the transformation of an existing urban fabric. Improvements in economic, physical, social and environmental conditions are the conditions that change. At the moment urban regeneration is applied worldwide on different urban scales.

   - There are differences between urban redesign and the current application of biomimicry.
     - First, the physical urban location forms the context for the existing problems. The physical location should be included as a starting point for a biomimicry strategy in urban redesign.
     - Second, biomimicry is about learning from ‘nature’. Humans distinguish themselves from ‘nature’. Knowing these differences, we must be critical about consulting nature when searching for solutions for our urban environment. Life in nature is hard, so nature must not be seen as the best idea by definition for solving human problems.
     - Third, the aspect of time and life span is important in urban redesign.
     - Fourth, biomimicry can be performed at three levels; form, process and system. Two design methods are currently in use. The principles that lay behind nature’s successes, which are specified in six life’s principles, form the requirements for biomimicry implementations. These starting points of biomimicry need to be taken into account in a biomimicry strategy for urban redesign.
     - Similarities are also present. Biomimicry is similar to urban design in the fact that both disciplines are solution based; there are existing problems, and possible measurements need to be found to improve the problems. Problems that humans face in the living environment can also be found in the urge of nature to survive. This means that nature and humans share conceptually similar problems, and we can therefor learn from one another. Nature is just like humans bound to an uncertainty of future conditions in the world around us. In order to survive an organism must be able to deal with unsuspected changes in the context and must thus be adaptable.

2. How could biomimicry be translated into a strategy for the field of urban redesign? Which points of attention should the strategy satisfy? (Chapter 4)

   - In this research the author invented a new application of biomimicry; the application of biomimicry in urban redesign. This is in the form of a novel design strategy which consist out of eight steps (see figure …). The aspects indicated in sub question one are taken into account.

   - Step one and two are analysis steps. The first step is an analysis of the natural systems on the location, the second is an analysis of human systems on the design location. Step 1 and 2 result in design requirements and needs for design solutions to come.

   - The design requirements and needs form a starting point for step 3: the generation of multiple solution ideas to solve the indicated problems. These solutions are found in nature with literature research, online database searches and brainstorms with a biologist and other actors if desired.

   - With step four and five a bridge is created
between the two fields of research (biology and urban design). An understanding of the discussed systems is the result of these steps, both in the field of biology as well as in the field of urban design. Step four is the classification of different scales and lifespans in nature and human systems. Step five is the classification of tangible urban aspects. These aspects ensure an understanding of the consequences of an idea for the urban environment. The results of step one to three are connected to the tangible aspects of both disciplines.

- In step six a selection is made of the ideas of step 3, in order to solve the indicated problems in step 1 and 2. The decision is based on the tangible aspects from step 4 and 5. The problems and ideas are compared with the tangible aspects, and based on that, ideas can be consciously chosen for further design elaboration.

- In step seven the chosen ideas are elaborated and translated into design interventions.

- The design is reflected in step eight on the design requirements and needs indicated in step one and two. When the requirements are not fulfilled, step six up to step eight should be repeated. If the requirements are still not accomplished step tree up to eight needs to be repeated. Finally step one up to eight can be repeated when this final repetition of the strategy did not result in accomplishing the design requirements.

Different actors can be involved in the strategy based on the nature of the design question. When a bottom-up approach is needed in order to accomplish a change in an urban area, local residents can be involved in the strategy for example.

Fig. 110: Design strategy for biomimicry in urban redesign, invented in this research
3. Which problems can be improved on two different locations in different contexts and what possible solutions arise? (Chapter 5, the Agniesebuurt in Rotterdam and Strijp S in Eindhoven are elaborated)

3.1 Which natural/human problems related to change can be improved at the locations? Problems that are faced by the municipality of Eindhoven in the area of Strijp S are related to changing environmental conditions. Conditions that change are the temperature and water quantities so more storage space is needed. Most important is the change of the occupation of the ‘empty’ area of Strijp S. The former industrial area of Philips is currently undergoing a transformation. The area is half empty and half occupied by modified dwellings buildings and old buildings housing permanent functions. The question for this area is how to facilitate a bottom-up change from a top-down position.

In Rotterdam the most important issues of change are related to water quality, water quantity, and changing temperatures. The geographical position below sea level and the nearby North Sea and Nieuwe Maas creates the problems related to water. The fact that the city is suffering an urban heat island effect ensures the change in temperature in the city centre.

3.2 Which natural/human solutions can be implemented to improve these problems? Searching through nature’s examples resulted in numerous ideas and measurements that can be implemented in urban environments in order to respond to the indicated problems. The ideas can be found in chapter 5. The problems related to changing conditions faced by human society, are conceptually similar to problems of nature, which answers those problems with concepts proven by thousands of years of evolution. Taking those proven concepts as a starting point for design concepts gives the urban designer a certainty of a well-thought strategy as a design starting point. This reduces the uncertainty a designer brings into a design process with his restricted capacity of creating and conceiving design solutions. This uncertainty is first about the capacity of creating the design ideas and secondly about the uncertainty of the success of the implementation.

The selection of the ideas is based on urban and biological characteristics and depends on the current problems of the locations. With this conscious choice, the starting point of the design is less uncertain than current starting points of concept developments without first considering numerous concept solutions.

The scale on which a solution is implementable varies from solution to solution, and so are the effects on the urban environment. The added sustainable value for example differs per idea. Multiple ideas can be integrated into one final concept. In this way multiple added values and multiple scales can be addressed with one concept. The choice for an idea depends on the specific aspects which need to be addressed in the redesign.

4. How can the theory of biomimicry be implemented in the urban design process of these two different locations in order to improve problems? (Chapter 6) The biomimicry ideas derived from nature are translated into design implementations in different ways and on different scales. The translation of an idea into design interventions is executed by an urban designer (in this research by the author). The extent of elaboration of an idea into a tangible design intervention varies. While one idea is translated into a transformation strategy, the other idea can be translated into a specific implementation in a building block, and again another one into a design concept. Multiple measurements are profoundly implemented in the design location. By implementing ideas on different scales, the designer is forced to think inter-scalar and on the system level.

A key element for understanding natural systems is a biologist with system level knowledge. The field of research of urban design does not cover the knowledge that is needed to understand the way nature works. When applying biomimicry, this knowledge is needed in order to understand the strategies of nature and developing them into an application in an adaptable urban environment.

5. Is the strategy a biomimicry product and general applicable? Does it improve the indicated problems of change in the urban environment? (Chapter 7) 5.1 Is a design strategy a form of biomimicry? The definition of biomimicry given by Gleich (2010) is partly in accordance with the strategy that has been constructed in this research. Biomimicry is defined by Gleich as: “1) New (technical) possibilities for 2) inno-
vations solving societal problems and/or fulfilling demands and 3) “learning from living nature,” or more precisely: learning, in the broadest sense, from: “biological research” (Gleich et al., 2010). The strategy is biomimicry in the broadest sense of meaning; inspiration is drawn from nature in order to solve human problems. However the definition of biomimicry by Gleich does not cover the complete message of this application of biomimicry in urban redesign. I suggest that the definition for biomimicry in urban redesign of this research should be extended and partly revised. the definition I propose for describing biomimicry: learning from biotic and abiotic systems in search for possibilities for solving societal problems and/or fulfilling demands.

5.2 Are problems (related to change) improved by this strategy? The problems related to change are improved by this strategy because of multiple aspects:
- By taking change as a starting point in searching for nature’s solutions, the focus of the solutions is based on change itself. The changing conditions in the urban environment are a starting point for the questions that are asked to the inexhaustible database of nature. Adaptability is facilitated by the very nature of the ideas derived from nature.
- The strategies that function as inspiration are proven solutions by thousands of years of evolution. Nature is struggling with the same problems related to changing conditions as human society does. Observing those solutions gives an urban designer a substantiated start of a concept to work out. Though a conscious choice in picking out ideas is required by the urban designer.
- In the search for solutions three levels of looking at nature are kept open. By looking at processes and systems, insight is gained in the mechanisms behind the changing conditions. The integration of form, process and system thinking ensures the understanding of the reasons behind a change. By understanding a mechanism behind change, a designer is better able to find working solutions for the problems.
- The multi-scalar approach of solutions ensures that changes can happen at different scales and on different ways. Adaptation is secured into the urban fabric because of this variety.
- Thinking in an integrated way between scales ensures that ideas are adjusted to each other and can function next to and with each other. The ideas strengthen each other.

5.3 Can the strategy also be applied in other contexts?
In this research the strategy is applied in two different contexts. The strategy could also be applicable in other fields of researches dealing with the complexity of scales or the need for adaptable solutions. Steps can be used separately from each other in other design strategies and methods. Step three, four, and five are the most interesting steps for application in other fields. The outcomes of this research can also be used on itself. The specific ideas that are generated in this research can be used again for the same indicated problems. These design ideas can be the start of a biomimicry database for urban design.

Answer to the main research question
The research question is divided into two parts, which I will answer independently:
1. Can biomimicry be applied in urban redesign?
Biomimicry can be applied in urban redesign by using the general strategy that is the result of this research. The field of biology is added to the field of research of urban design. Most importantly, a bridge is created between these two fields of research.
A question for the strategy that popped up was ‘how much do you need to know from nature to get inspired?’ To completely understand the strategies and principles from nature, the aid of a biologist is recommended. It depends on what you want to achieve with this strategy. If you completely want to imitate the principles of nature, one should understand nature in a profound way and consult a biologist. However, if you have performed the strategy for a specific problem, and the same problem arises the next time, the ideas from the first time can be consulted again. In this case a biologist is not needed. When more ideas need to be added, a biologist is required again. The experience of the author is that deepening into scientific resources did not made that one understands nature in depth. Nature is a complex system so it is suggested to consult a biologist in order to understand nature. After consulting a biologist the author was able to understand systems and able to translate the solutions of nature into applications in the field of urban design.

2. Does it facilitate change?
Change is facilitated. This strategy makes it possible to consciously make choices and incorporate change
in the design. The extent to which the change is facilitated is dependent on the solutions. This strategy leads to designs that can better cope with a changing context, incorporating design solutions that focus more on the ability to change. Change is facilitated in multiple ways:

- Adaptability is facilitated by the nature of the ideas derived from nature.

- The focus is about the change itself and not on a final snapshot or long term plan about a future situation. Options are kept open to changing directions, magnitude, and nature of functions and implementations. In this way, the urban design does not make a snapshot of what the future will look like, but a possibility for an area to change over time.

Added value of biomimicry in urban redesign
The strategy conducted in this research brings added value to the field of urban redesign in the following ways:

- Less uncertainty in the design process of adaptable urban environments because design concepts are based on proven solutions. Taking those proven concepts as a starting point for design concepts gives the urban designer a certainty of a well thought strategy as a design starting point. This reduces the uncertainty a designer brings into a design process with his restricted capacity of creating and conceiving design solutions.

- Thinking in scales and linking scales. Search for relations and effects of scales on each other. Thinking in systems and searching for relations between scales and systems. If you understand the system and relation in which you are interfering, you can make a well thought design which functions on the predicted way (as far as possible).

- Conscious choice of concepts. The selection of the ideas is based on urban and biology characteristics and depends on the current problems of the locations. With this conscious choice the starting point of the design is less uncertain than current starting points of concept developments without multiple trade-off options. This Bridge between two fields of makes the ideas tangible in two worlds. With this bridge, ideas can be selected based on tangible aspects. By connecting the tangible aspects to the idea, the users look one step further to the consequences of the implementation of an idea. The implementation of an idea is well thought.

- Profound concepts. Multiple measurements are profoundly implemented in the design location. By implementing ideas on different scales, the designer is forced to think inter scalar and systematic.

- Multiple ideas form a starting point for further biomimicry implementations. Numerous ideas for measurements are developed during the searching phase in nature. This resulted in a ready to use measurement/idea database. I experienced that it was very easy to combine ideas and implement multiple thoughts through ideas after the database formation. Easily combining ideas and thinking integrated is an added value of this strategy.

- It stimulates creativity because a designer is challenged to translate solutions and concepts from one field of research to another, or from one context into another. Therefore will the urban designer come to ideas that he or she never would have thought of otherwise.

Furthermore: this strategy can play a role for sustainable designs to come. In society, the demand for sustainability is rising. Biomimicry is a way of thinking with a lot of potential for sustainable solutions and measurements.

Before this research there was not a suitting strategy for applying biomimicry in urban design. The presented strategy can fill in this gap and be of aid in solving social problems of today and tomorrow.
8.2 RECOMMENDATIONS

During the research, various questions arose regarding different topics. First, I recommend further research on the topic of biomimicry. Second, further research on the application of biomimicry in urban redesign is suggested.

Further research on biomimicry:
Some elements from the theory of biomimicry were questioned when presented to an evolutionary biologist in this research. This proves that opinions about this theory differ and raises questions for research to come. Further research on the topic of biology and evolution is possible to verify the scientific theory of biomimicry. However, I experienced that for the outcomes of biomimicry in urban design, this knowledge is not specifically needed. So far implementing the theory of biomimicry I do not pose this as required but it could be an interesting research for other fields of research.

- Can biomimicry also answer social questions?
- Experiment with asking a question of a social dimension. Can social issues also be approached by the strategy? With the added sustainable values in the classification of People Planet Prosperity, social issues can be mapped. But those are effects of an implementation. It is questionable if you can start with a socials question to ask to nature. Or are social problems in urbanism always related to physical aspects? These physical aspects can be asked to nature with the strategy.

Biomimicry and urban design:
Raising questions for further research on the application of biomimicry in urban design:
- Put the ideas that are a result of this research in an online database.
- In this was an extensive overview of general examples from nature is created that could be useful for urban design. This helps in finding solutions for urbanism with the discussed strategy and consulting existing information. Also, it can increase awareness about the added value biomimicry brings for adaptable urban designs.
- Research other questions for nature; choose another life’s principle to start with:
  - Are all life’s principles starting points for urban design? Or only the ‘adapt to changing conditions’ principle?
  - Can natural systems also be a starting point for an urban design or maybe a landscape design?
  - Research the complete ecosystems on the location more into depth, in order to find out whether the design spiral of biology to design can also be implanted on its own in urban design.
  - Research systems of urbanism:
    - With this, find relation between interventions and scales and systems. In this way, suggestions can be done about the relation between scales of urbanism. Research the systems behind ecosystems and relations between the organisms. In this way you can map the differences between human systems and natural systems.
    - Try to discover the emerging property of scales in urbanism.
    - When finding the emerging property of urbanism, more control is ensured about the working and relation between scales. More certainty is derived when the properties of the ‘next’ scales is appointed for urban designers. When the properties are known, the urban designer can influence the things that happen at scales more certain.
- Let other people try out the strategy:
  - Try out the strategy I composed and try to implement the best ideas into the urban fabric to check if another designer would implement the same measurements. In this way you can find out if the strategy is qualitatively replicable. Is it a general strategy that can be repeated by someone else, with the same results? The strategy can be verified in this way.
- Work out the possible solutions further to see the result of biomimicry in urban design in a detailed scale.
  - Maybe biomimicry ideas can also be implemented in other and more detailed levels of design.
- Compare strategy with industrial ecology and pattern language of C. Alexander.
  - In order to find relations with existing urban design strategies this is interesting to research. Maybe lessons can be learned from this strategy for improving the strategy of biomimicry in urban redesign. The strategy of pattern language is adduced because of the scales which C. Alexander works with. The strategy of industrial ecology because of the overlapping field of research of biology.
- When looking at nature, it is clear that nature does not plan with premeditation. In urban design we do, so we cannot completely copy or mimic nature systems for urban design. But we can be inspired for implementations of smart and integrated solutions. Or should we let go of the premeditation character of urban design?
REFERENCES

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GREEF, D. P. 10-02-2014 2014. RE: Interview municipality of Rotterdam.


HOPMAN, M. 07-10-2013 2013. RE: Exploratory interview.


LIST OF FIGURES


OPEN UNIVERSITY. 2014. The linear dimensions, surface areas and volumes of three different-sized cubes are compared here to show how surface area: volume ratio decreases as the linear dimensions increase [Online].


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I. OVERVIEW OF INTERVIEWS

1. **Overview of exploratory interviews**

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<tr>
<th>Name</th>
<th>Date</th>
<th>Background</th>
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<tr>
<td>Giancarlos Mangone</td>
<td>30-09-2013</td>
<td>PhD BK TU Delft</td>
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<tr>
<td>Ernst-Jan Mul</td>
<td>04-10-2013</td>
<td>IO TU Delft</td>
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<tr>
<td>Bas Mentink</td>
<td>04-10-2013</td>
<td>Student TBM/BK TU Delft</td>
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<td>Marian Hopman</td>
<td>07-10-2013</td>
<td>Ministry of Economic affairs agriculture and innovation</td>
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<td>Bianca Nijhof</td>
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<td>ARCADIS NL</td>
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<td>Jaco Appelman</td>
<td>09-10-2013</td>
<td>TBM/ educational advisor TU Delft</td>
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<tr>
<td>Paul Breedveld</td>
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<td>3ME TU Delft</td>
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<tr>
<td>Elma van Beek</td>
<td>16-10-2013</td>
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2. **Overview of specific interviews**

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<tr>
<td>Ernst-Jan Mul</td>
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<tr>
<td>Bas Sanders &amp; Stefan de Bever</td>
<td>20-11-2013</td>
<td>BiomimicryNL en De Bever Architecten Eindhoven</td>
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<td>Pieter de Greef</td>
<td>10-02-2014</td>
<td>Gemeente Rotterdam</td>
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<tr>
<td>Saman Mohammadi &amp; Niel Slob</td>
<td>11-02-2014</td>
<td>Draaijer + Partners &amp; PhD RE&amp;H TUDelft</td>
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<tr>
<td>Bastiaan von Meijenfeldt</td>
<td>16-04-2014</td>
<td>Biologist</td>
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<tr>
<td>Alwin Beernink</td>
<td>23-04-2014</td>
<td>Park Strip Beheer Eindhoven</td>
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<tr>
<td>Florian de Boer</td>
<td>02-05-2014</td>
<td>De Urbanisten</td>
</tr>
<tr>
<td>Douwe Jan Joustra</td>
<td>02-05-2014</td>
<td>One Planet Architecture institute (Rau Architecten)</td>
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3. **Overview of brainstorms**

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<tr>
<td>Bastiaan von Meijenfeldt, Josephine van Lohuizen, Yannick Vos</td>
<td>17-03-2014</td>
<td>Searching in nature’s database</td>
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4. **Overview of exploratory master classes**

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<tr>
<td>Master class sustainable innovation Schiphol</td>
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<tr>
<td>Symposium Groene Golflente Radio Kootwijk</td>
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*For the complete documentation of the interviews and brainstorms please contact the author.*