Graduation Plan

Master of Science Architecture, Urbanism & Building Sciences

Graduation Plan: All tracks

Submit your Graduation Plan to the Board of Examiners (Examencommissie-BK@tudelft.nl), Mentors and Delegate of the Board of Examiners one week before P2 at the latest.

The graduation plan consists of at least the following data/segments:

Personal information	
Name	Dimitrios Ntoupas
Student number	5386489

Studio		
Name / Theme	Design Informatics	
Main mentor	Dr. S. Asut	Design Informatics
Second mentor	Ir. B. Lubelli	Material Science
Argumentation of choice of the studio	Over the last two decades there is an increasing awareness of the need for a sustainable and circular approach towards many aspects including architecture and construction. Advancements in new technologies can contribute to creating more environmentally benign solutions, enabling comparison and evaluation even before a project has been built. Additionally, there is a need to discover new, more innovative methods of interaction between manufacturing and design from an early design stage. At the same time, there is an urgency to replace unsustainable building materials with others which are more environmentally friendly and to look into underlying material properties, such as bioreceptivity, and their potential benefits. Bioreceptivity is when materials can be colonized by living organisms without necessarily going under any biodeterioration. Bioreceptive materials are becoming more and more popular, demonstrating the potential of replacing vertical green walls. However, the research and experiments that have been conducted concerning bioreceptivity are very limited, especially in correlation with architectural design. Design informatics in combination with material science could be the driving force of investigating both in digital and physical space, at a large and small scale and ultimately taking the concept of bioreceptivity a step further.	

Graduation project	
Title of the graduation project	Primary Bioreceptivity Topology and Material Optimization via Digital Fabrication
Goal	
Location:	The Netherlands

The posed problems	Urbanization creates several environmental challenges including loss of biodiversity, heat stress and increased air pollution. Several strategies of introducing vertical green walls have been introduced in cities but in many cases they have been proven unsuccessful due to the non-adaptability of the chosen plants, climate conditions, incorrect maintenance or a combination of these factors. What is more they require extra costs and energy for their structural, maintenance and irrigation systems.
Research Questions	<u>Main Research Questions:</u> • How and to what extent does a surface's topology influence its bioreceptivity performance and how could this be optimized taking into considerations extrinsic and intrinsic parameters? • To what extent could the material composition of a lime-based mortar be optimized in terms of bioreceptivity? • Which types of bryophytes are the most convenient to aim introducing on bioreceptive substrates and how could these be integrated in the development of a design workflow for producing surfaces that could be colonized in a predictable and scalable way? • How could such complex geometries be produced in reality and to what degree could digital fabrication become beneficial in manufacturing? <u>Secondary Research Questions:</u> Literature Research: • What is bioreceptivity and what types of bioreceptivity exist?

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Which variables influence bioreceptivity?
Which materials are bioreceptive?
How do bryophytes disperse and how do they reproduce?
What are bryophytes and cryptogams?
What is biocompatibility and bioscaffolding?

Parameterization:

How could bioreceptivity be integrated in a digital workflow? What parameters should be taken into account?
How could a method of bioreceptivity evaluation be constructed in digital space?
Which material properties increase bioreceptivity?

Fabrication:

How can physical (material) and digital (workflow) investigation be combined in a unified methodology?
What are the potential architectural applications?

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<tr><td>Design Assignment</td><td>
The present thesis is focused on the digital workflow and on the methodology behind topology optimization of bioreceptive materials. The final product will be a digital “toolbox” able to target segments of a given geometry which fulfill specific requirements in a defined location. The proposed segments are processed in order to captivate microorganisms at a micro and macro level. A half-sphere pavilion which faces all directions will demonstrate, as a case study, how differently segments need to be treated in order to achieve optimal bioreceptive performances.
On the other hand, a material investigation will be conducted taking into consideration existing bioreceptive limestone-based mortars in order to find out how and to what extent these recipes could be improved in terms of biological growth encouragement.
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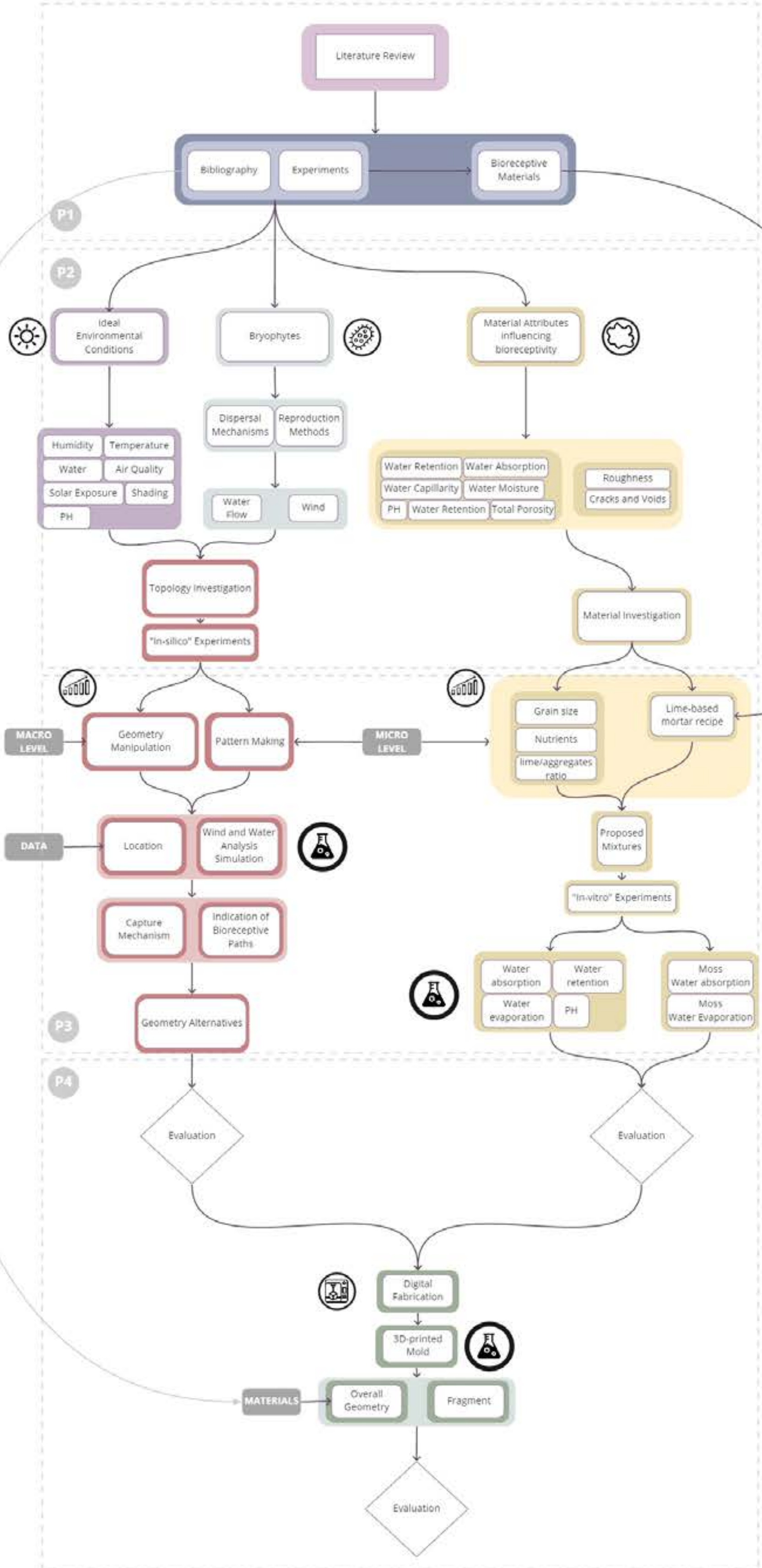
	Finally, parametric design and material investigation will be combined through digital fabrication and by utilizing new technologies (i.e. additive manufacturing) in order to research potential methods of manufacturing bioreceptive components at different scales.

Process

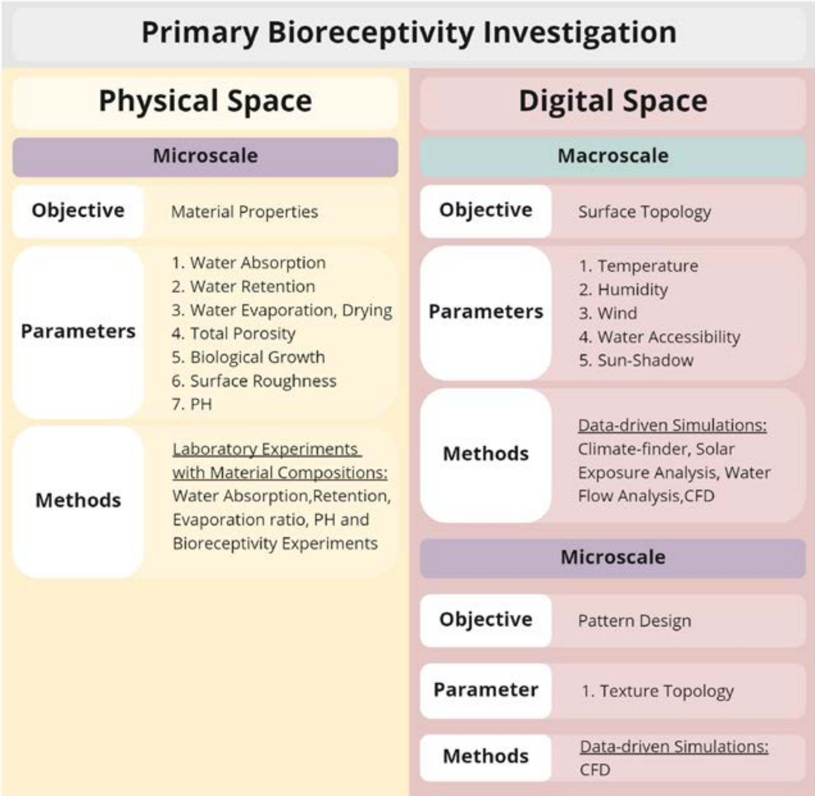
Method description

Bioreceptivity is a multifactorial process which depends on extrinsic and intrinsic variables. These factors could be simply divided into two principal categories that are firstly related to the materials' attributes and secondly to the environmental conditions that take place each time. The present thesis research investigates the bridge of these two main categories through a research-by-design approach in physical and digital space. Experiments are being conducted both "in-vitro" and "in-silico". For "in-vitro" experiments, a material investigation will be conducted, examining how an existing lime-based mortar can improve its bioreceptivity performance. As far as "in-silico" experiments are concerned, potential bioreceptive-related parameters, such as climatic conditions (i.e. sun exposure, microclimate, shadow, wind loads and water flow) and location, will examine how surface topology can encourage biological growth. As a sequence, a digital "toolbox" is being engineered taking into account all the parameters that influence bioreceptivity in micro and macro scales. Finally, the intersection of these two experimental approaches will result in the realization of a bioreceptive component thanks to digital fabrication. Possible digital fabrication techniques including robotic assembly and additive manufacturing techniques will be investigated in order to evaluate whether new technologies could offer a sphere of new possibilities to the manufacturing field through applications.

The above mentioned explanation is depicted in the figure below with a higher degree of detail. The simulations are going to be conducted in digital space using grasshopper and CFD software. Physical experiments are going to be held in Heritage + Architecture Laboratory and in LAMA. Finally, a simple estimation of what it is expected to be finished in every presentation is noted in the figure.



Literature Review
Bibliography
Experiments
Bioreceptive Materials
P1
P2
Ideal Environmental Conditions
Bryophytes
Material Attributes influencing bioreceptivity
Humidity
Temperature
Water
Air Quality
Solar Exposure
Shading
PH
Dispersal Mechanisms
Reproduction Methods
Water Flow
Wind
Water Retention
Water Absorption
Water Capillarity
Water Moisture
PH
Water Retention
Total Porosity
Roughness
Cracks and Voids
Topology Investigation
"In-silico" Experiments
Material Investigation
MACRO LEVEL
Geometry Manipulation
Pattern Making
MICRO LEVEL
Grain size
Nutrients
lime/aggregates ratio
Lime-based mortar recipe
DATA
Location
Wind and Water Analysis Simulation
Proposed Mixtures
"In-vitro" Experiments
Capture Mechanism
Indication of Bioreceptive Paths
Water absorption
Water retention
Water evaporation
PH
Moss Water absorption
Moss Water Evaporation
Geometry Alternatives
P3
P4
Evaluation
Evaluation
Digital Fabrication
3D-printed Mold
MATERIALS
Overall Geometry
Fragment
Evaluation



Literature and general practical preference

The detailed bibliography can be seen in the report document (pg. 54-56). The topics that have been covered to a great extent are the following:

<u>Literature :</u>

Bioreceptivity:

- Backround of bioreceptivity
- Bioscaffolding
- Biodeterioration
- Unit of Measurement and Bioreceptivity Index
- Categorization of Bioreceptivity
- Bioreceptive Factors
- Limitations
- Bioreceptive Applications

Bryophytes:

- Mosses
- Cryptogams
- Dispersal Mechanisms
- Advantages of Bryophytes
- Applications

Parameterization:

- Digital Fabrication

- Additive Manufacturing
- Rapid Prototyping
- Case studies and examples

Practical Preference :

- Experimenting and assessing the properties of lime-based mortars.
- Growing moss on lime-based mortars.
- Creating prototypes through a 3D-printed mold.

Reflection

Climate change is already upon us, alerting us that there is an urgency to develop new building materials and methodologies in order to achieve social, energy and environmental sustainability. Building technology is about “constructing” innovative concepts and workflows in the building industry field. In many cases innovation can be realized, not by discovering new technologies but by combining existing ones in a more intelligent way. In this fashion, in order to make a change there is a need to provide insight into facts that are unexplored and may be hiding myriads of possibilities. As such, bioreceptivity is not a novel concept but it remains largely uninvestigated but there is evidence that it could replace vertical green walls by eliminating existing drawbacks, regarding costs and embodied energy for maintenance, structural and irrigation systems. In parallel, there is clear proof that bioreceptive materials could benefit cities in acoustics, air-infiltration, pollutants’ absorption and through cooling methods. The present thesis follows a research-by-design methodology investigating bioreceptivity both in physical and digital space by applying new technologies and striving to shed light on unknown opportunities and eventually contribute to sustainable development. Consequently, there is an excessive need to adopt innovative, circular and environmentally benign strategies along with new materials in a more holistic design approach from small to large scale. Bio-design, Bio-fabrication and material-driven design are some new emerging approaches that are able to offer new potential to the build sector. By utilizing new technologies and applying them into the architectural workflow, new prospects arise by taking into account a wide variety of different parameters. In this sense, computational and generative scripts could become toolpaths for fabrication and in our case even predict and dictate the biological growth on a bioreceptive surface.