# TRANSFORMATION IN NATURE

Integrating biomimetic design into
New Pavilion Design in Seismic Groningen

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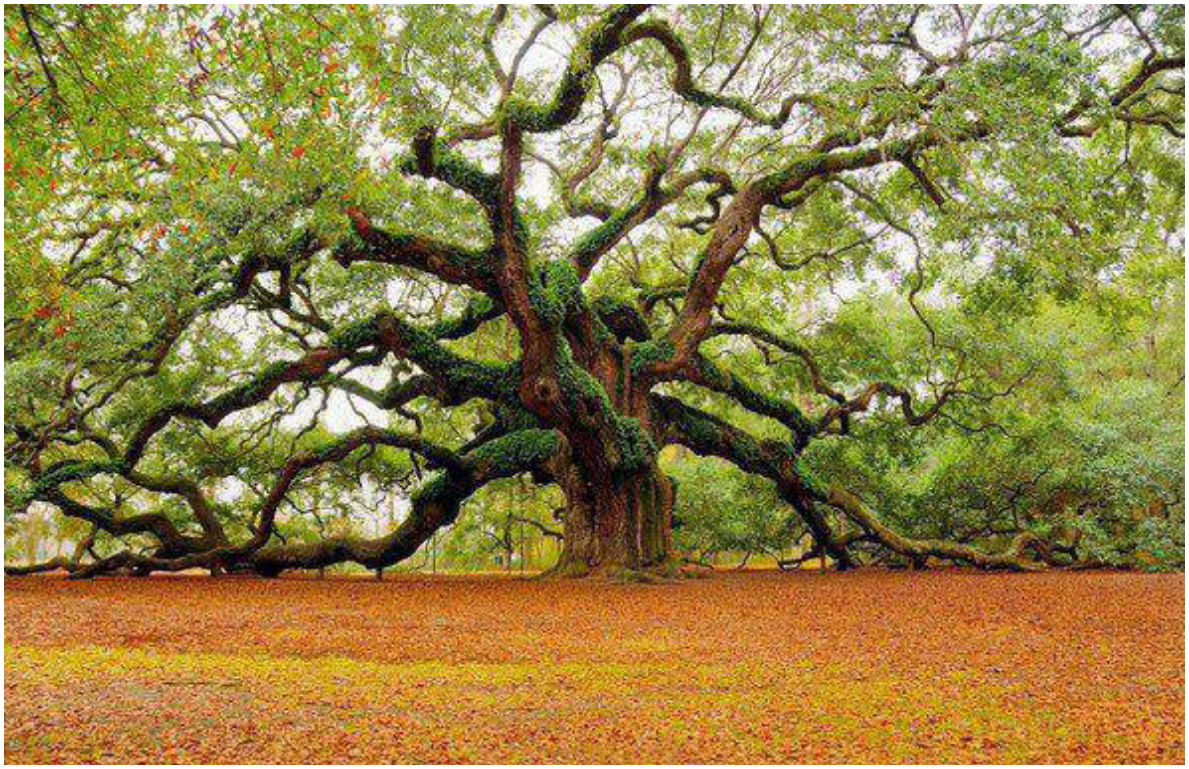
# TABLE OF CONTENTS





# 1. Background

## 1.1 Reforestation Program

The Netherlands currently shares with Ireland the title of Europe's least wooded country—trees currently cover just 11 percent of its surface area.

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## 1.1 Reforestation Program

The Netherlands currently shares with Ireland the title of Europe's least wooded country—trees currently cover just 11 percent of its surface area.

1. Increasing the extent of woodlands, less-developed spaces in "Green Heart" area. (Rotterdam, Amsterdam, the Hague, and Utrecht)

2.Northern provinces (Drenthe, Groningen), poor agricultural productivity left it largely empty land.

# 2. Problem Statement

## 2.1 Earthquake:

The Groningen is facing a permanent danger of potential earthquake these years due to over extraction of the gas oil.

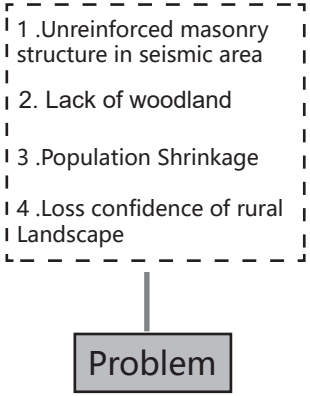
Although very few constructions are really collapse, buildings are in different extents of the damage.

# 2. Problem Statement

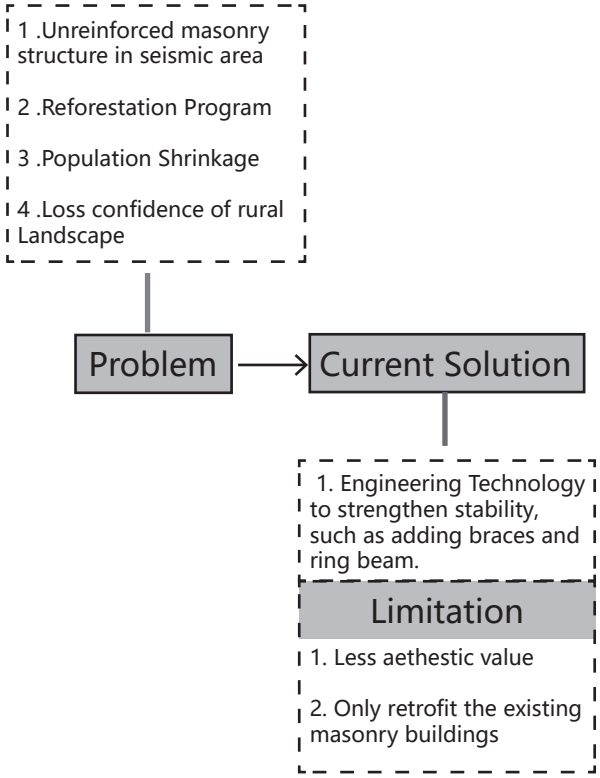
## 2.2 Population Shrinkage & Loss interest of rural life

Groningen has abundant landscape resource in farmland. People are not interested in the community life and rural lifestyle.

# 3. Diagram



# 3. Diagram



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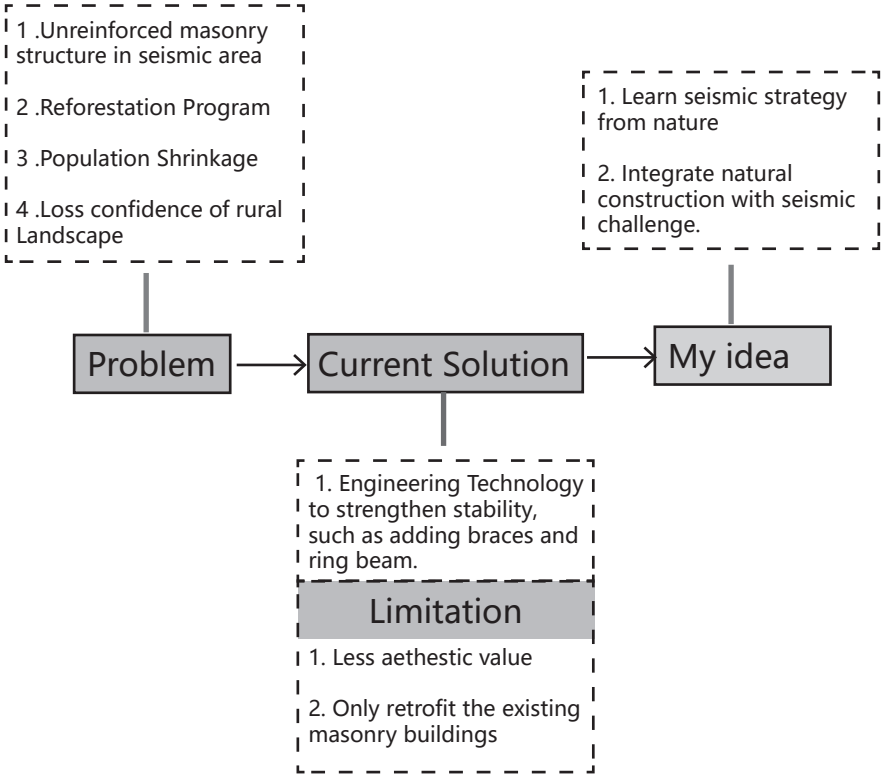

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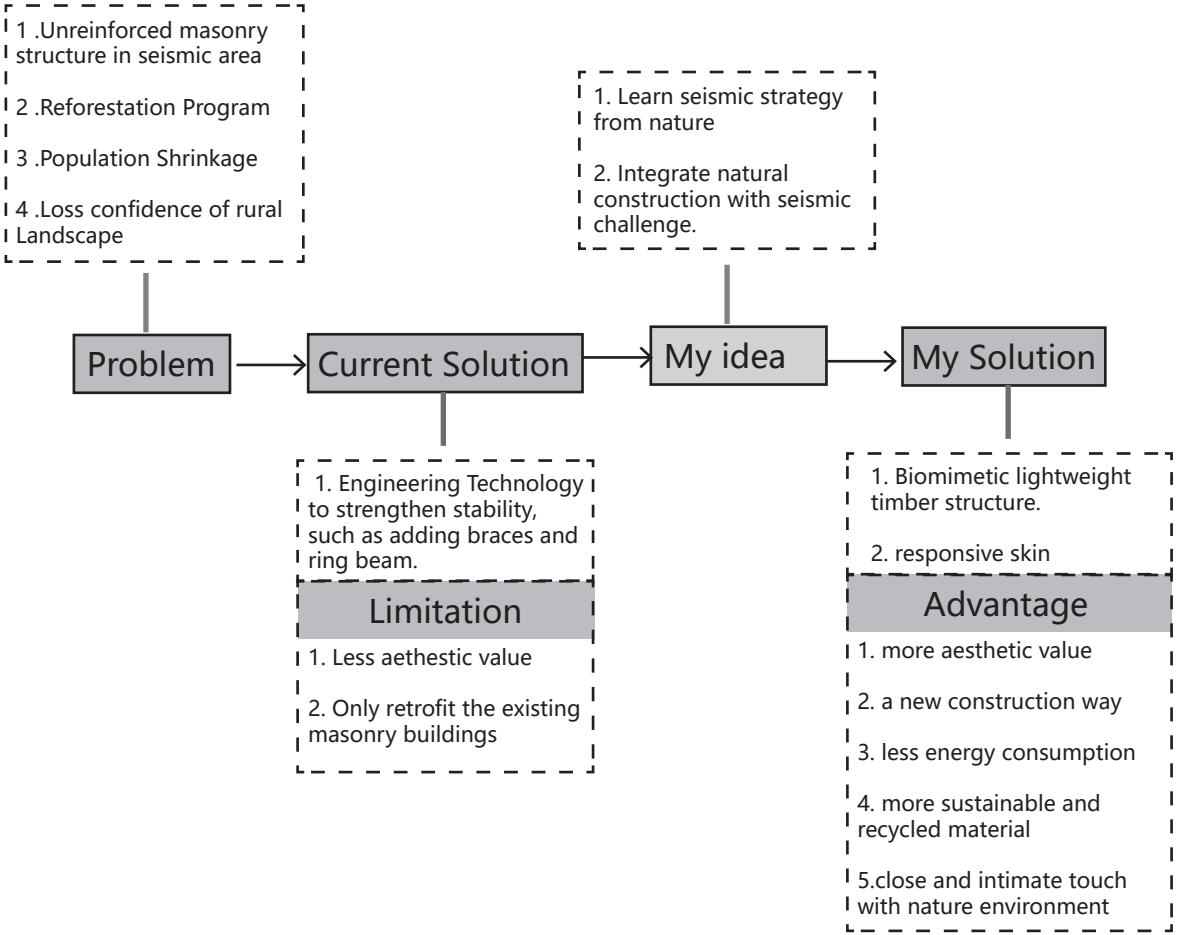

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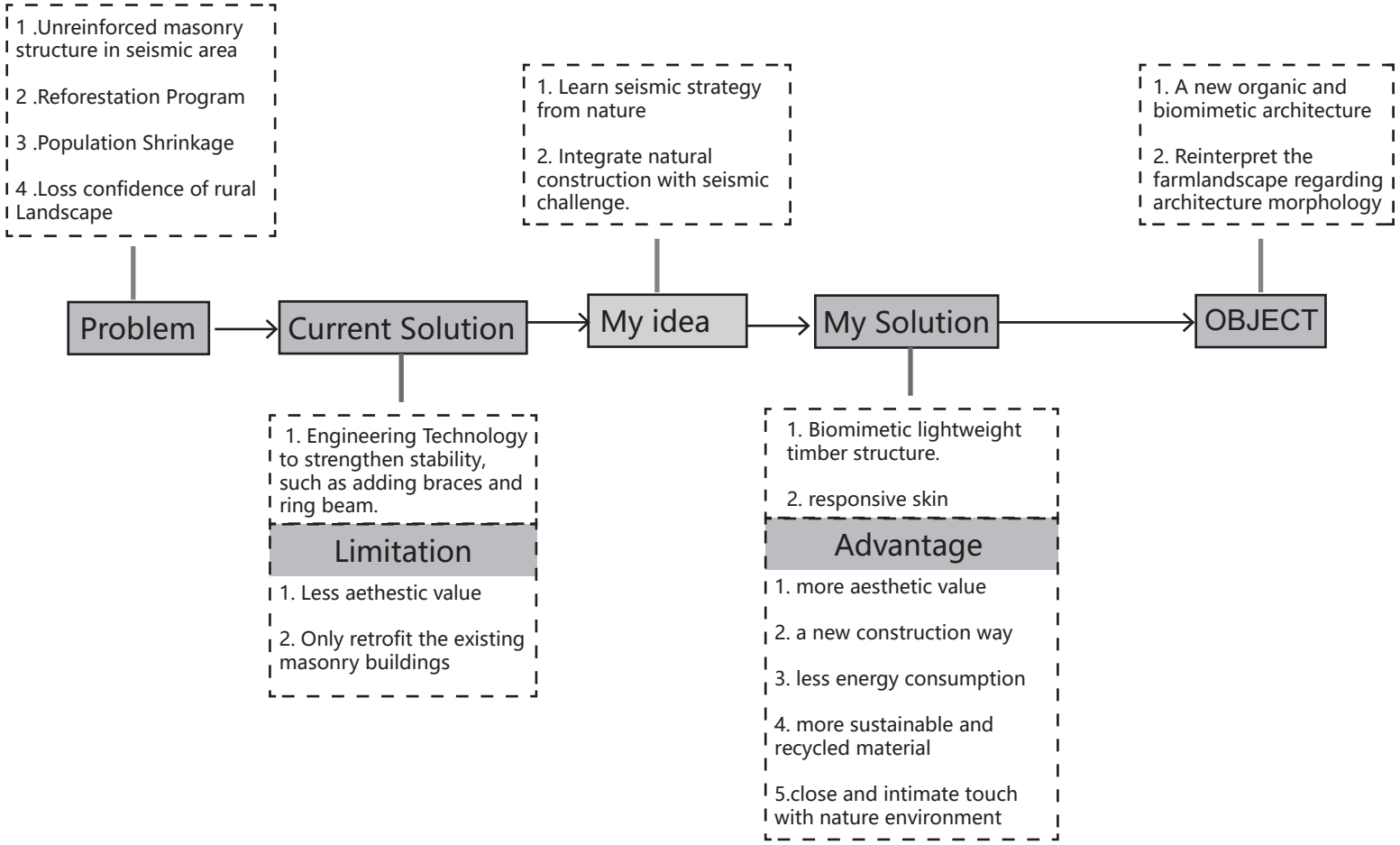


# 4. Research Question

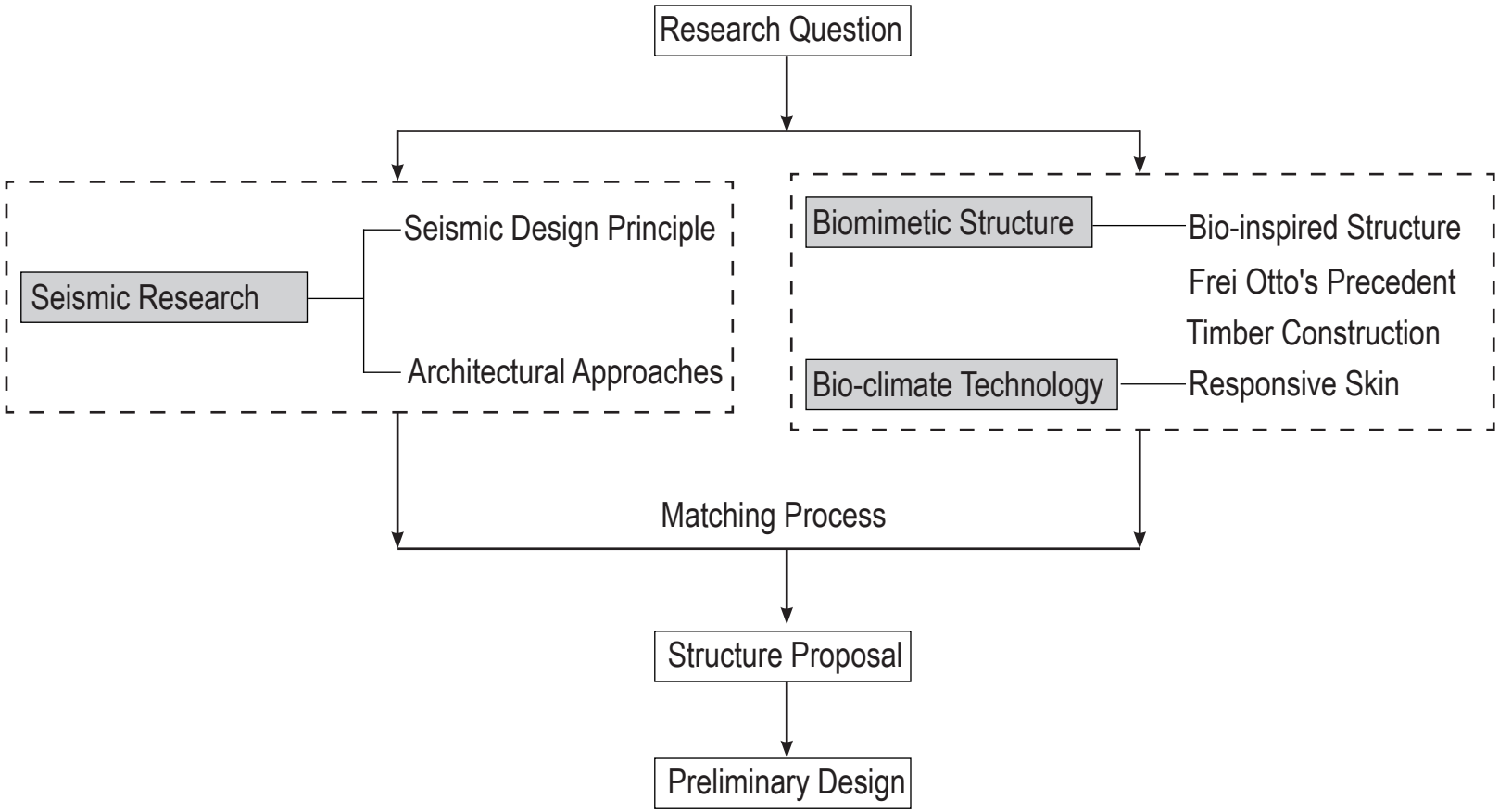
"How to adopt a biomimetic method for the seismic Groningen, taking the landscape, context, and technology into account?"

**seismic design research**
-1.what Principles should architecture design comform to for the seismic resistance ?

**Biomimetic structure research**
-1. what kind of biology-inspired structure could better match with the anti-seismic principle?

**Bioclimate technology research**
-1. what kind of responsive skin technology could be integrated into the museum design?

# 5. Research Framework

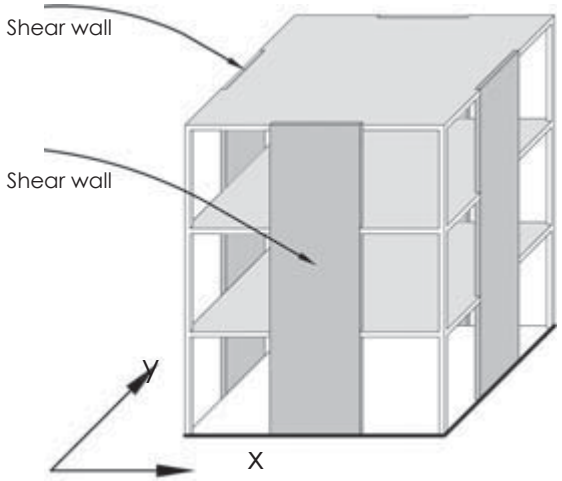


# 6.0 Seismic Design Principle

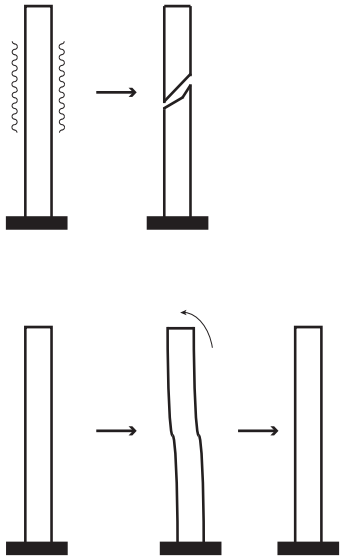
. lightweight mass

. Strength and Stiffness of structure, ductile material

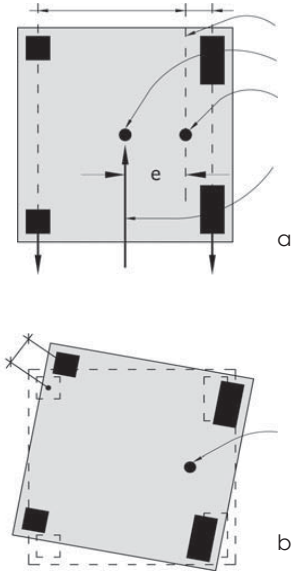
. Preventation of torsion




The shear force can resist the bending moment, wall force and "Xy" directional force.



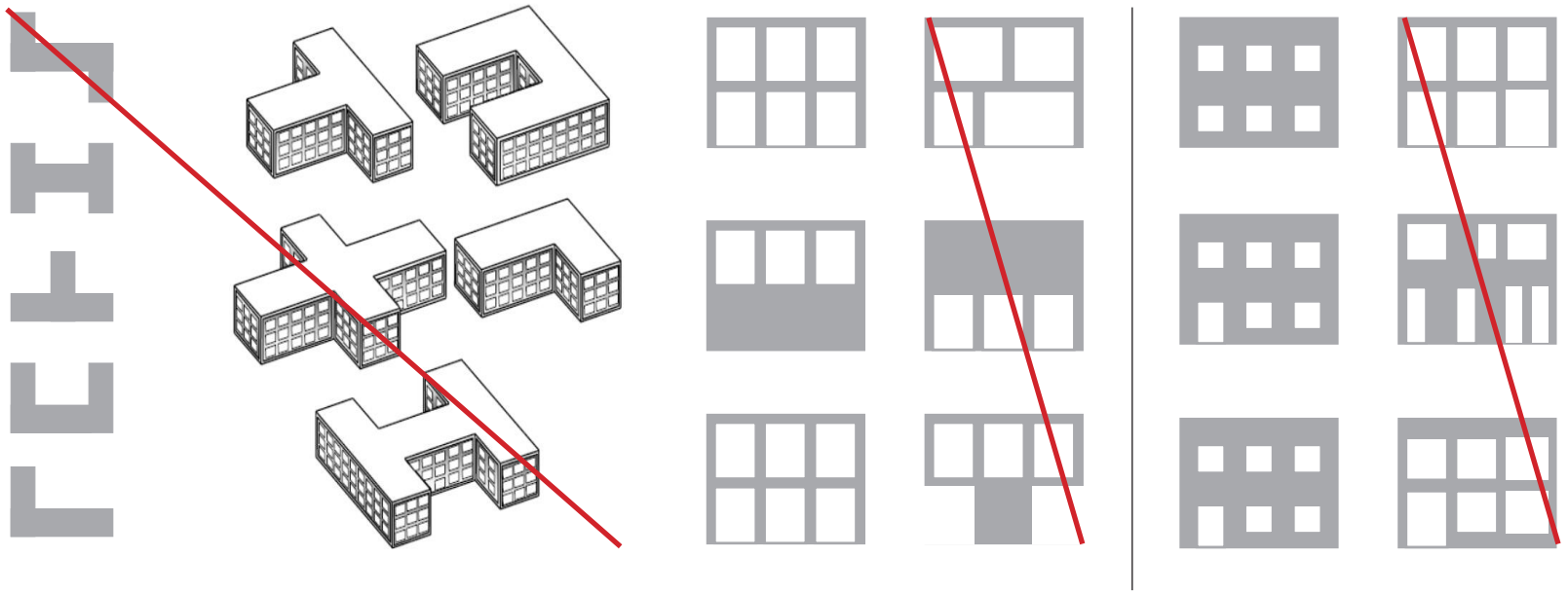
The different ductility of structure responds to the seismic force




a.deeper right-hand columns resist more force than left-hand columns. b. Twisting at roof level about the CoR

# 6.0 Seismic Design Principle

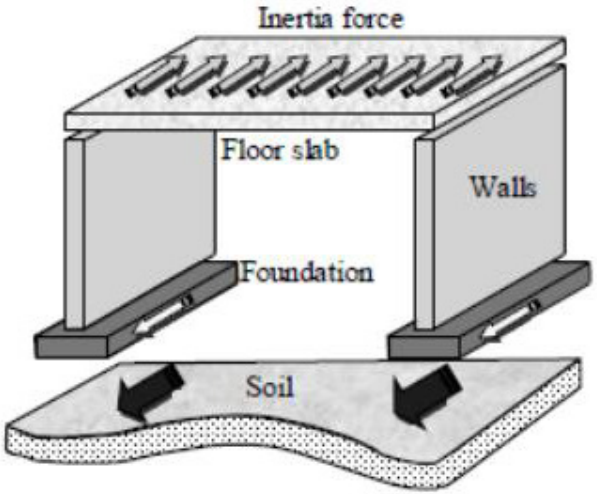
. Building configuration: Regularity in plan and elevation



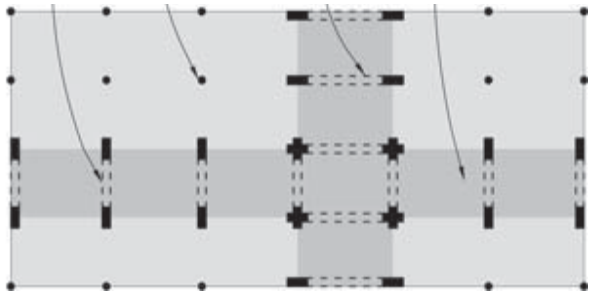
# 6.0 Seismic Design Principle

. Reasonable loadpath transfer

. Provide the building with second load paths and redundancy in structure




Load path tranferring

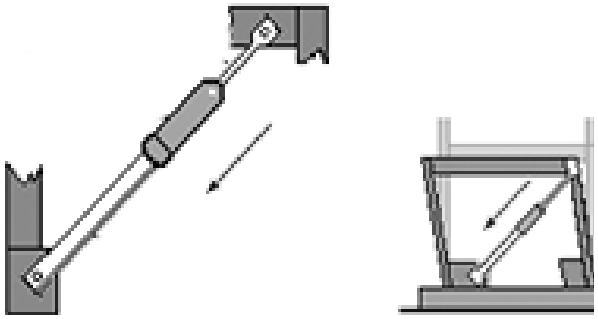


Two-way moment frame resisting inertia force whose strucrually symmetrical layout integrate with gravity only columns.

# 6.0 Seismic Design Principle

. Reduce the demand by dissipating energy, or increasing the building period

. Non-structure elements like triangular or hegxagonal windows and doors stablize the structure.



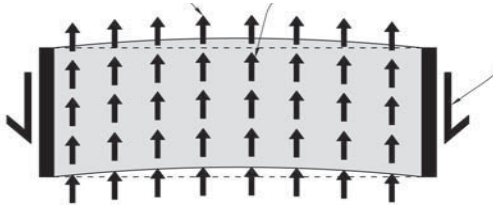
damping system dissipate energy

non-structure elements

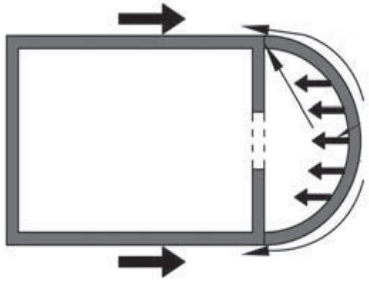
# 6.1 Toolbox For Seismic Resistance

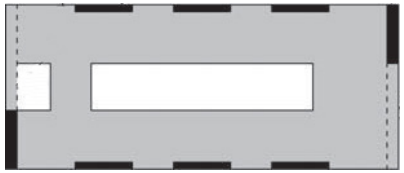
**STRENGTHEN THE HORIZONTAL STRUCTURE:**

. Consolidate the connection between horizontal diaphragm and vertical shear wall

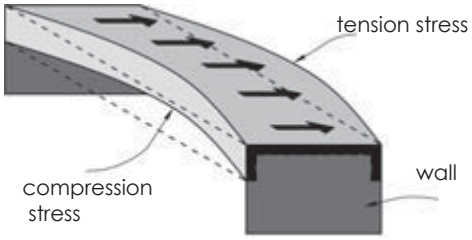


plan of inertial force in diaphragm

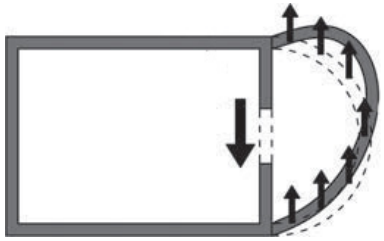




Short wall in x direction as collector members would effectively resist the inertial force.




connection of diaphragm and wall



Curve bond beam acting as arch

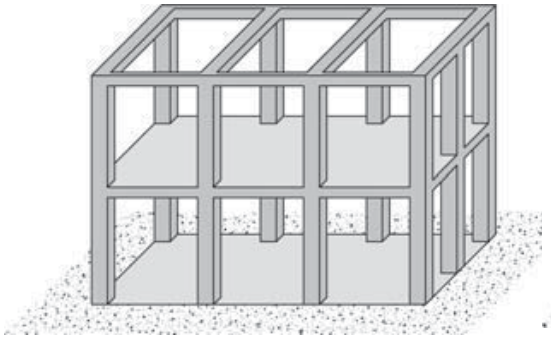
# 6.1 Toolbox For Seismic Resistance

**STRENGTHEN THE VERTICAL STRUCTURE:**

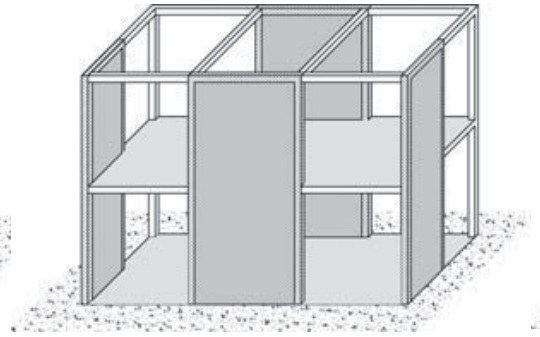
. X-brace to stablize the loadbearing members

. Shearwall

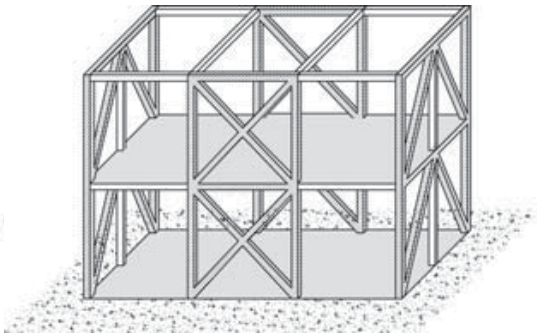
. Moment frame



Moment frames



shear walls

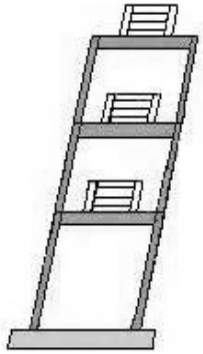


Brace and chord

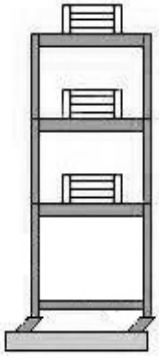
# 6.1 Toolbox For Seismic Resistance

. Add damping isolate member under the base to dissipate the earthquake energy.

. Add the building components with high ductile capacity like cable and strut.



Fixed base



Isolated base

Cable in tension

Strut in compression

# 6.2 Biomimetic Transformation

what is biomimetics? Biomimetics is not only about nature imitation, but by studying their mechanics and principles in order to transform and develop these principles into complicate technological and architectural solutions.

***"Being an integral part of nature ourselves, we shall never be able to talk about it from the outside but only from the inside, uncertain whether to consider something created and produced by man as being 'outside' nature."***

Paolo Portoghesi

# 6.2 Biomimetic Transformation

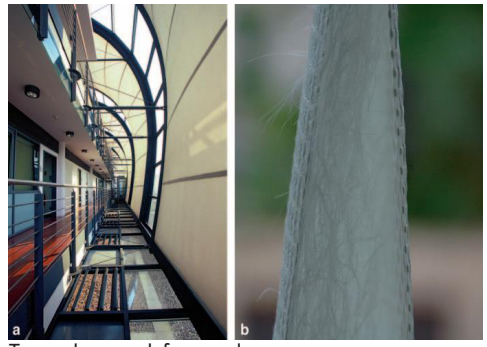
**1. Biomorphic structure**
The appearance of the building is similar to the natural shape as sculptures

**2. Process and mechanism analogy**
biomimetic natural construction is building methods analogous to nature, like form finding, self-organization process.

**3. Interactive information**
Living skin performs the tasks of load distribution, substance exchange, information communication as well.... Mimic moisture constrol, acoustics and sound insulation, heat insulation and so on.


Calatrava- Metropol Parasol


Stadium in Munich



Translucent facade

# 6.2 Biomimetic Transformation

**Transferring Method:**

The transfer of information from one discipline to the other disciplines is the most interesting part of the biomimetic process. The transfer of form, the application of morphological characteristics , information flow, construction process and material.

**1.Biology push approach**:
Bottom up approach, Biomimetric technology is stimulated from insights of biological research

**2.Technology pull approach**:
Top down approach, driven by a technical scope, extracting the biological approach to improve an already mostly existing technological product.

**3.Pre-researched "Pool Research" approach**
“Pool Research” ---- filling with the biological data reservior, which are oriented to a quick generaton of knowleadge.

# 6.2 Biomimetic Transformation

**-Phrase 1: Screening**
the laser confocal microscopy, a series of structure compare with the technical object

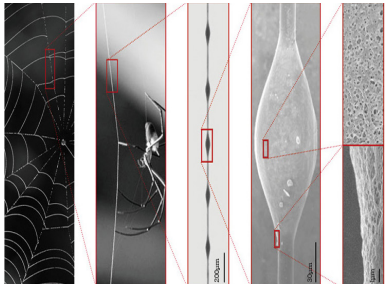
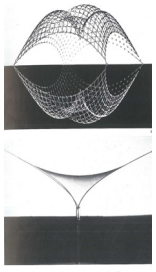
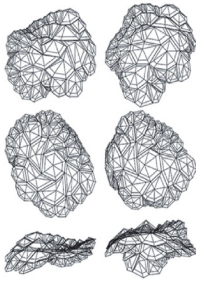
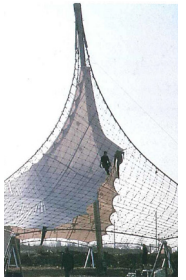
**-Phrase 2: Investigation of structure**
The screened geometries of structure are modelled in cad

**-Phrase 3: Abstraction**
structure principle is simplified and abstracted. Stress regions are identified in order to replicate the simplified structure.

**-Phrase 4: Optimization**
the abstract models are parametric and tested

**-Phrase 5: Fabrication**

Phrase 1 | Phrase 2 | Phrase 3 | Phrase 4 | Phrase 5

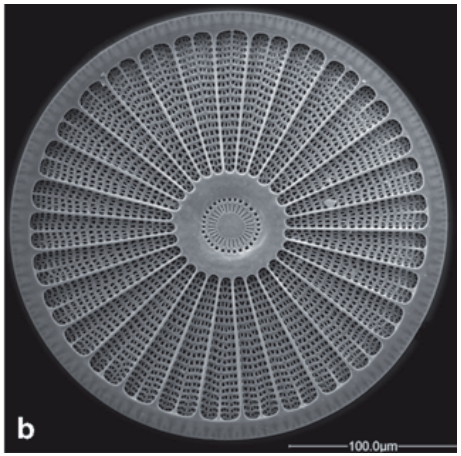
# 6.3 Biomimetic Structure

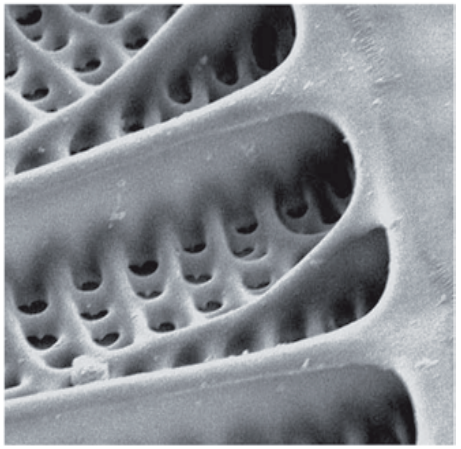
**Diatoms and radiolaria inspired structures:**

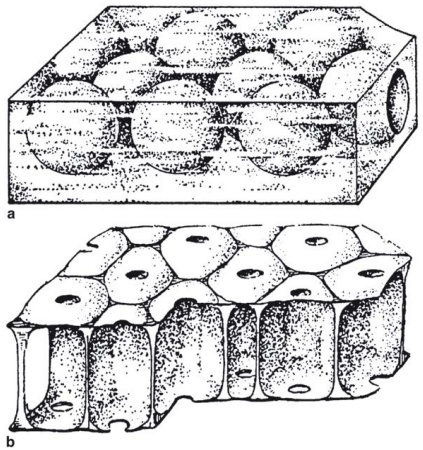
a lacy, mesh-like skeleton. open pores are filled with several mesh layers, which nested inside the one another.

1. elongated oval shape, radially symmetric; The radial ribs run from center outwards supporting the fine mesh layer in between

2. **hollowed hexagonal frame form**



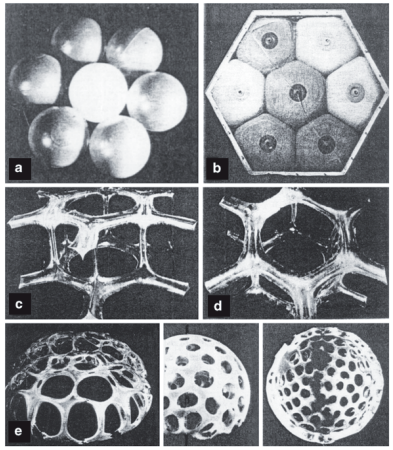


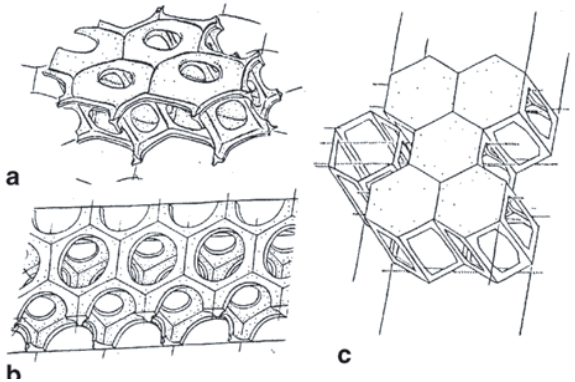
# 6.3 Biomimetic Structure

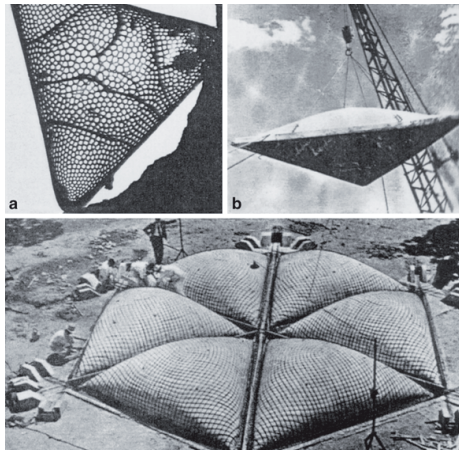
**Panel structures:**

1. The **hexagonal panels roof** and the hexagonal **concret building blocks** are connected covering the hollow hexagonal frame, which are easily to be produced and assembled.

2. six pieces of diatom-shaped **steel reinforced concrete shells** for water reservoir is arranged together



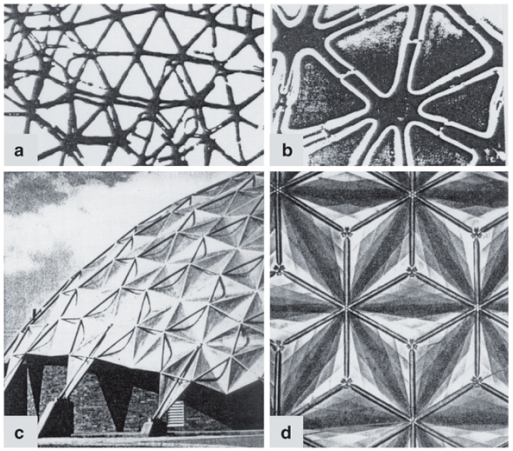
# 6.3 Biomimetic Structure

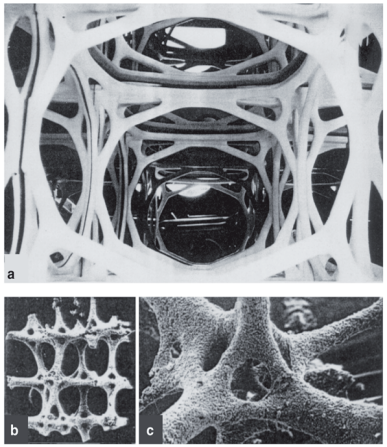
**Nods and rods framework**

**siliceous sponges,** the nodal points are more dissolved and forming a network of branching struts. The entire structure is oriented on the tragectories of forces

1. grow with the accumulation **strandardized elements**. **basis, large, long-spanning**

2. **fossilized** sea sponge, **spatial** nod-and-rod framework, high **torsion-resistant capacity**, **force trajactory**



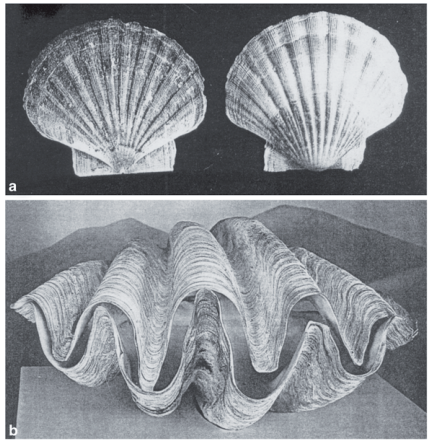



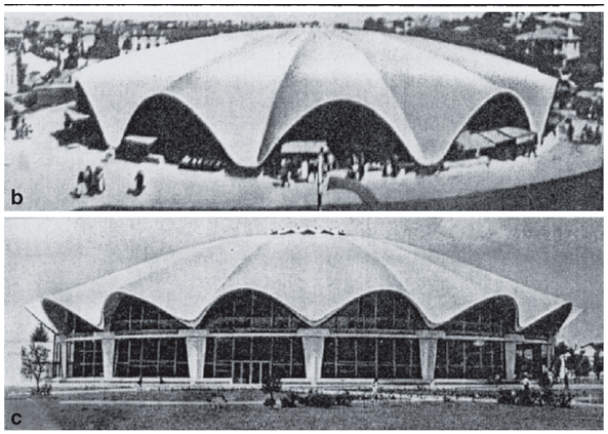
# 6.3 Biomimetic Structure

**shell structure**

1. wide-stretched, thin-walled form, building material like **pre-stressed concrete.**
**self-supporting network** found by ***hanging chains***

2. the **ratio** between the diameters and shell thicknesses, 1/1000



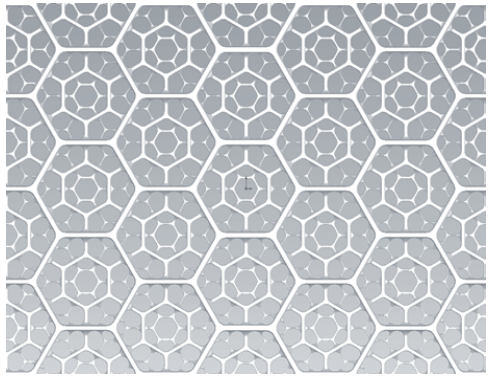



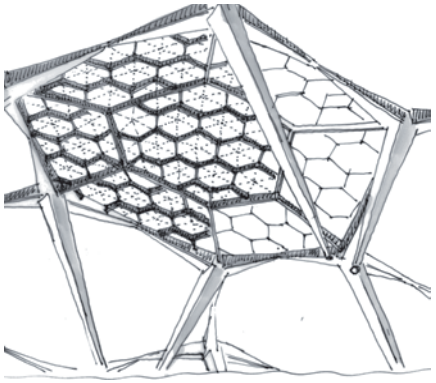
# 6.3 Biomimetic Structure

**hierarchical structure**

1. the diatom exhibits **rigid ribs** and secondary **branching structures**. The large ribs are supported by smaller substructures.

2. **hexagonal** structure unit, **modularly** constructed with the **same size** ,**pressure-resistent shell structure, efficient**.



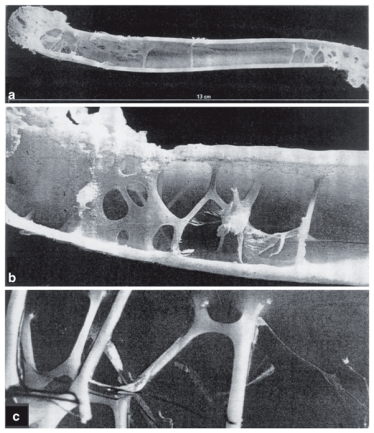


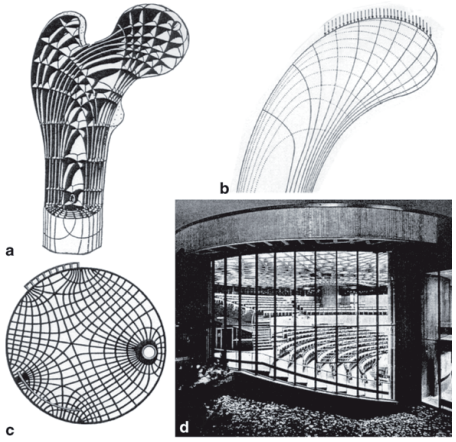
# 6.3 Biomimetic Structure

**Bone Brace structure**

1. interior bone correspond to the **stress trajectories** of compression and tension. **light.**

2. **bone strut** is base on the existing available prefabricated products (T profiles), optimize the structure stability.



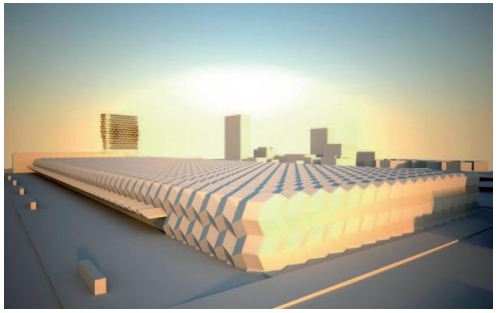




# 6.3 Biomimetic Structure

**Folding system**

increasing the rigidity of surfaces and surface area

Around **X-shape** vertex, the **direct transformation, difficult**. One panel can be best coodinated with the neighboring panel automatically **resisting the deformation** and **movement**, and lastly forming a very rigid frame.

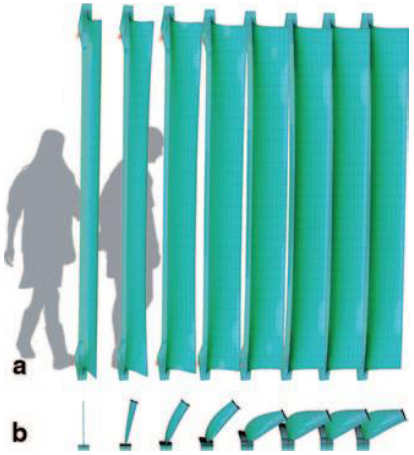



# 6.3 Biomimetic Structure

**Autonomous Movements**

Triger: chemonastic, seismonastic, thermonastic, photonastic
Natural apparatuses that open and close themselves without mechanical elements

based on the **elastic deformation property** in material, sun shading facade is changeable.



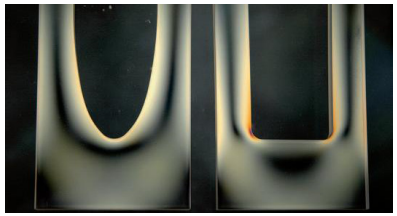
# 6.3 Biomimetic Structure

**Sturcture Optimization**

**1. Optimize form:** Branch is superior than perpendicular shape

**2. Reduce mass :**

**3. SKO methods:** "Soft kill option": adaptive bone mineralization, which is that heavily burdened region have increased rigidity while less burden regions are reduced in mass.



# 6.4 Frei Otto's Precedents

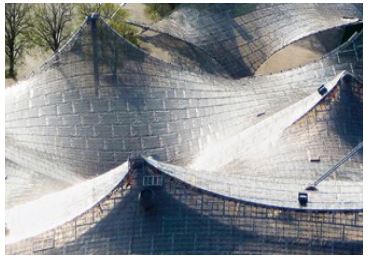
**cable net system**

- Simple saddle membrane
- Arch-type membrane
- Ridge-type membrane
- High-point-type membrane
  (Mast and cable supported membrane)

- **Pre-stressed** cable
- **The loops "eye"** is introduced in the web structure to ease the exessive point load also found in spider web
- **Extra mass** in the severely stressed nodal structure. spiders strengthen these regions by adding more silk threads or thickening the individual threads.
- **Large span** can be bridged by tensile structure.


Simple saddle membrane


Arch-type membrane


ridge-type membrane

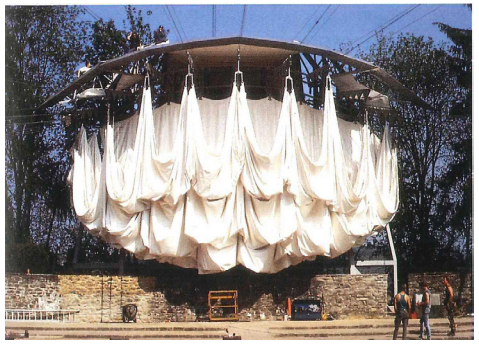

High-point-type membrane

# 6.4 Frei Otto's Precedent

**Retracble roof & Umbrellar structure**

Cable, pulley, cloth roof, minimum material, **minimum** intervention

The major load-bearing is concentrated into the **central column**



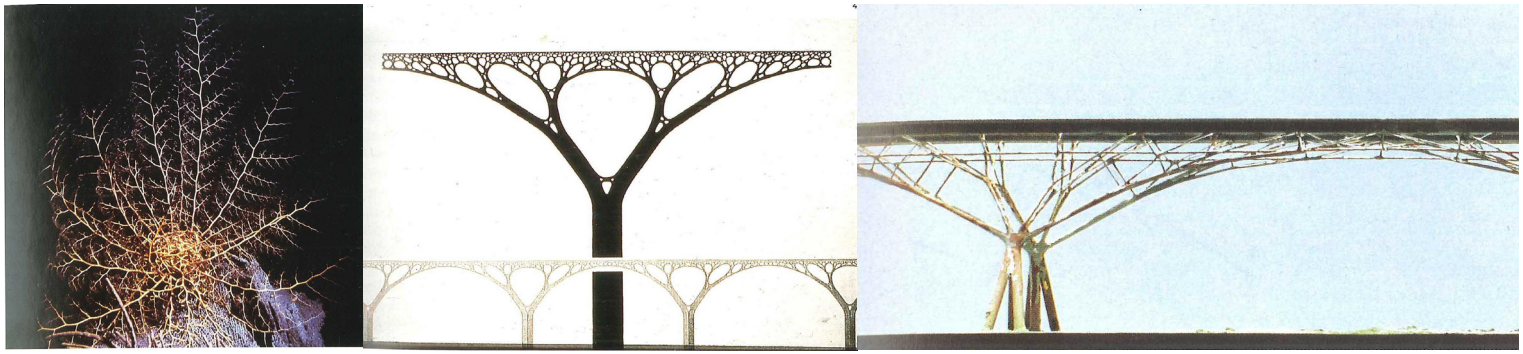
# 6.4 Frei Otto's Precedent

**Tree Structure**

flat roof is supported by the **a few point** column, load is distributed into **many point tree-branched column**.

each column bears **less force** than the former one, evitably with **less material**

**Structure optimization process**

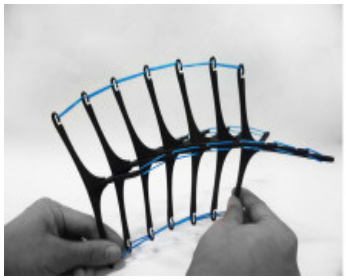
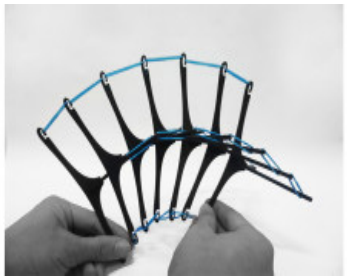
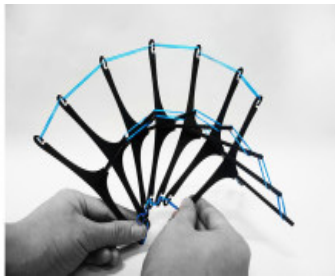


# 6.4 Frei Otto's Precedent

**Spine structure**

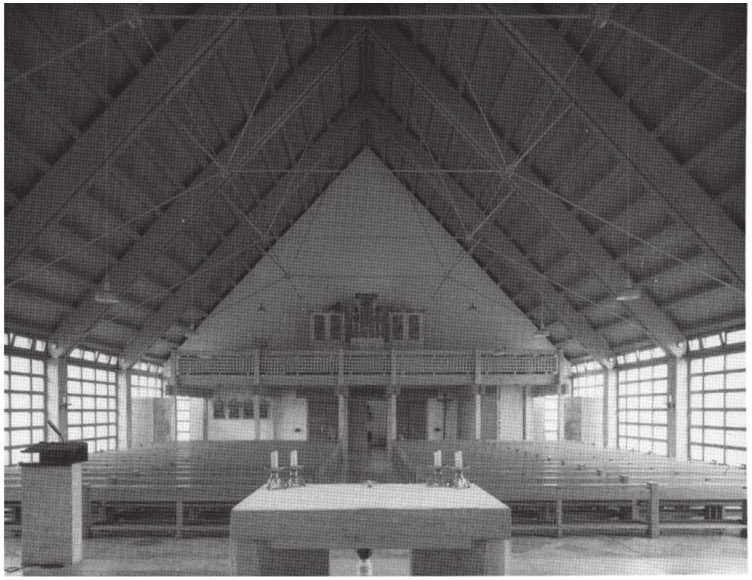
The human spine is a system of ligaments, tendons, muscles and bones, connecting the extremityies in body.

Frei Otto experiments with structure system of spine,
**pre-tensioned steel cable** to imitate the ligment and muscle.

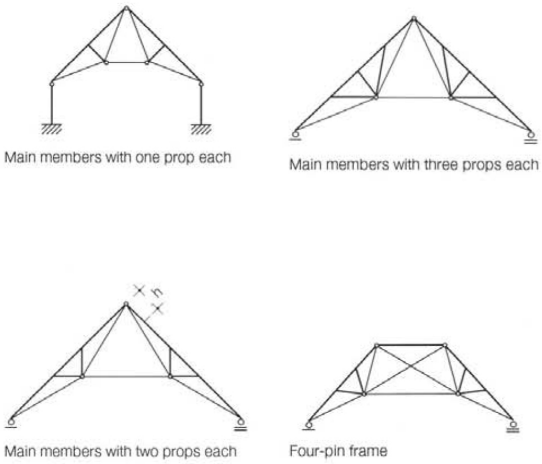





# 6.5 Timber Construction

**-Transform tensile stress to compressive stress**



81. St Martin's Church

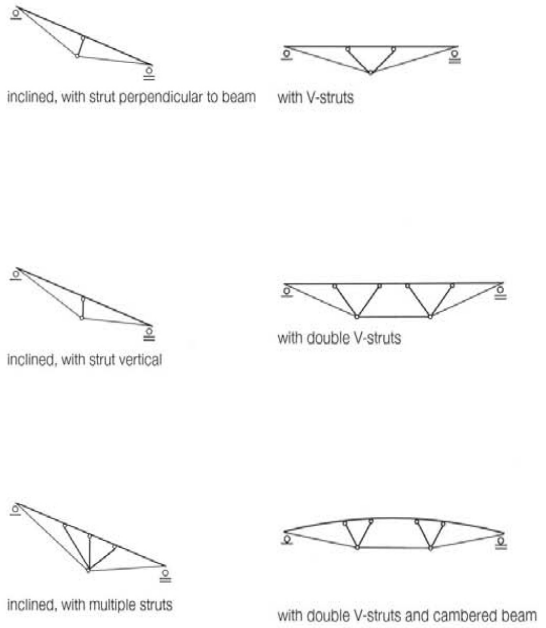



Three-pin frame with raised tie

# 6.5 Timber Construction

**-Transform tensile stress to compressive stress**

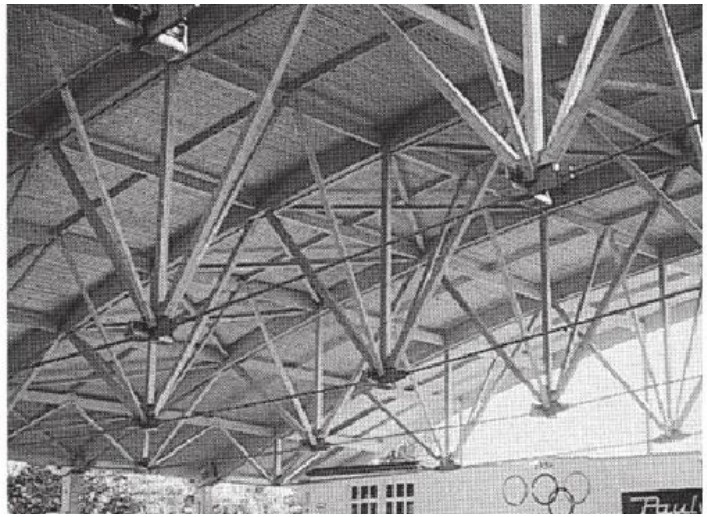
Multiple-purpose hall in primary school



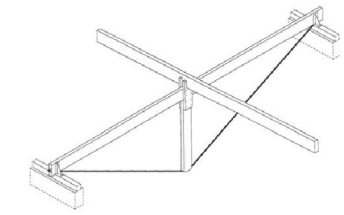

Trussed beam with tie in middle or steel

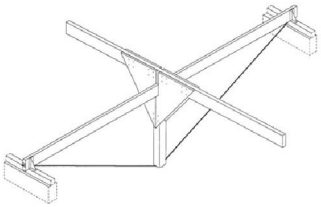
# 6.5 Timber Construction

**Fish belly truss with steel tie**



Fish belly truss with steel tie



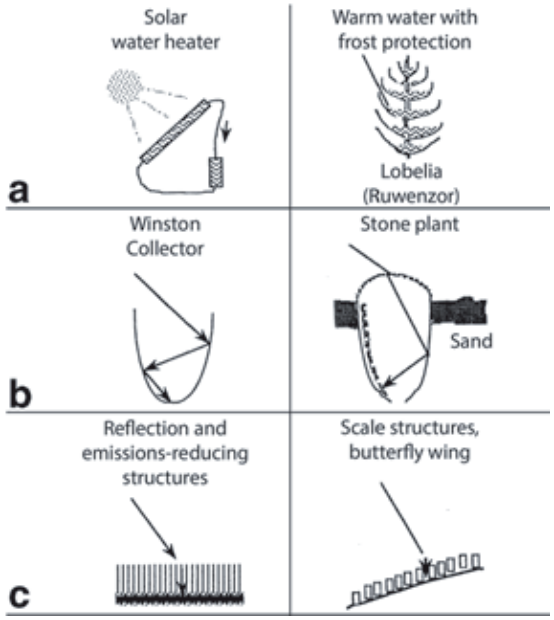



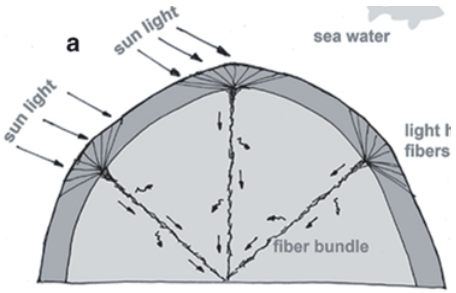

buckling of tension chord in trussed beams

# 6.6 Responsive Skin

**-Ative Light Control and Collection**

The **orange puffball sponge** (Tethya aurantia) lives in deeper waters. The speciality of this living thing lies in its ability to **transfer, distribute** light through the **bio-fiber bundles**. (See figure 93) the light havesting fibers is showing a form of bundles. The ending part of the silicate shreads **absorb sun light** from the environment and emit it into the interior of the body.



# 6.6 Responsive Skin

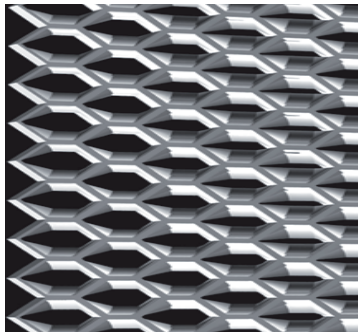
**- HUMIDITY REACTIVE SKIN**

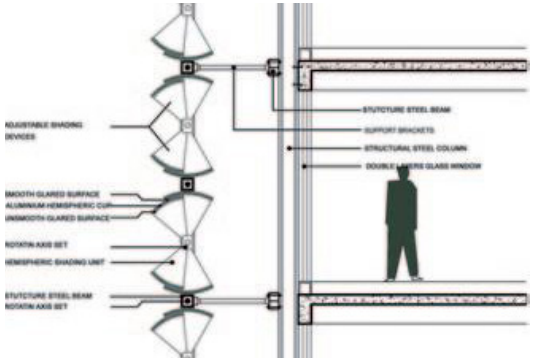
Cones of conifers is sensitive to the environment of "humidity" and "airdity". The exterior skin process hygroscopic changing abilities, which are evoked by **anistropic behavior of the wood fibers**. The wood changes with **absorption** or **desorption** of water, the cones open in dry conditions and close in moist conditions.

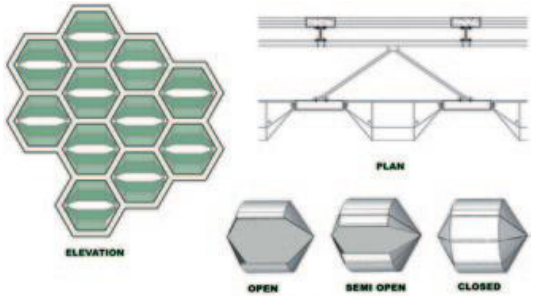
# 6.6 Responsive Skin

**- ACTIVE SUNSHADING FACADE SYSTEM**

**A double-layer** skin is made with the outer layer as "**guard cells**" controlling light and heat transmission, the inner layer consisting of **louvers** to redirect or prevent the light into the interior space.





# 7. Comparison & Assessment

| Seismic design Principles & Toolbox | | Biomimetric structure application | Structure Member |
|---|---|---|---|
| **DESIGN PRINCIPLES** | | **STRUCTURE SYSTEM** | |
| . lightweight mass | | . Diatoms and radiolaria-inspired structures | roof structure, column |
| . Strength and Stiffness of structure, ductile material | | . Nods and rods framework | roof, frame structure |
| . Preventation of torsion | | . Shell structures | roof |
| . Building configuration: Regularity in plan and elevation | | . Hierarchical structure | column, arch and vault |
| . Reasonable loadpath transfer | | . Bone braces | arch frame |
| . Provide the building with second load paths and redundancy in structure | | . Folding system | roof and facade |
| . Provide Adequate connection between the members | **Matching Process** | . Tensile structure -- cable net system | tensile cable member |
| . Reduce the demand by dissipating energy, or increasing the building period | | . Tensegrity system -- retractable roof | roof |
| . Non-structure elements like windows and doors stablize the structure. | | . Umbrella structure | column and roof |
| **TOOLBOX FOR SEISMIC RESISTANCE** | | . Tree column system | column |
| . Strengthen the connection between horizontal diaphragm and vertical shear wall | | . Spine structure | arch and vault |
| . X-brace to stablize the loadbearing members | | . Parabolic arch system | arch |
| . Add the building components with high ductile capacity like cable and strut. | | **CONSTRUCTION STABLIZATION ELEMENTS** | |
| . Add triangular or hegxagonal non-structure members like window | | . umbrella brace support | truss & beam |
| | | . Fish belly Truss | cable truss & beam |
| | | . K-brace Truss | truss & beam |
| | | . Post-trussing connection | cable truss & beam |
| | | **TECHNOLOGY OF SKIN** | |
| | | . Active light control system | roof glazing, facade |
| | | . Addaptive sunshading facade | facade |

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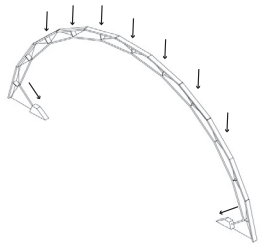
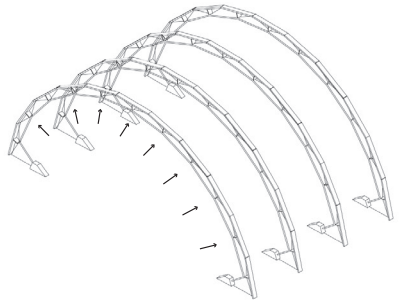
| | | . Addaptive sunshading facade | facade |

# 8. Structural Proposal

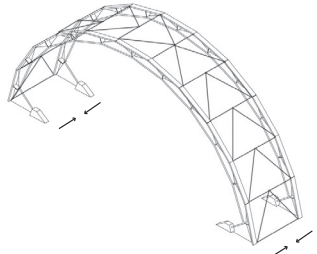
Fish belly beam replicates itself one by one, tranforming the **tension** of cable into the **supporting force**.



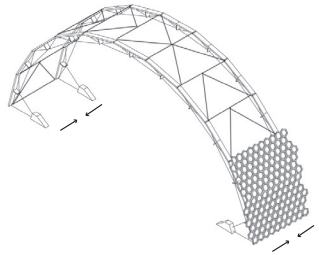
Windload and gravity on the arch



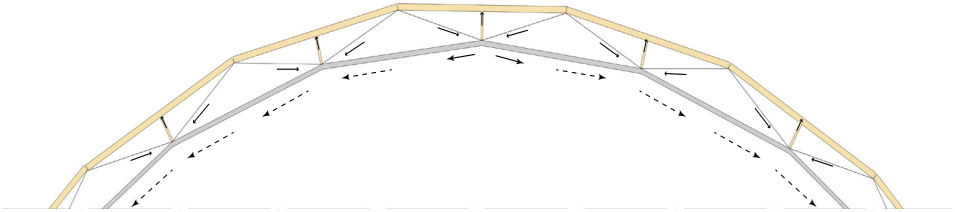
supporing struts of the beam



Lateral triangle brace between archs

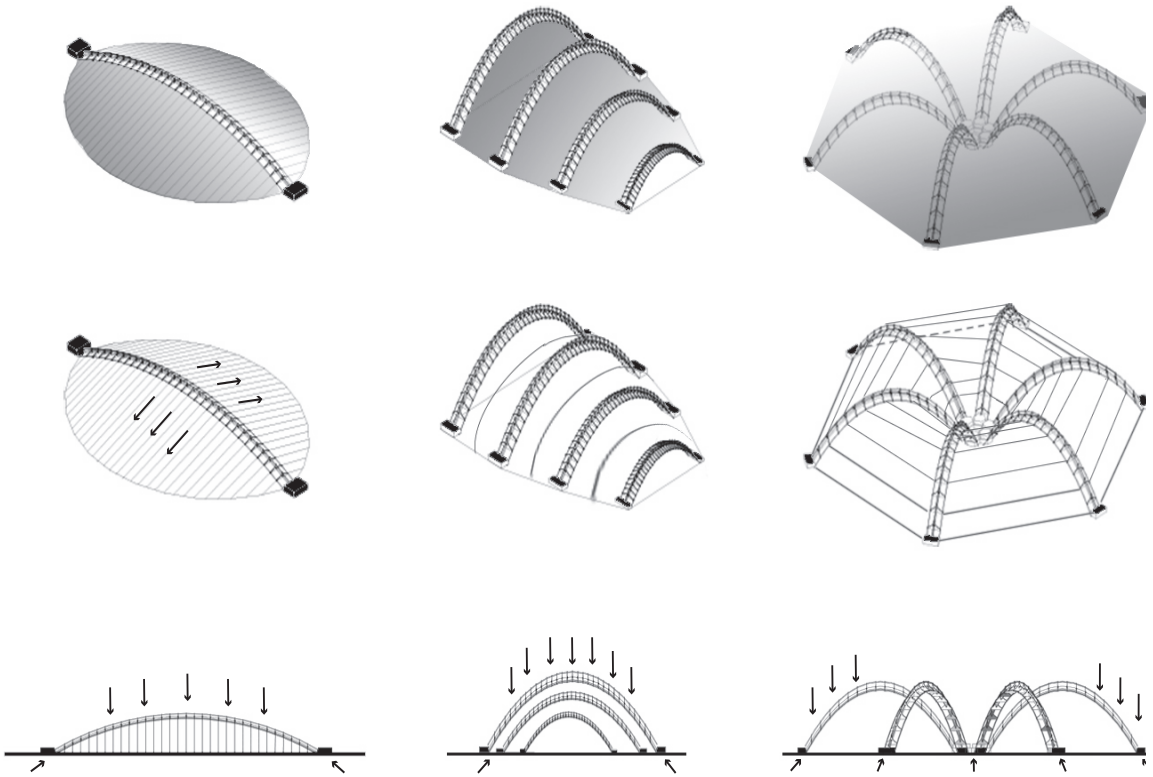


Hexagonal panel skin as secondary structure



The force analysis of structure

The spine-arch is an integrial structure system consisting of both tension and compression of members.



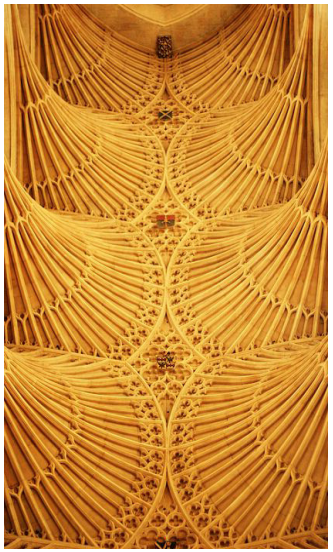
One arch in middle

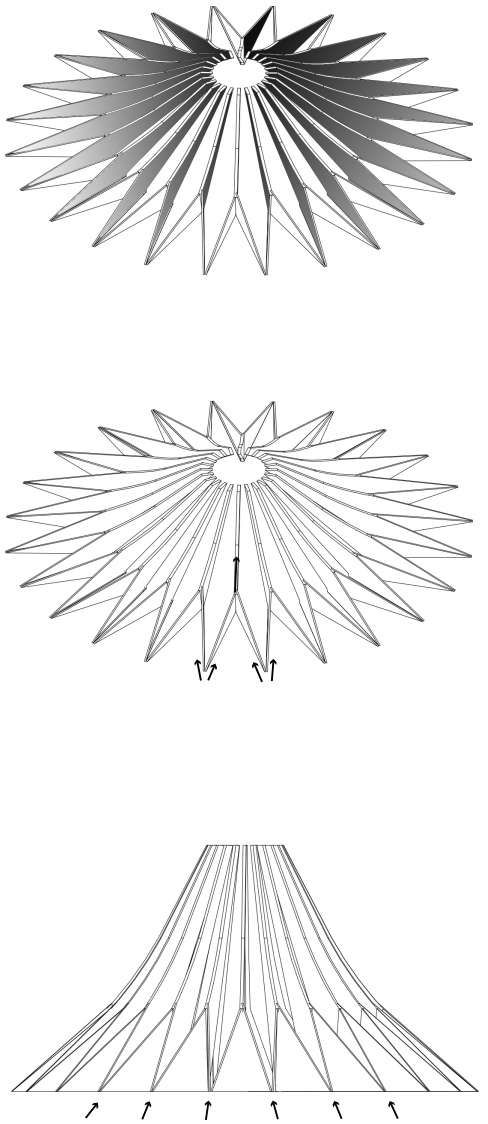
Parallel arches of various heights

arches arranged in two dimensions

# 8. Structural Proposal

The hierarchical tree columns form into a bunch structure to support the roof. The branches of support stand in a circle.





Hierarchical tree structure

# 1. Site & Context





The site is located in the south of the Menkenma garden in Uithuizen, surrounded with high trees.

The Menkenma garden is designed by Allert Meijer in 16th century. "The gardens are marked by a clear cut, orderly and symmetrical layout with principal axis and a transverse axis which intersect at the center of the house. The style proclaims "man, the master of nature."

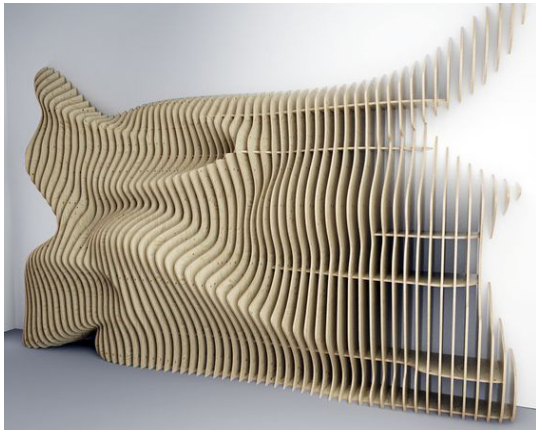
# 1. Site & Context


# 2. Design Question

**"Can I design a bio-inpired additional museum in Seismic Groningen, with reinterpretating the local landscape?"**

-1.How to create a new inspirational structure with the knowledge of biomimetic research and timber construction?

-2.How to integrate the responsive skin technology into the museum design creating a charming space atmosphere?

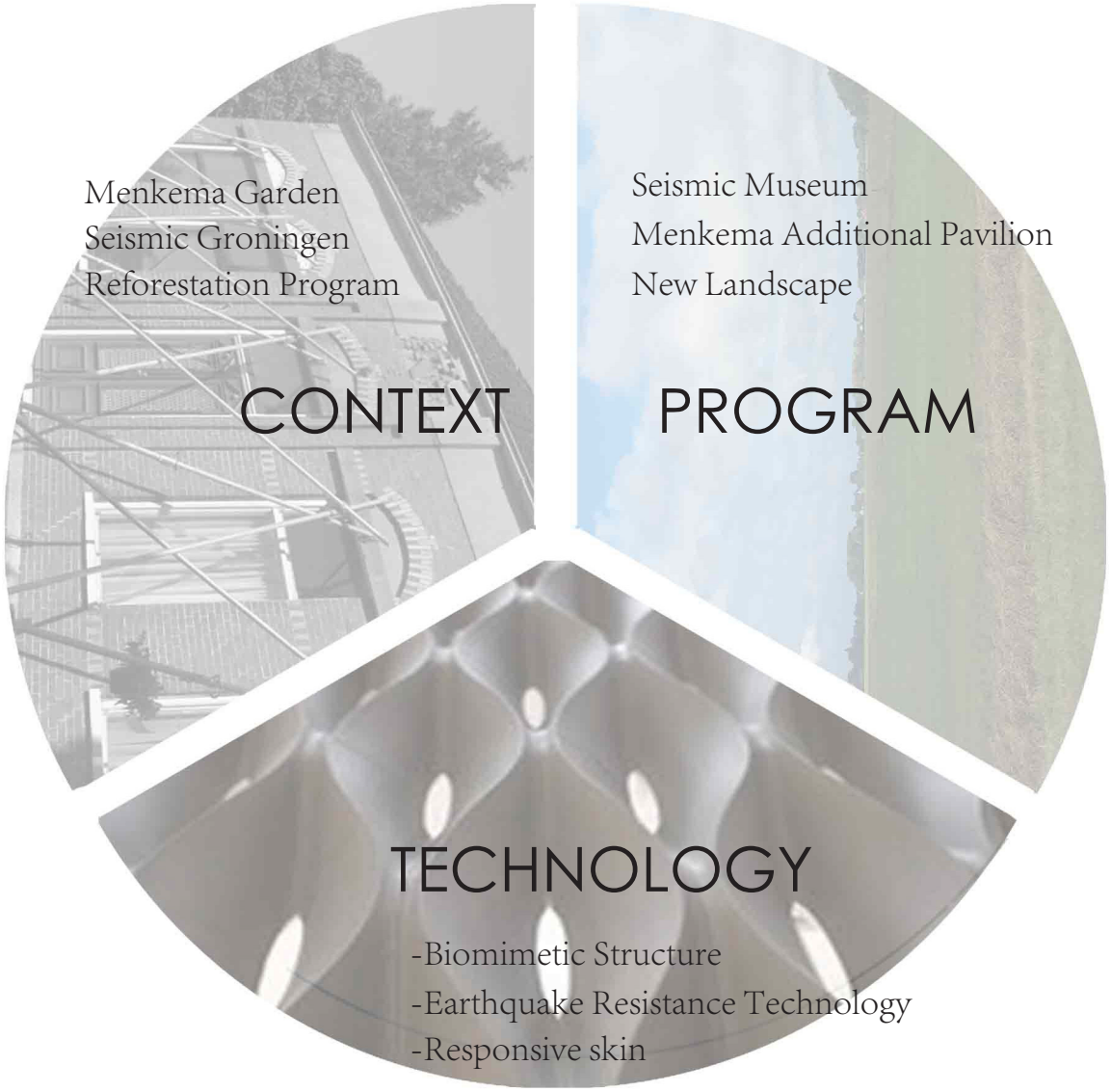


## A. Research

1. Background
2. Problem Statement
3. Diagram
4. Research Question
5. Research Framework
6. Research Content
7. Conclusion
8. Structural Proposals

## B. Design

1. Site & Context
2. Design Question
3. Preliminary Design



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**Thank you for your Attention, Time for questions!**