



THE 8TH ANNUAL  
**BIOMIMICRY  
EDUCATION SUMMIT**  
AUSTIN, TX 10.04.2015

# Load bearing duct

*Infusing Biomimicry in  
civil/structural engineering design*

**Dr Stelios Yiatros**

PhD DIC MEng ACGI AMASCE

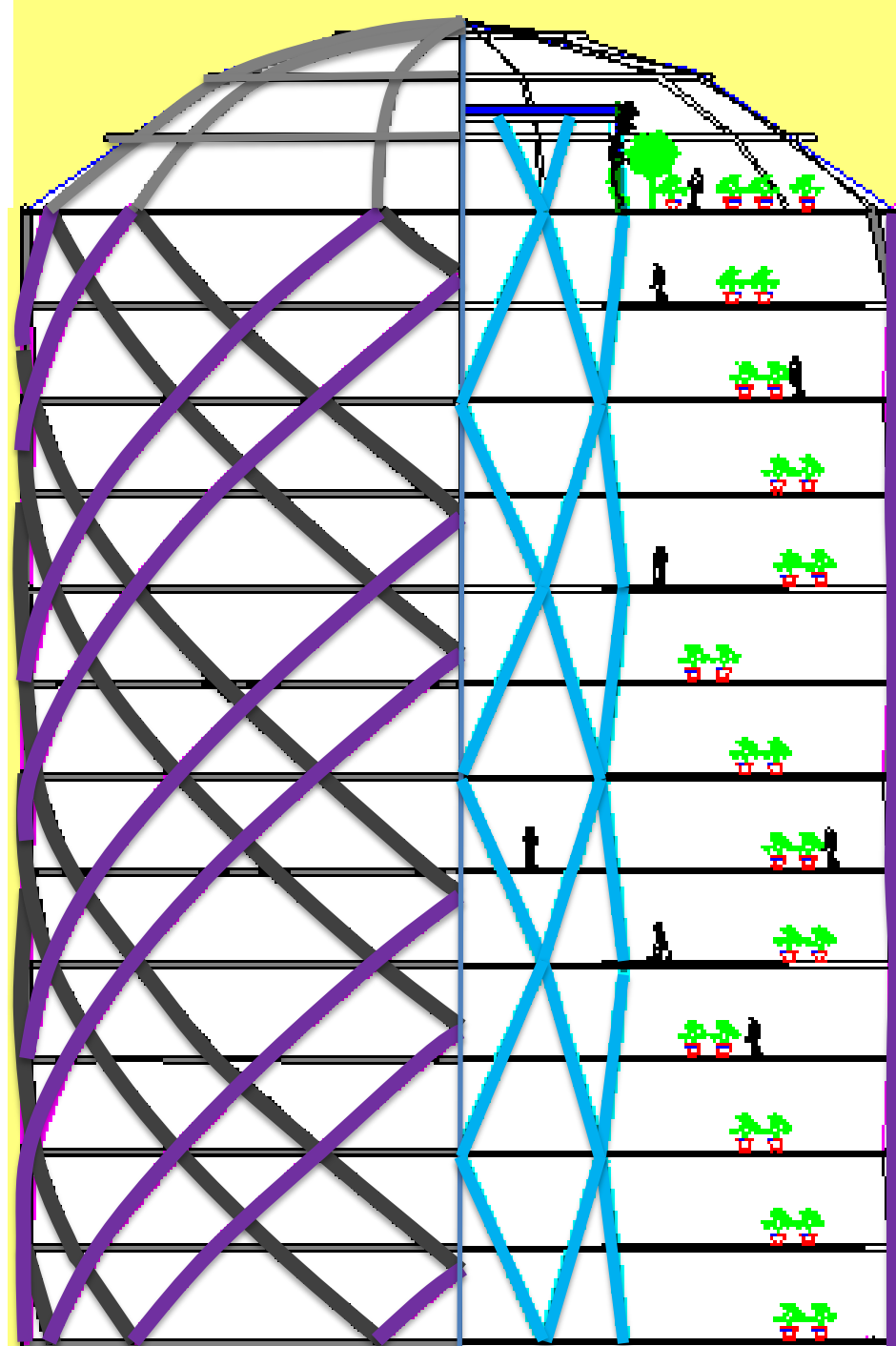
*Lecturer in Structural Engineering*

**CUT (CY)**



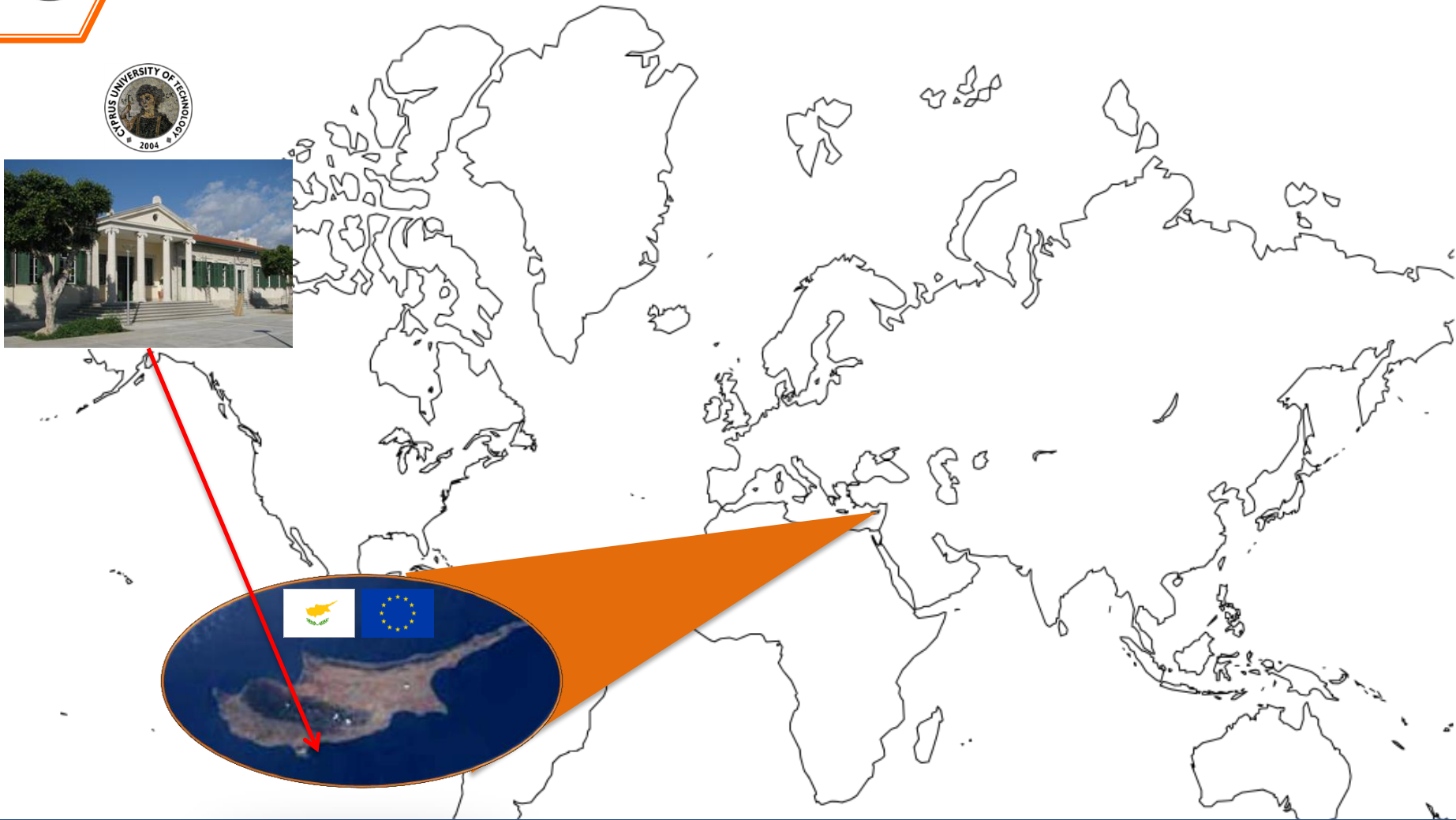
*Marie Curie Fellow*  
**Cranfield University (UK)**

*Cranfield*  
UNIVERSITY



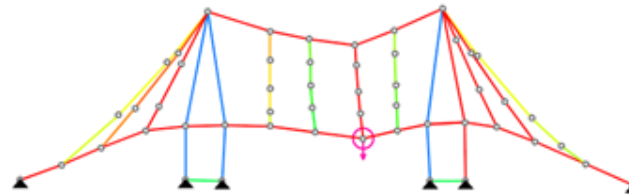
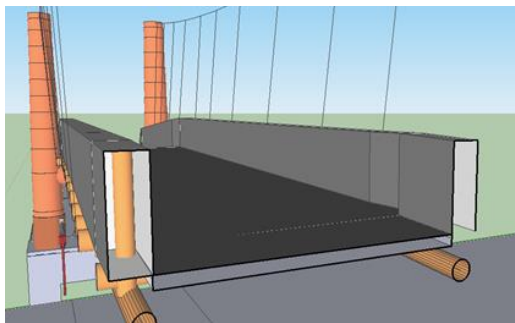
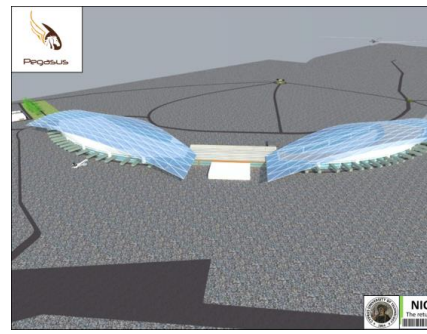
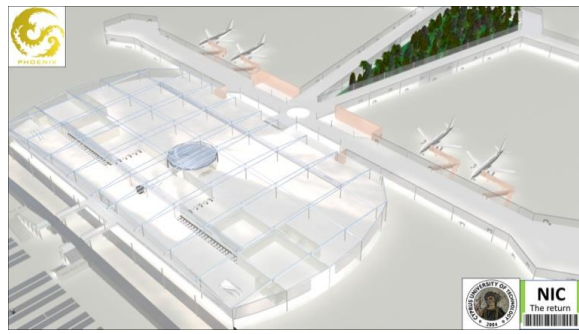


# Civil Engineering & Geomatics at the Cyprus University of Technology





# Courses that address societal and environmental challenges of today and tomorrow



## Sustainability & Social Responsibility at CUT





# Civil Engineering

# Land Surveying & Geomatics

Mechanics, Structures, Hydraulics, Materials, Geotechnics, Transport, etc

Maths, Physics, Computing, Languages

Geodesy, Cartography, Photogrammetry, Remote Sensing, GIS etc

Professional Skills  
Drafting & CAD  
Integrated Design  
Industrial Placement  
Dissertation

Biomimetic applications





Cranfield  
UNIVERSITY

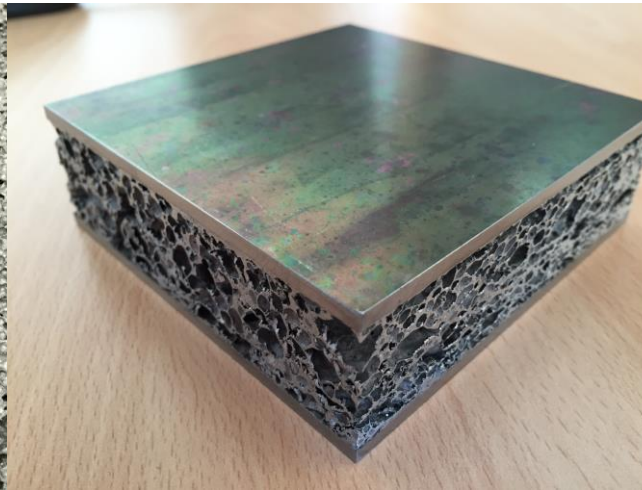


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# INSIST

INVESTIGATION OF THE STRUCTURAL INTEGRITY AND STABILITY OF  
STEEL FOAM SANDWICH PANELS  
A MARIE CURIE IEF (FP7) PROJECT

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[www.insist-eu.weebly.com](http://www.insist-eu.weebly.com)



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AUSTIN, TX 10.04.2015

*“The first Cyprus based accelerator for clean tech and sustainable development business ideas”*

[www.chrysalisleap.com](http://www.chrysalisleap.com)



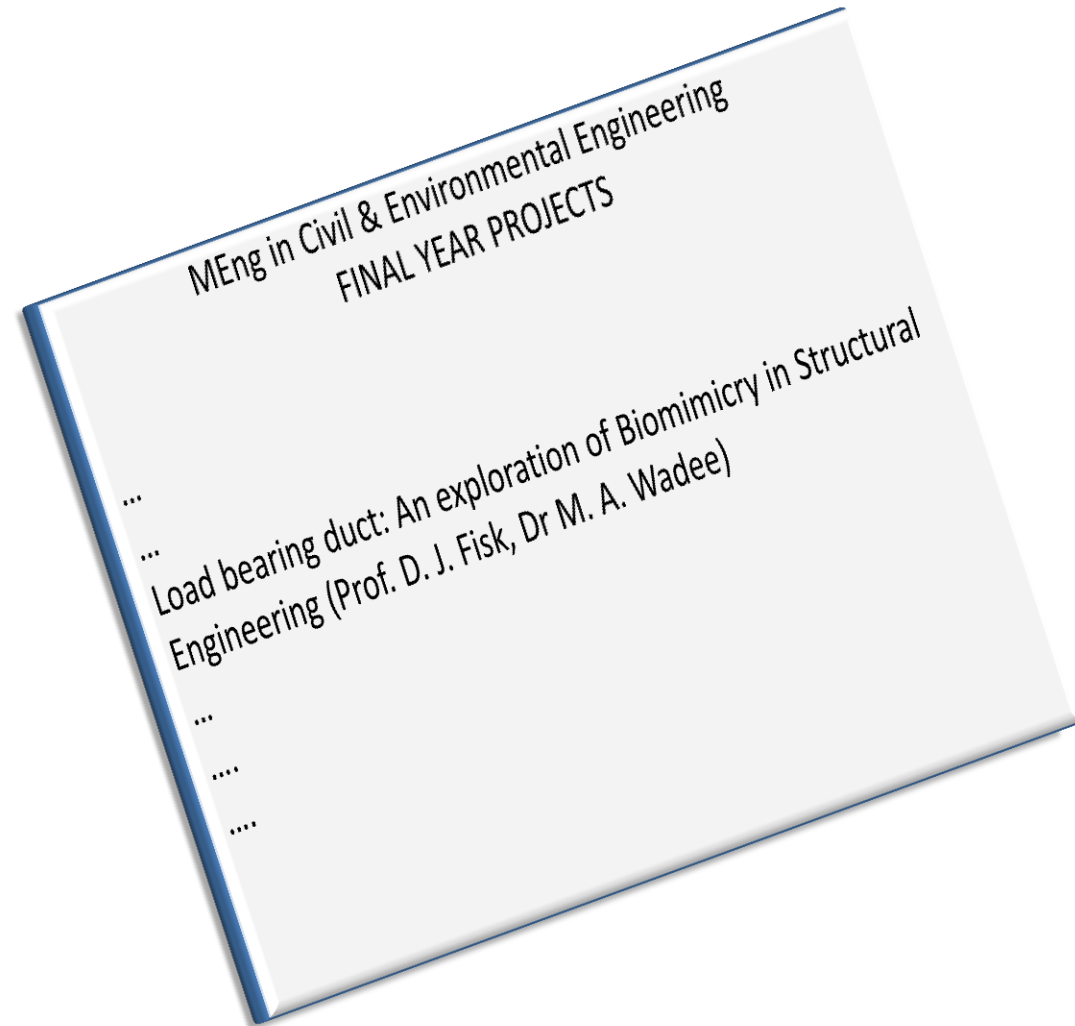
Climate Launchpad 2015  
Europe's Largest Cleantech Business Idea Competition  
by Climate-KIC

Affiliates, Partners and Sponsors



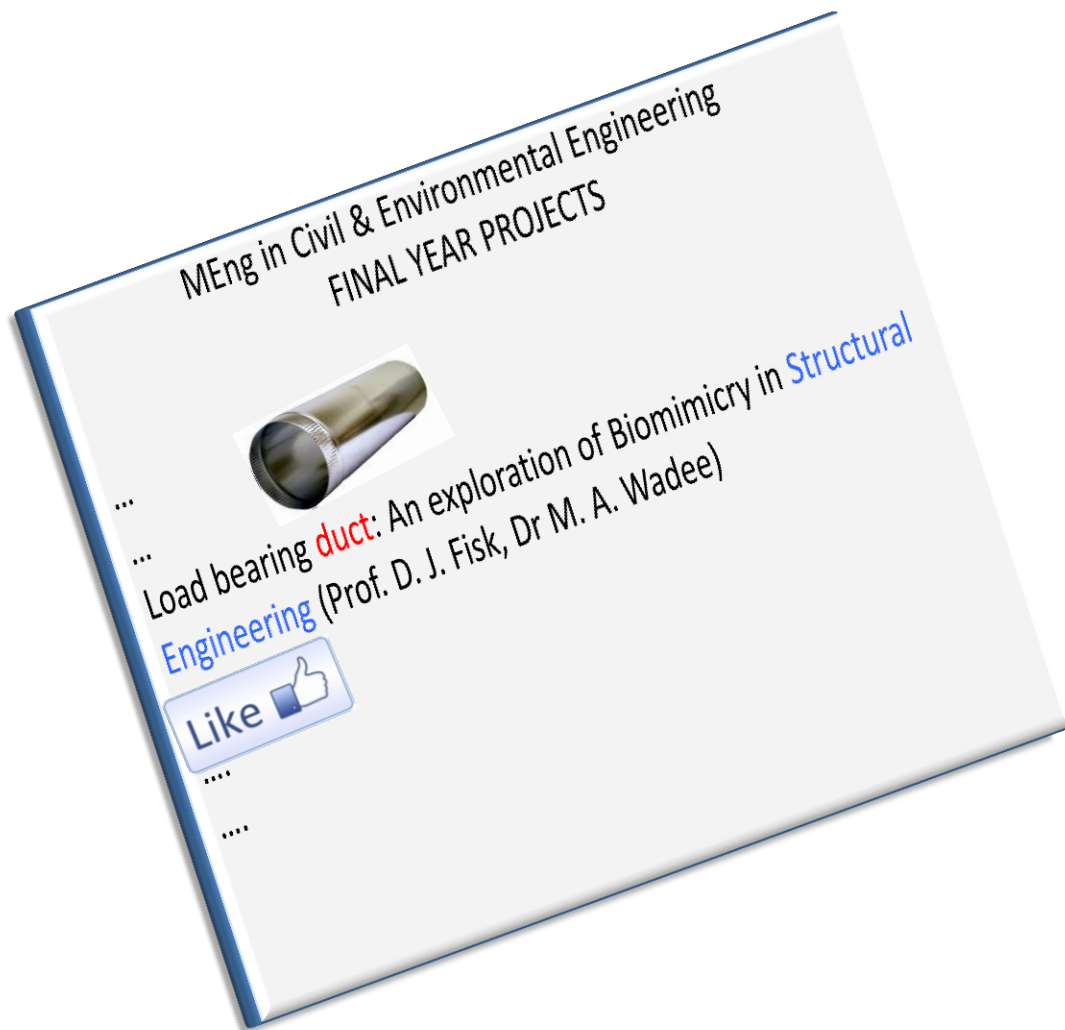


# My introduction to Biomimicry



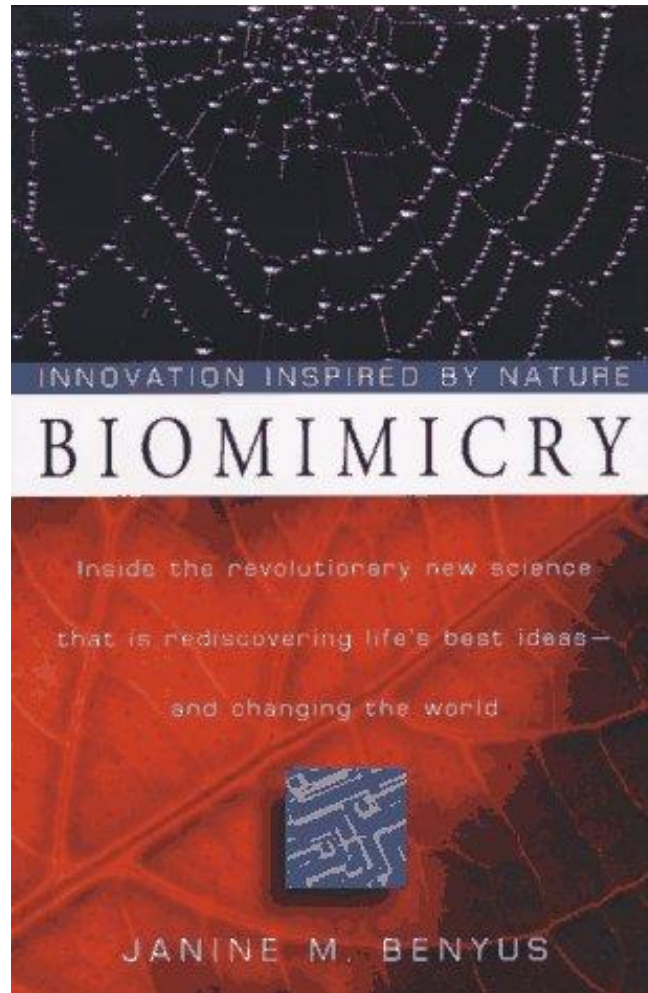


# My introduction to Biomimicry









an accidental love affair



# Task at hand

- Explore Biomimicry as a design methodology for civil / structural design
- Design a multifunctional structural component that combines load bearing with one or more building services.

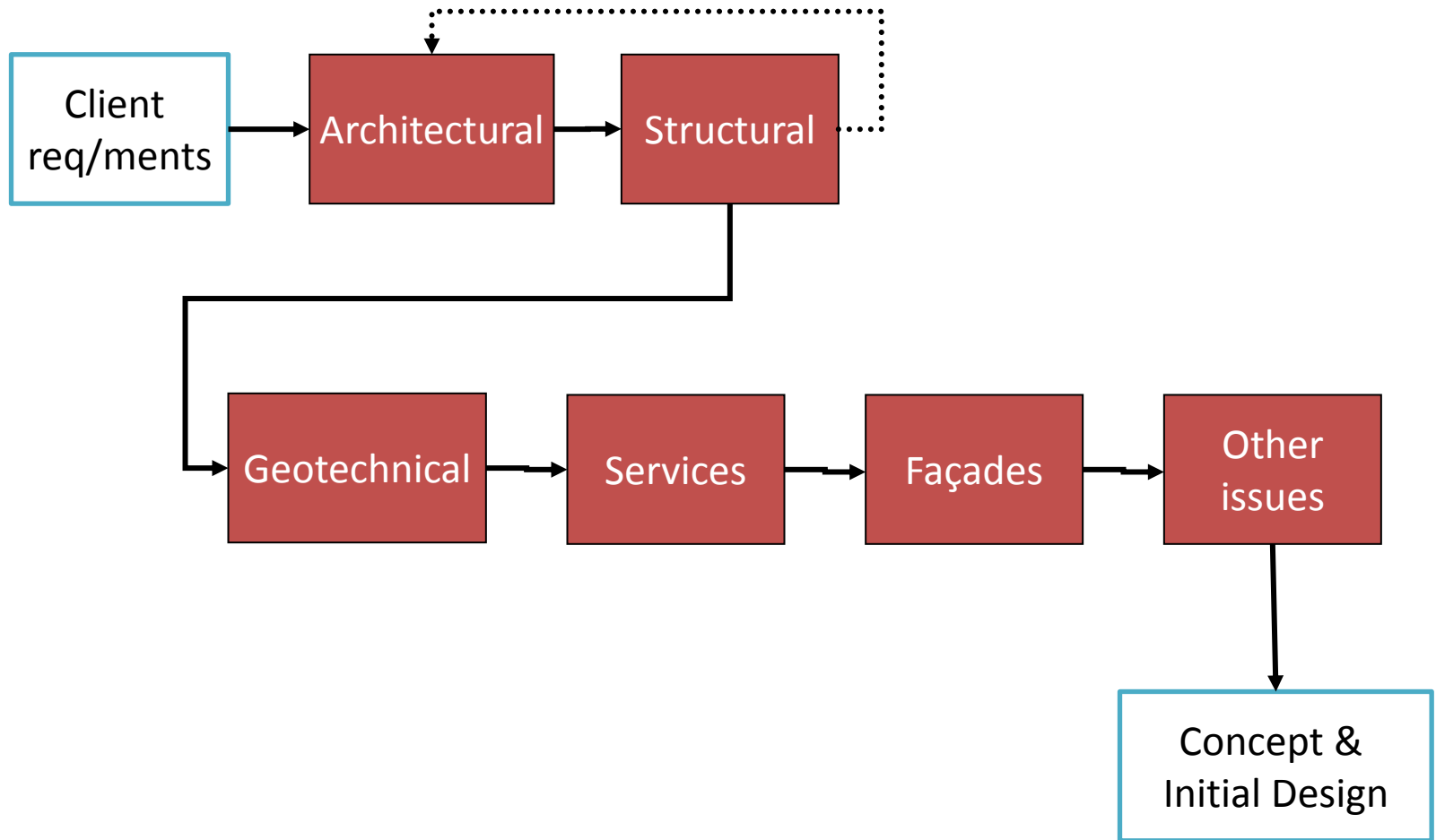


# Why infuse Biomimicry in civil/structural engineering?

- Large projects with **large carbon footprint**
- **Local** solutions to **local** problems
- Unique and complex systems with **long life-spans**, that are traditionally designed **sub-optimally**.



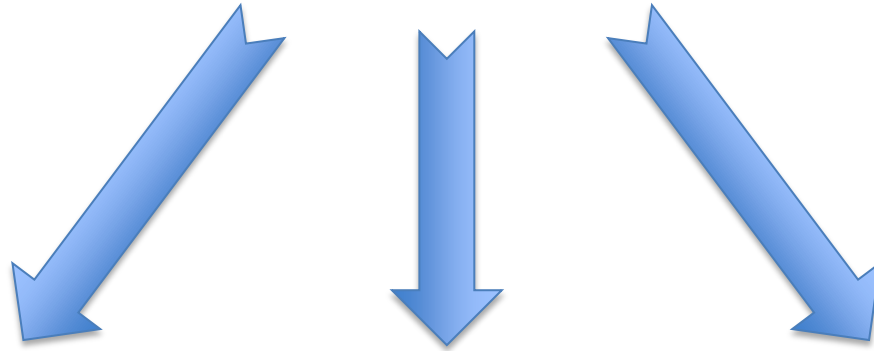
# Teaching the way we design...



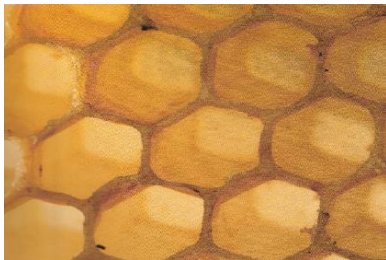




# Natural Design



Form  
(Geometry)



Process



Material





# Early engineers used Biomimicry

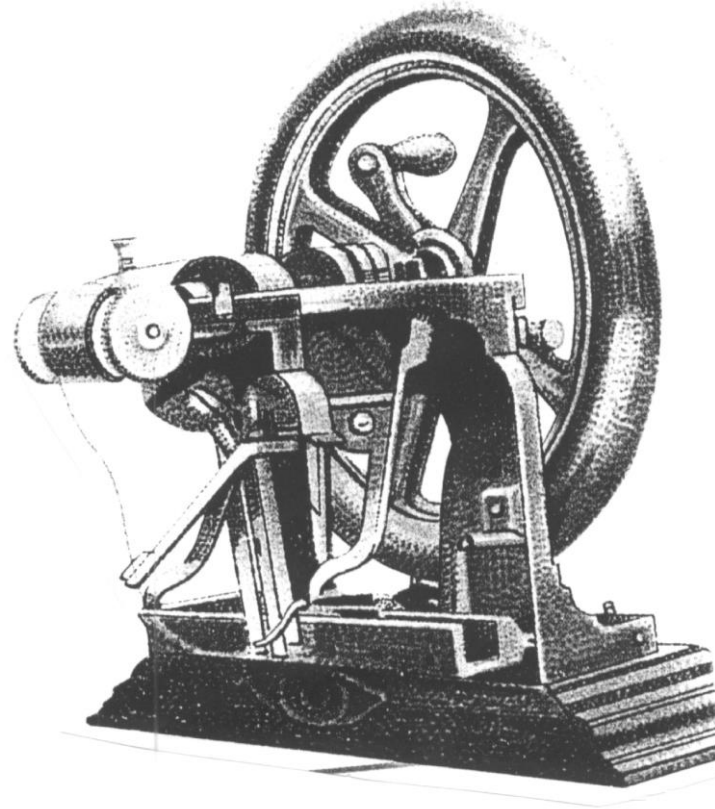


*"... do you know where I found my model? An upright tree; it bears its branches and these in turn the leaves and every individual part has been growing harmoniously, magnificently ever since God, the artist, created it..."*  
A.Gaudí





# How did we forget?



Industrial revolution

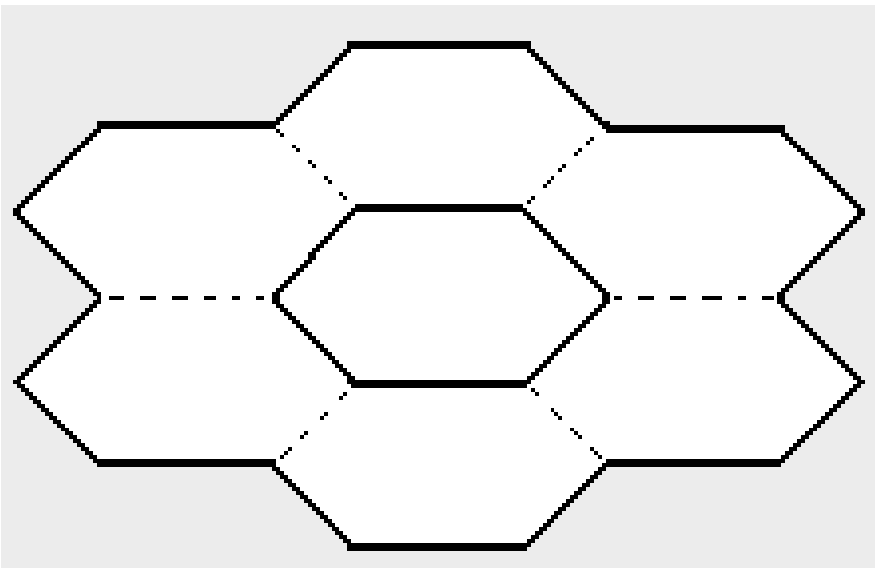


# Asking the right questions

- Design for verbs, not nouns.
  - How could people **work** efficiently with safety?
    - To provide a safe and redundant structural system.
    - To build it with minimal waste and efficient methods.
    - To have an adaptable space that satisfies current and future working needs.
    - To provide clean air and environment.
    - To provide natural lighting.

## Tessellation

- Maximize space with the least possible supporting material.



## Modularity

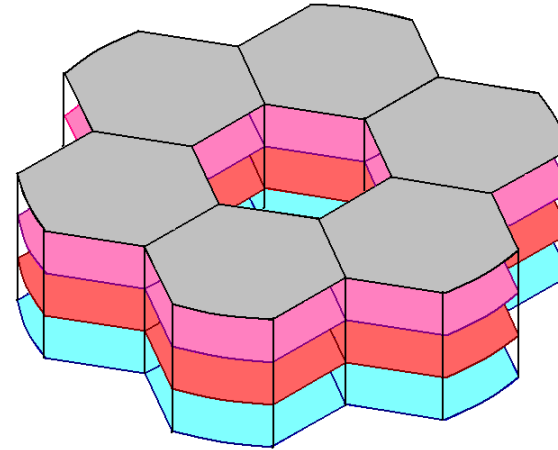
- Standardization of elements and joints



# Structure: Vertical Alignment

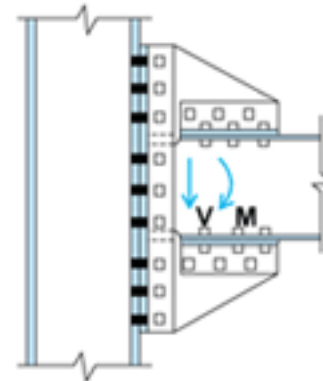
- Moment Resisting Frame

- Deep sections
- Complicated joints



- Frame with another system for lateral stability

- Not efficient
- View obstructions

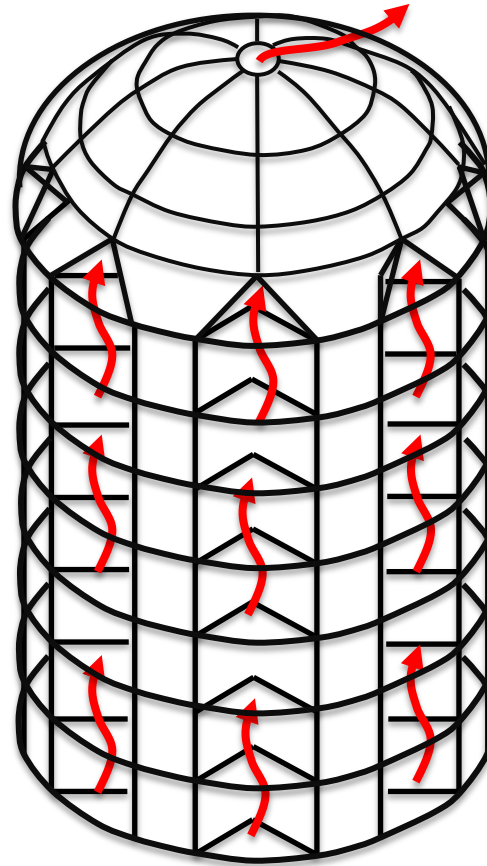


# Ventilation Strategy

Cylindrical shape with a dome on top



- Reduction of drag
- Lightwells in the perimeter drive natural ventilation
- Dome at the top with a hole at the top enables the escape of hot air



- Chimney effect localized
- Need to increase chimney length

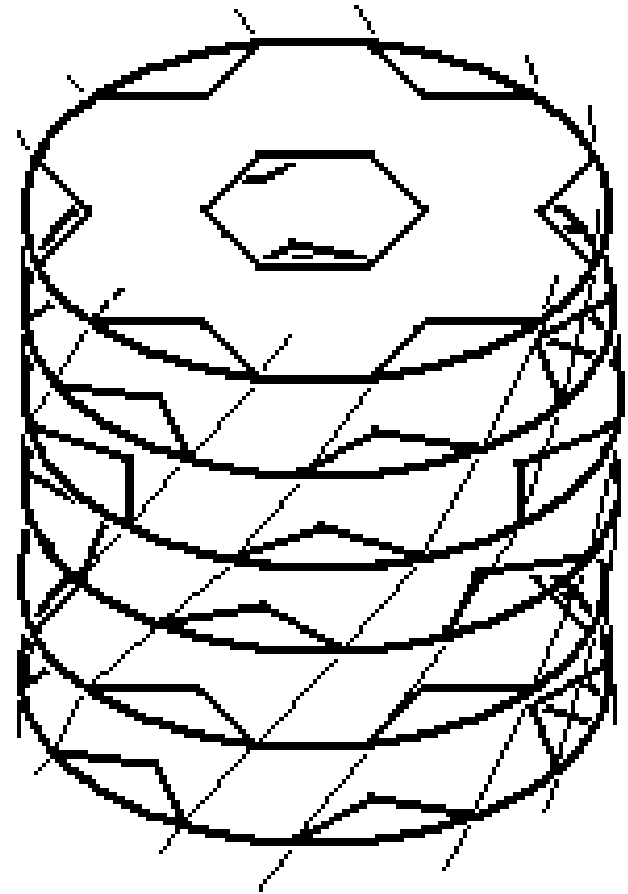


# The spiral tree grain



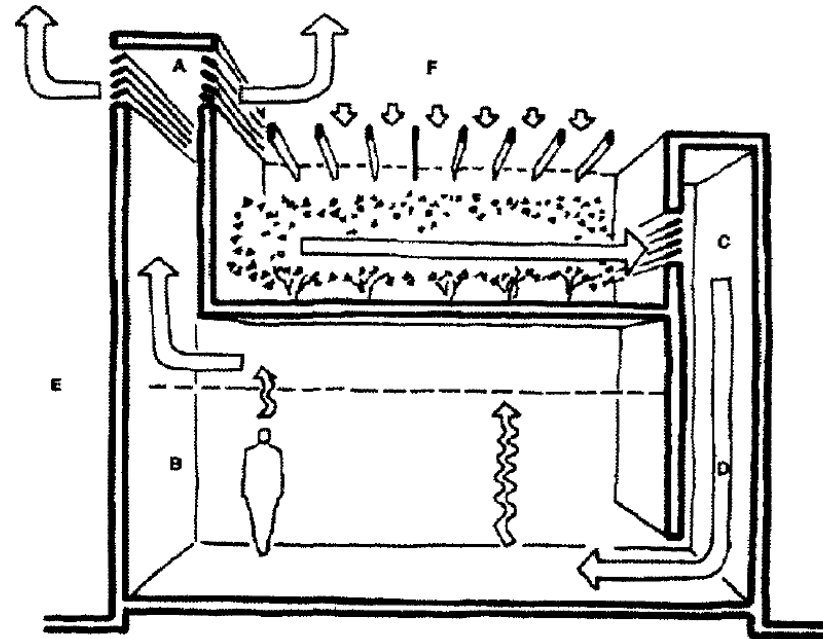
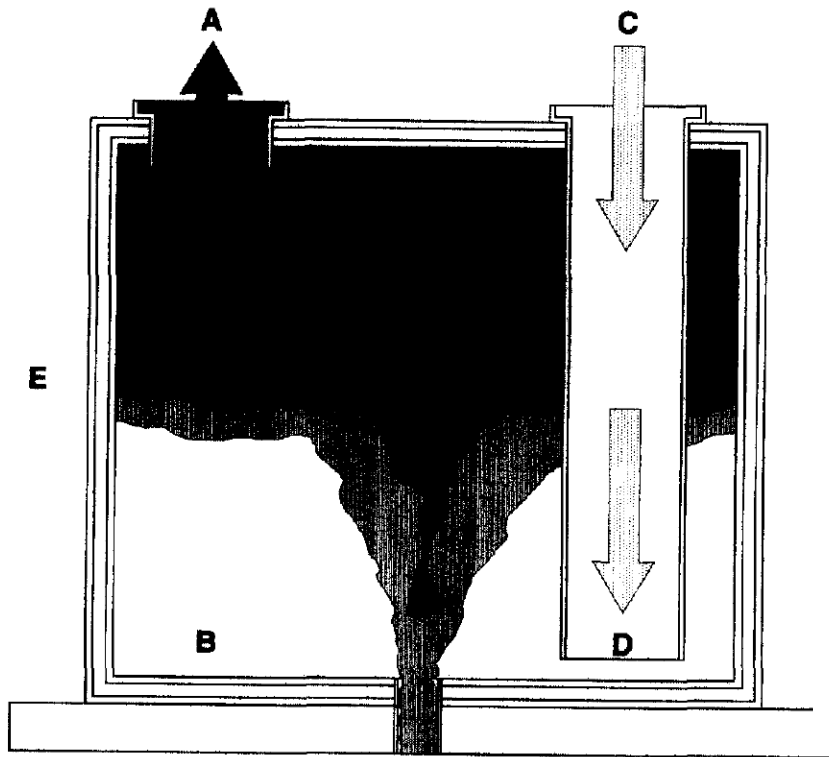


# The spiral tree grain



# Top Down Ventilation

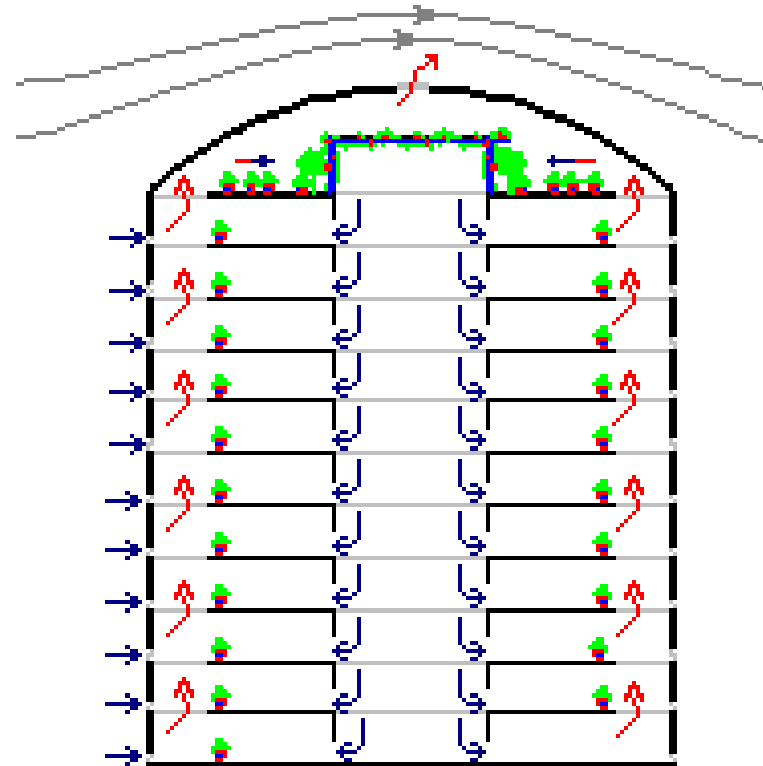
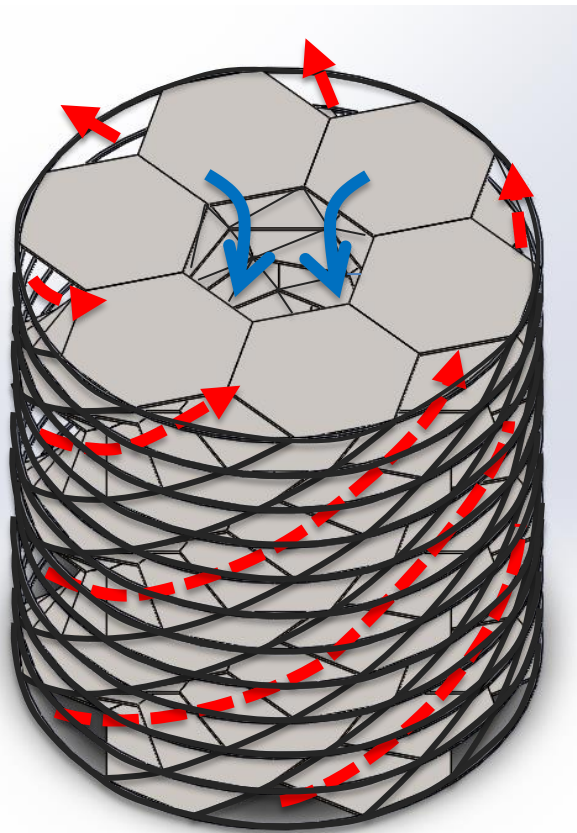
- Gage, Hunt and Linden (2001)





# Top Down Ventilation

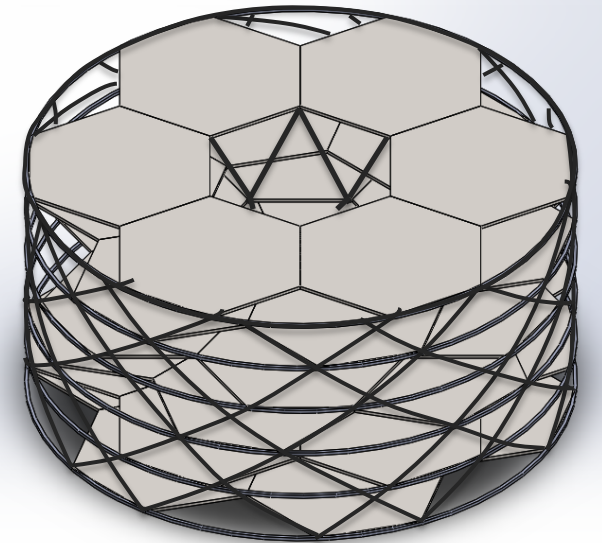
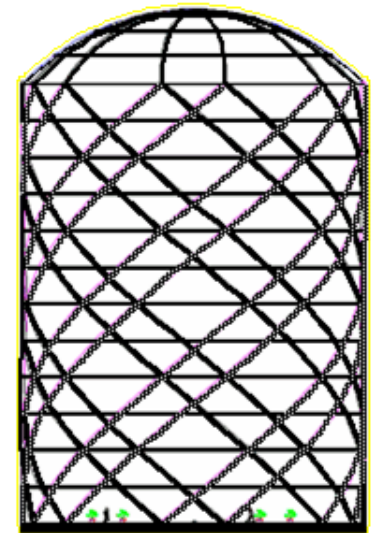
- Recycling Air



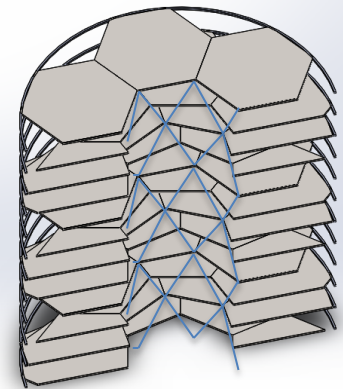
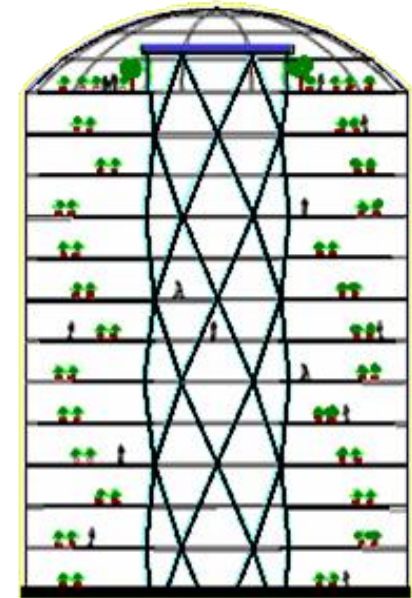
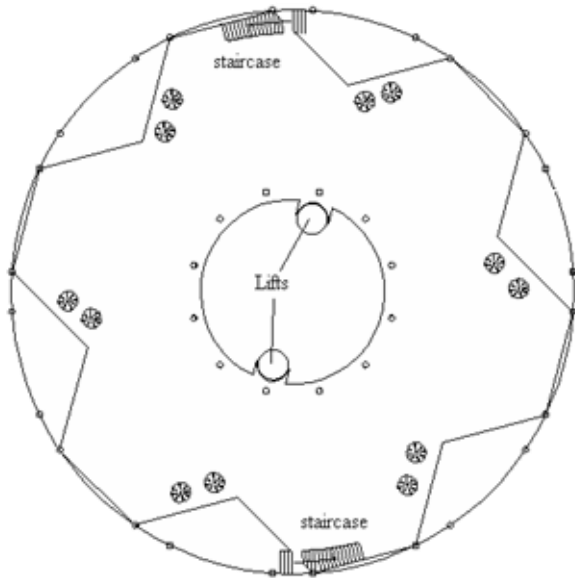


# Feeding back to the structural system

- Integrating resistance of gravity and lateral loads
- Structural redundancy
- Construction efficiency through standardization of members and joints
- Virtually columnless!

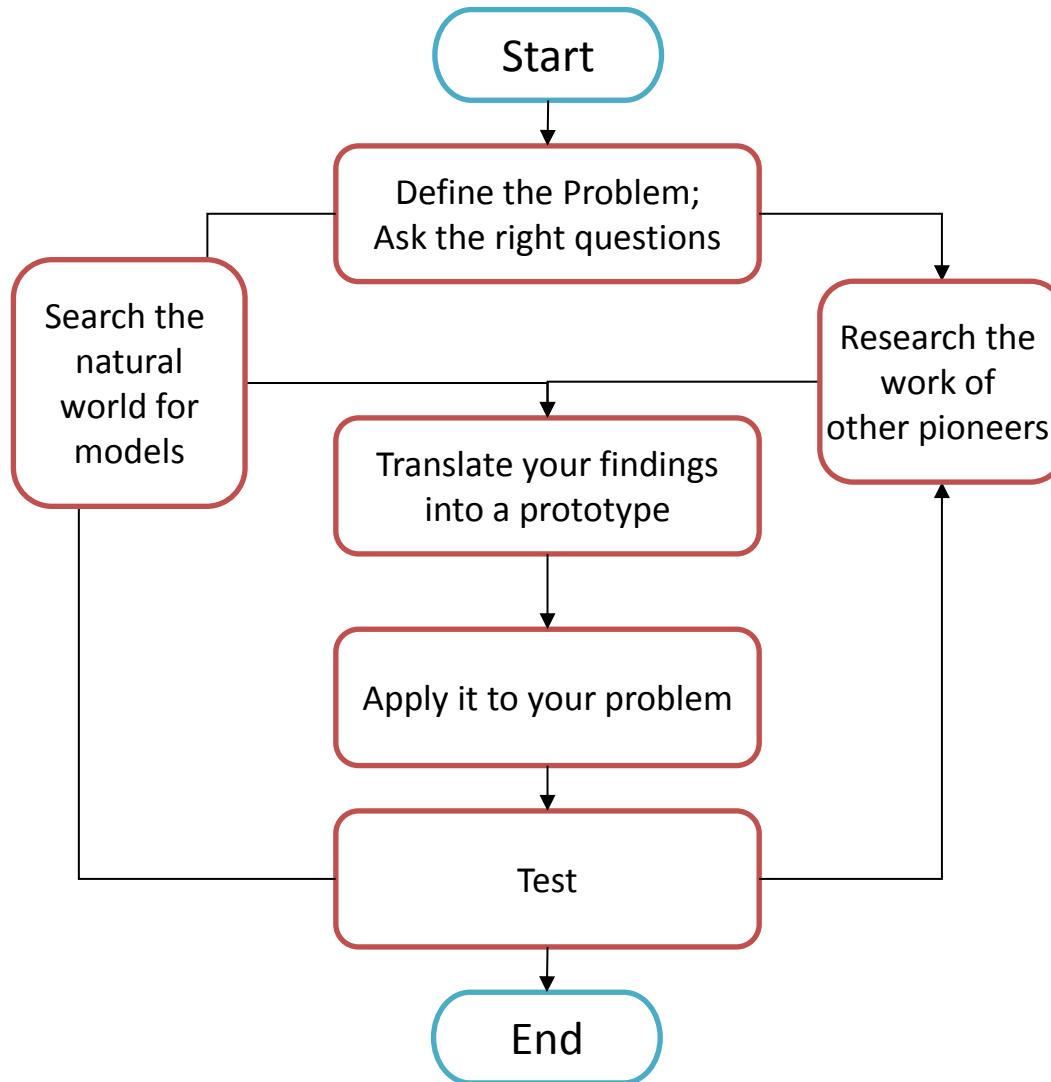


# Vertical access – Learning from wasps





# Standard practice Vs biomimetic design procedure





# Study results

- Tested the concept qualitatively against Biomimetic principles with good, but not perfect results.
- **The principal outcome of the study was the rethinking of the design methodology process.**





# Biomimicry in Integrated Building Design

Proceedings of the Institution of Civil Engineers  
Engineering Sustainability 160  
December 2007 Issue ES4  
Pages 179-188  
doi: 10.1680/ensu.2007.160.4.179

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## The load-bearing duct: biomimicry in structural design

S. Yiatros MEng, ACGI, M. A. Wadee PhD, ACGI, DIC, CSci, CMath, MIMA and G. R. Hunt PhD

Philosophical aspects of applying the principles of biomimicry are explored in a case study of structural design. Integrating structural engineering with services engineering can be regarded, to some extent, as taking inspiration from biological systems and applying them to structural design. The end-product discussed is a novel load-bearing duct, a functional naturally inspired multi-storey office building that takes the form of a duct, providing efficiently both structurally and cost-

provide cleaner power production and less environmentally impacting construction and manufacturing processes.

### 2. BIOMIMICRY IN BUILDINGS: POSSIBILITIES

#### 2.1. Imitating shape, process and material

Biomimicry could offer sustainable alternative solutions to conventional design practice, as its basis is to reduce the energy consumed by the system by combining functions and reducing



**Trevithick Prize  
for Best Paper in  
Engineering  
Sustainability  
2008**



# MSc Workshop at Imperial College London (2008 – 2013)



- Interdisciplinary postgraduate civil engineering courses with sustainable development

MSc  
Concrete  
Structures

MSc Structural  
Steel Design

MSc  
Environmental  
Engineering

MSc Hydrology

MSc  
Engineering  
Geology

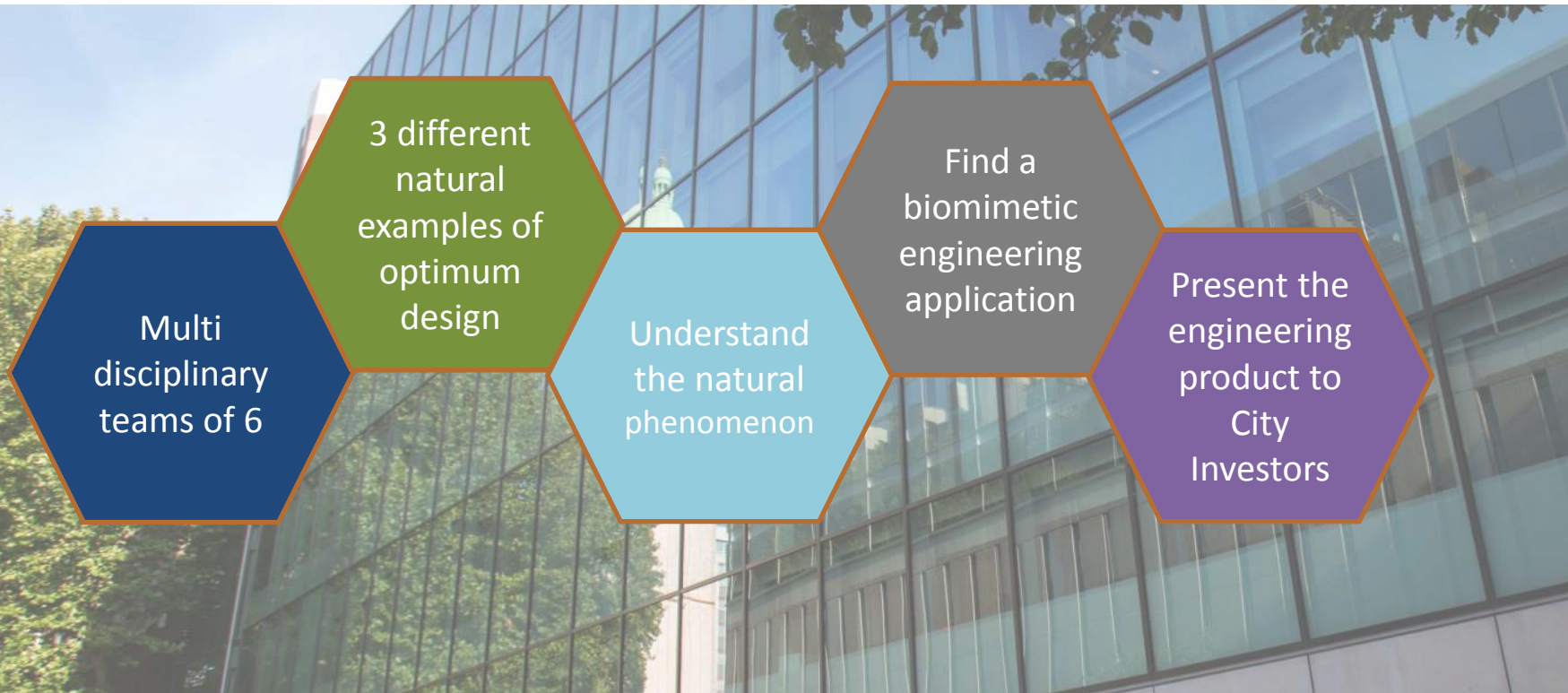
MSc  
Soil  
Mechanics

MSc  
Transport

- Case studies of sustainable development once a week



# MSc Workshop at Imperial College London (2008-2013)



**Imperial College  
London**



*“Refreshing and enjoyable”*

*“No continuity beyond the project”*





# UG Integrated Design at CUT (2013-present)

- Introduction to civil / engineering design through a combination of individual and group design exercises of various lengths
- Initiate design thinking and skills to students who have analytical training and skills
- Year 1 & Year 2 modules



# UG Integrated Design at CUT (2013-present)

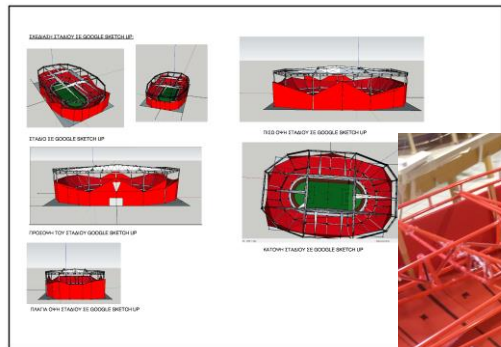
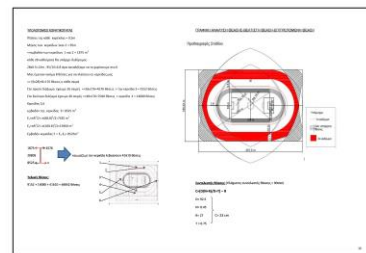
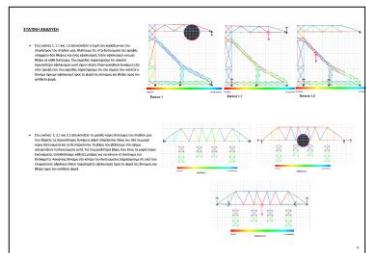
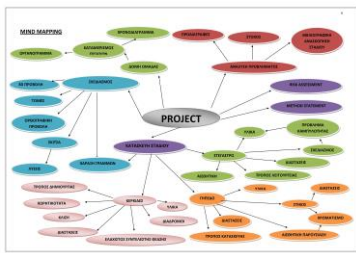
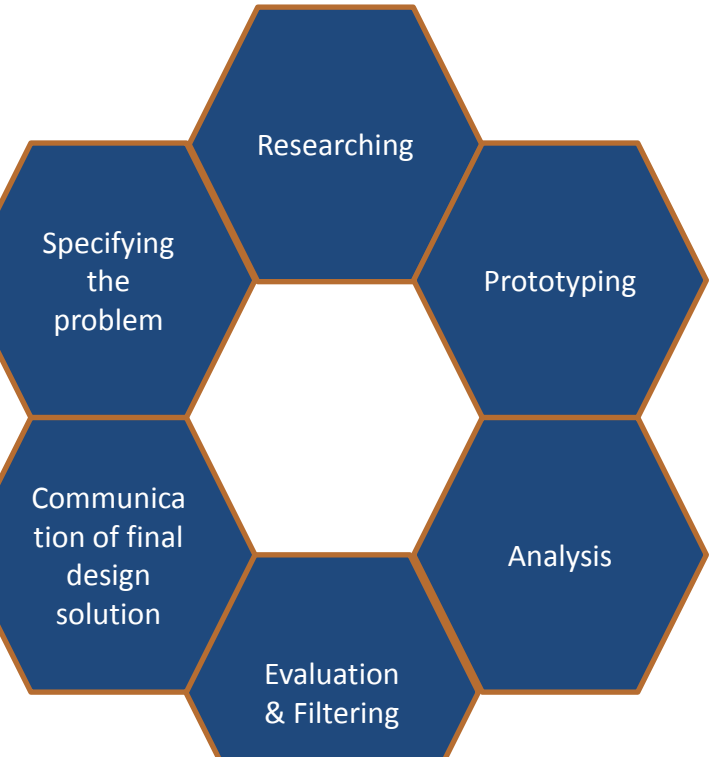
## Year 1

Engineering design cycle



Large Group Design Project

- Structural and Operational design
- Qualitative analysis
- Project management
- Sustainable model construction



**YouTube**  
 Check out our videos on YouTube by following **CIVENGatCUT**



# UG Integrated Design at CUT (2013-present) Year 2



INTEGRATED DESIGN FOR CIVIL & GEOMATICS ENGINEERS II

HOME

THE BRIEF

ABOUT

MORE...

Biomimicry Workshop

Asknature.org

Mini-project

Business Model Canvas Workshop

Pitch for investment



Large Group Design Project

Structural Design  
Spatial Design  
Environmental Assessment  
Biomimetic Application  
Business Model and LCA

## NICOSIA INTERNATIONAL AIRPORT



2014 INTEGRATED DESIGN PROJECT FOR YEAR 2 CIVIL ENGINEERING AND GEOMATICS STUDENTS AT CUT

SEE THE BRIEF

**NIC**

The return



YouTube

Check out our videos on YouTube by following

**CIVENGatCUT**

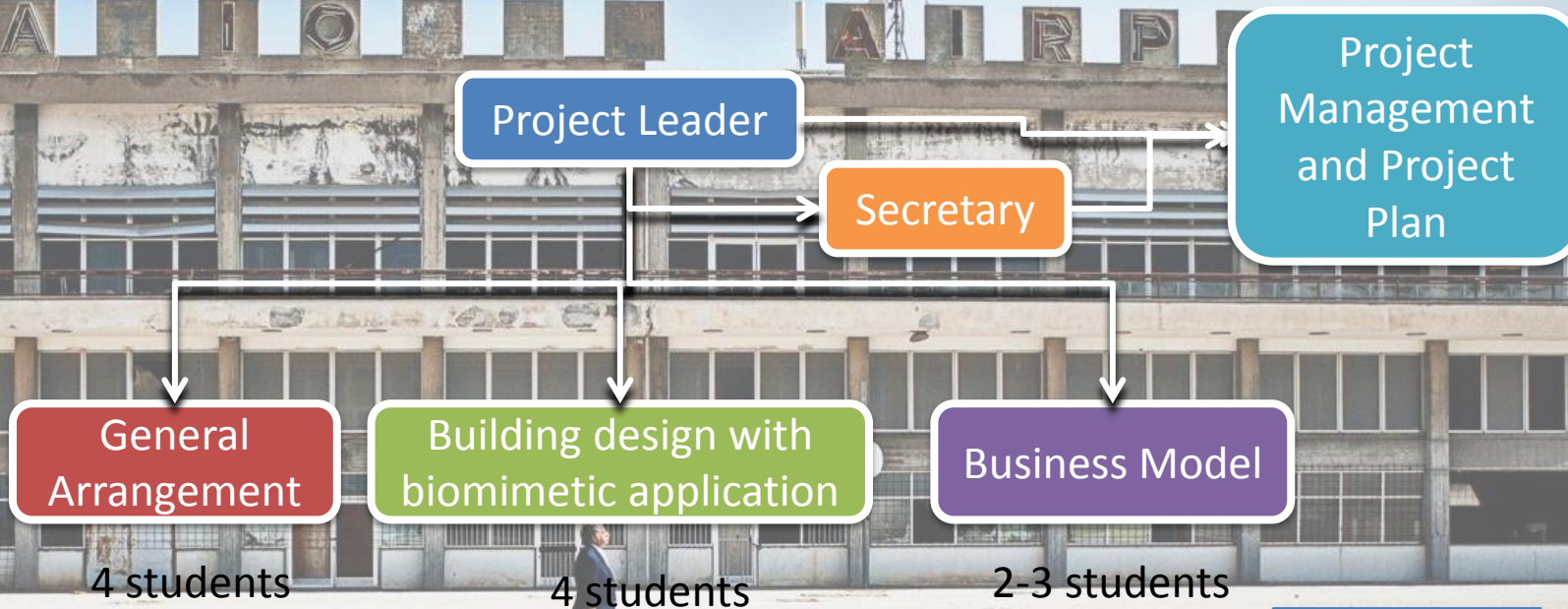
[www.nia-the-return.weebly.com](http://www.nia-the-return.weebly.com)



# UG Integrated Design at CUT (2013-present) Year 2



## 3 Competitive Groups (12-13 students each)



Courtesy of Andros Efstathiou  
[www.isnotgallery.com](http://www.isnotgallery.com)

Project briefs in English at

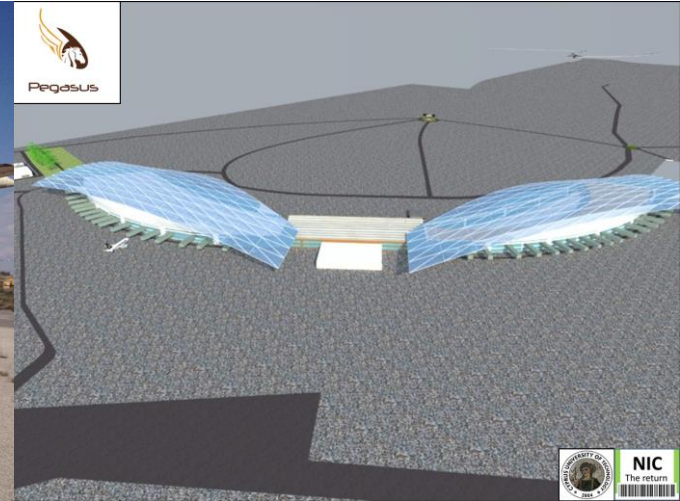
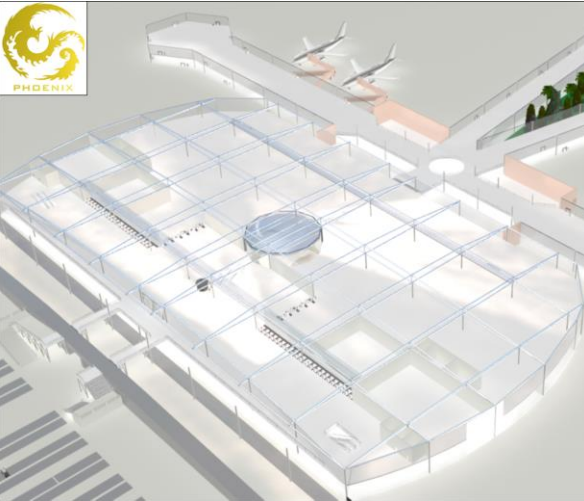
[www.nia-the-return.weebly.com](http://www.nia-the-return.weebly.com)



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# UG Integrated Design at CUT (2013-present) Year 2



*“Continuation improved understanding and increased interest (enquiries for dissertations)”*

*“Early exposure with less diverse groups, led to less innovative solutions”*

*“Civil Engineering examples had greater impact than general product design applications”*

# Dissertations (UG / PG)

## Multitude of options

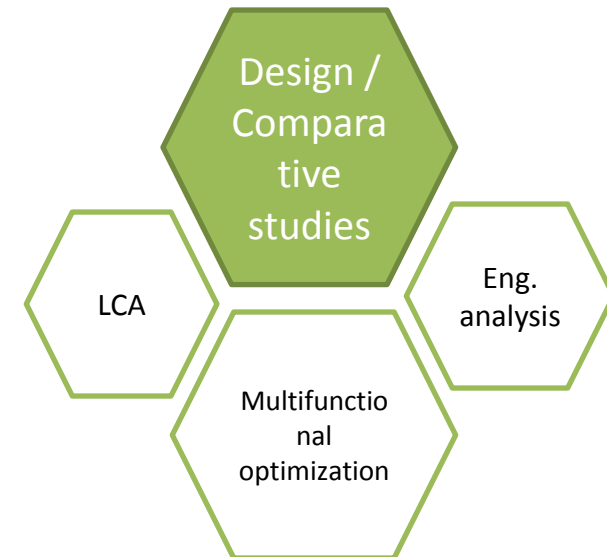
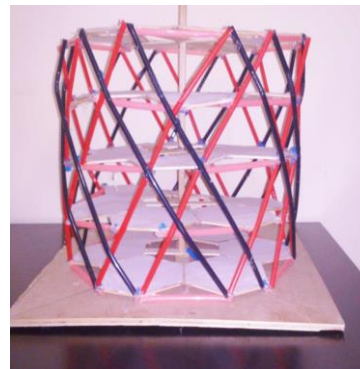
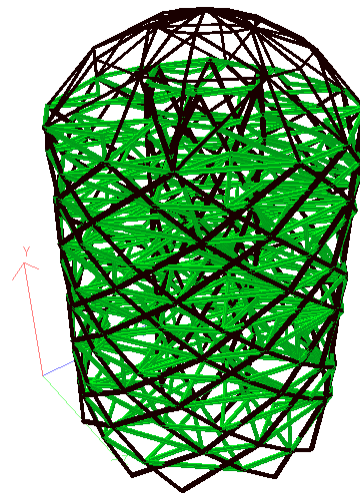
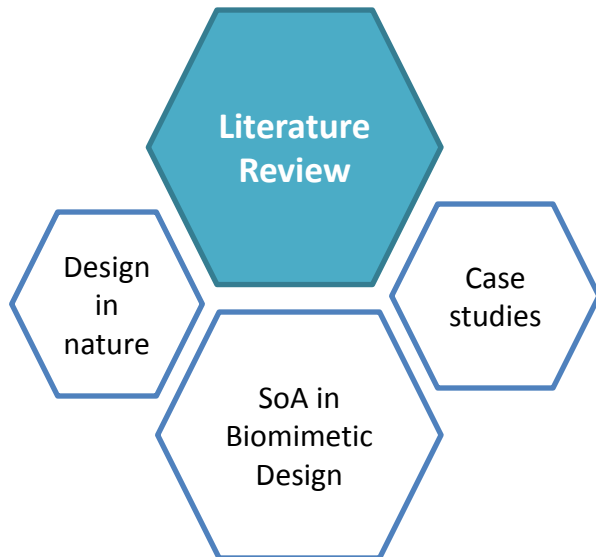


Photo credit:  
Vassilis Polykarpou ,MSc student 2013



# CPD at major architects

**CPD** 

Location TBC in here...  
Tuesday 27 September, [TBC: 6pm]..

## Biomimicry in Structural Design: Challenges and opportunities

Dr Stylianos Yiatros will present his award-winning paper on exploring Biomimicry in Structural Design, highlighting key challenges and opportunities of its implementation in integrated building design.

A composite image for a CPD event. The top left shows a close-up of a tree trunk with a glowing orange pattern. The bottom left shows a close-up of a tree trunk with a glowing orange pattern. The right side shows a 3D wireframe model of a cylindrical structure with a central vertical axis and horizontal rings, resembling a biological structure like a tree trunk or a honeycomb.

## Foster + Partners

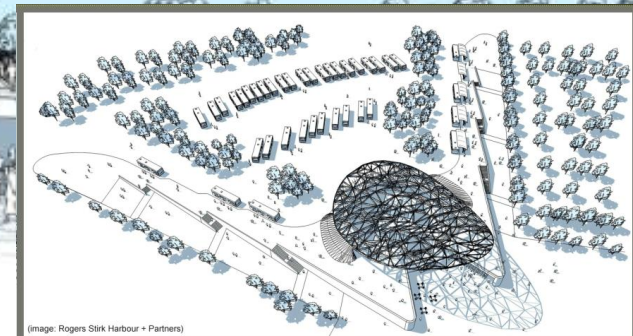
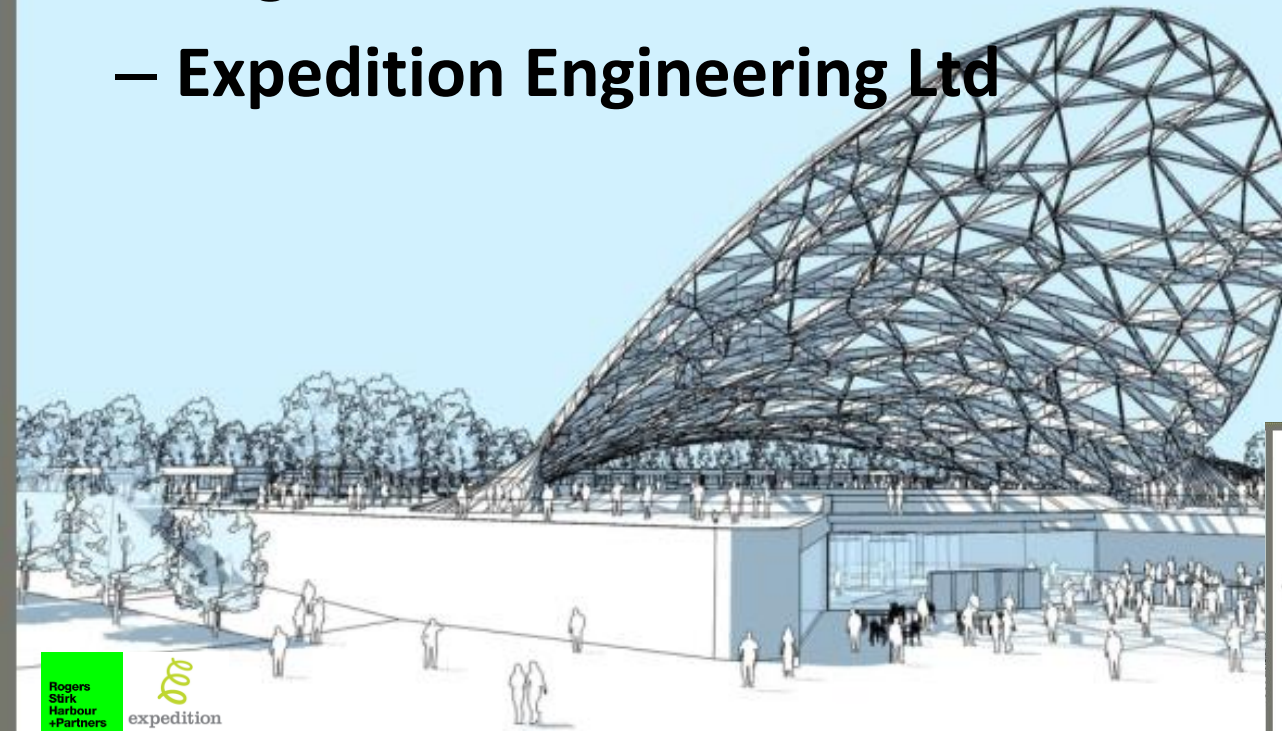
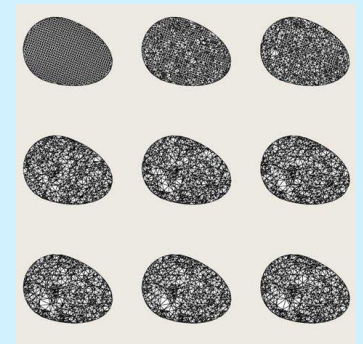




# Multi-objective design optimization

From the gecko and velcro to big infrastructure projects

- Santa Maria Del Pianto, Naples, Italy
  - Rogers Stirk Harbour + Partners
  - **Expedition Engineering Ltd**



Rogers  
Stirk  
Harbour  
+Partners expedition

(image: Rogers Stirk Harbour + Partners)

(image: Rogers Stirk Harbour + Partners)

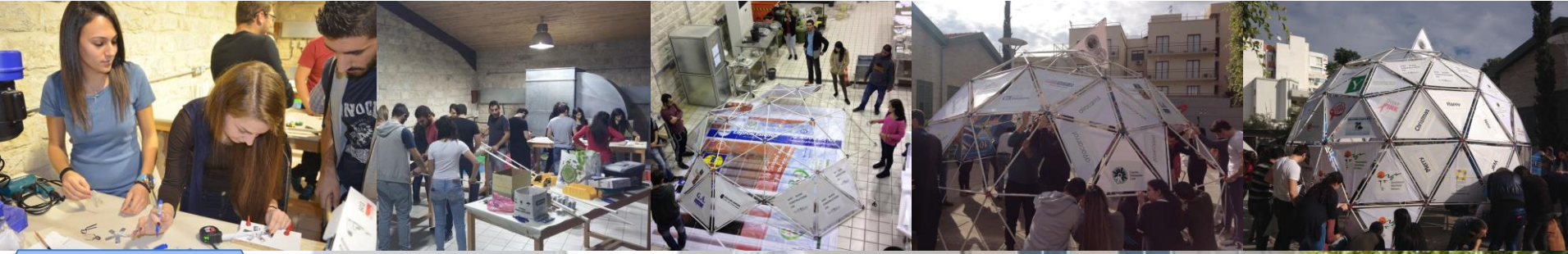




# CiGeSoc project – a Xmas Bucky ball!



*“Building a large biomimetic structure with students from all years to raise money for the CUT student welfare fund”*



**YouTube**  
Check out our videos on YouTube by following **CIVENGatCUT**





# Conclusions

- Current tools and trends allow engineers to rethink their design process and pursue multi-objective optimizations. Nature has been doing this for centuries and all we need to do is to tap into its vast toolbox of strategies.
- Infuse Biomimicry and sustainability in design classes at different stages to ensure continuity.
- Biomimicry makes sense when considering the whole picture (include concepts of circular economy).
- Misconception that sustainability comes at the expense of societal welfare can be rectified through biomimicry.
- AskNature – an amazing data bank, but in need of urgent inspiration walk to the park or the beach, pick or look something and ask how?



# Thank you

Question time!

## Get in touch:

email: [stylianos.yiatros@cut.ac.cy](mailto:stylianos.yiatros@cut.ac.cy) /  
[s.yiatros@cranfield.ac.uk](mailto:s.yiatros@cranfield.ac.uk)

twitter: @SteliosYiatros

Youtube : CIVENGGatCUT