12 Fractal Dimensions: Phyllotaxis in Design Evolution

Students work Biomimcry Elective

Kalpa, Vol.05, 2024, pp.78-84

Abstract: This segment explores the learning methodologies and the application of nature-inspired design by students of RV College of Architecture under the guidance of Seema Anand, Co-founder of Biomimicry India. Through a process of observation and experimentation, students engage with biomimicry principles to explore various strategies aimed at enhancing structural systems, passive cooling and heating mechanisms, architectural elements, material innovation, and sustainable construction approaches.

The exploration of natural systems allows students to gain insights into how biological forms, patterns, and processes can inform design decisions that are more adaptive and resource-efficient. A deeper understanding of ecological interdependence is fostered, encouraging a design approach that aligns with nature's inherent wisdom. The emphasis is placed on studying and applying biomimetic concepts across various scales, from urban planning and architecture to interior and landscape design.

For the past seven years, I have been conducting a Biomimicry Elective at RV College of Architecture, Bangalore. This elective introduces students to nature's principles, biomimicry methodology, and case studies through experiential and game-based learning, making complex concepts engaging and accessible.

A key focus of the course is to train students to become keen observers of nature, understanding its deep wisdom and applying it to human challenges. They explore how artists draw inspiration from nature to create biomimetic art, broadening their perspective on the intersection of design, sustainability, and natural systems. As part of the learning process, students undertake a group project where they study nature's strategies and translate them into solutions for pressing issues in the built environment.

Through a mix of hands-on activities, interactive discussions, and collaborative exercises, students not only reconnect with nature but also develop a sense of humility about its problem-solving abilities. The emphasis is on learning from nature rather than just extracting from it, shifting their approach to design towards regenerative and sustainable solutions.

By the end of the elective, students develop both a scientific and artistic understanding of biomimicry, enabling them to integrate these insights into their design thinking. More importantly, the course helps them move beyond conventional sustainability approaches, encouraging them to view nature as a mentor that offers invaluable lessons for creating resilient, future-ready architecture.

Through a mix of hands-on activities, interactive

1. Phyllotactic

Chumki, Hari Kiran, Manasa,Navya Ub, Alisha

Phyllotaxis- refers to the arrangement of leaves on a plant stem. Phyllotactic spirals form a distinctive class of patterns in nature.

PHYLLOTAXIS

SPIRAL

YOUNG LEAVES
- Divergence angle = 137.5° (Golden Angle)

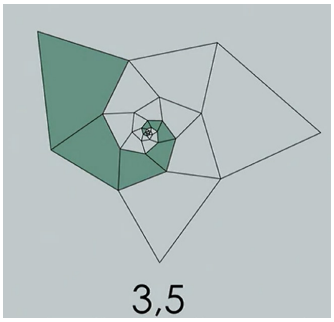
DEVELOPED LEAVES
- Sequence of Fibonacci fractions, such as 1/3, 2/5, 3/8, 5/13

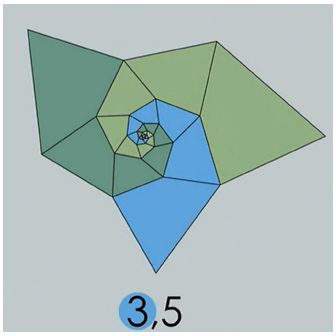
NON-SPIRAL
- Divergence angle = fraction of 360°
- Ex: distichy, decussate and whorled phyllotaxis

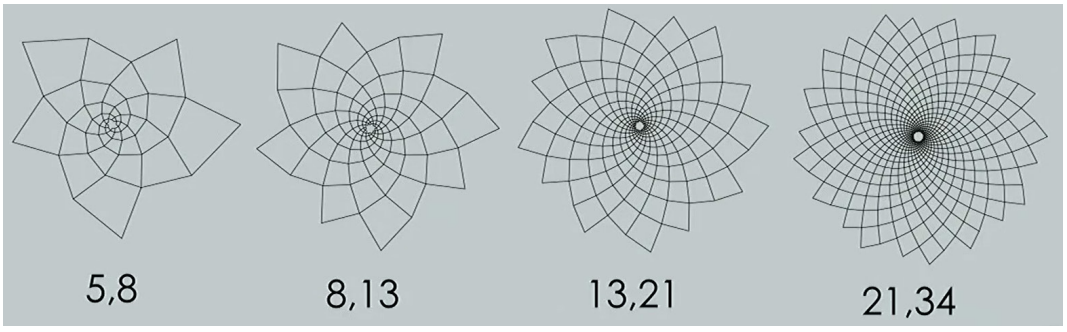
Phyllotactic arrangement of leaves

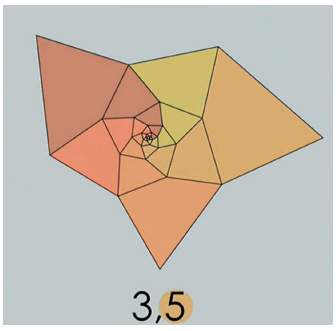
Spiral Phyllotactic Arrangements

The rotational angle from leaf to leaf in a repeating spiral can be represented by a fraction of a full rotation around the stem. The numerator and denominator normally consist of a Fibonacci number and its second successor. Ex: In sunflowers and pear, it is 3/8, and in willow and almond the angle is 5/13.

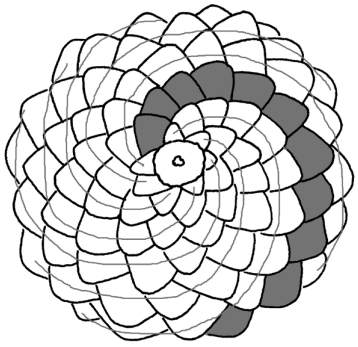


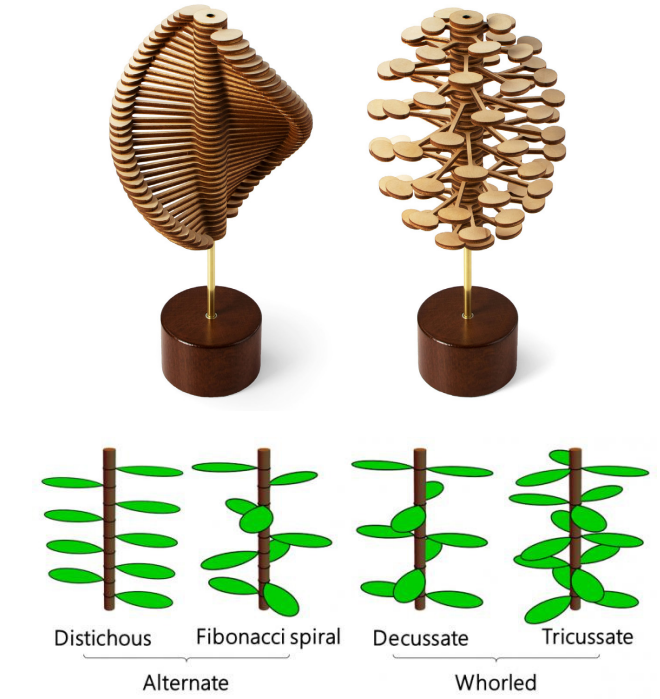






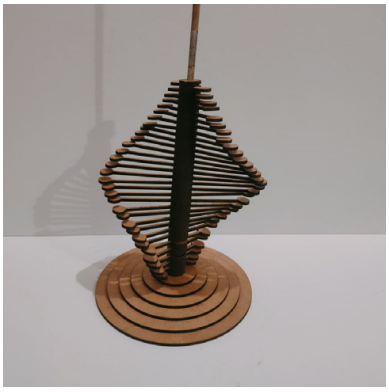
Edmark studied the connection between math and the natural world to create the Helicone. Specifically, he translated numerical, nature-based concepts like Fibonacci Numbers and the Golden Ratio into a plaything that shapeshifts into two natural forms right before your eyes. Edmark opted to craft the Helicone out of wood. In addition to giving the piece a rustic look and feel fit for a pinecone. Through the use of internal stops, each arm is constrained to rotate a maximum of 68.75° (1/2 the Golden Angle) relative to its neighboring layer.

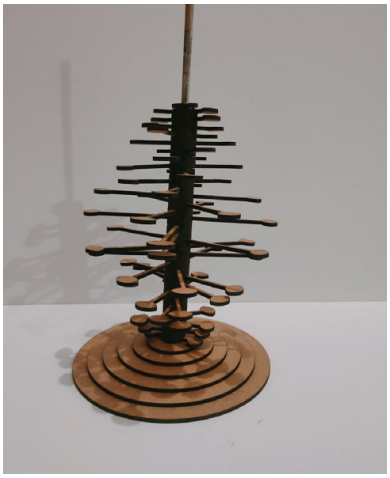


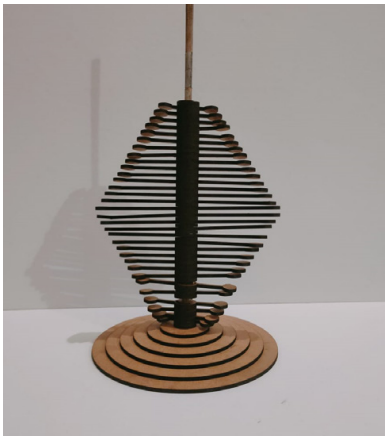


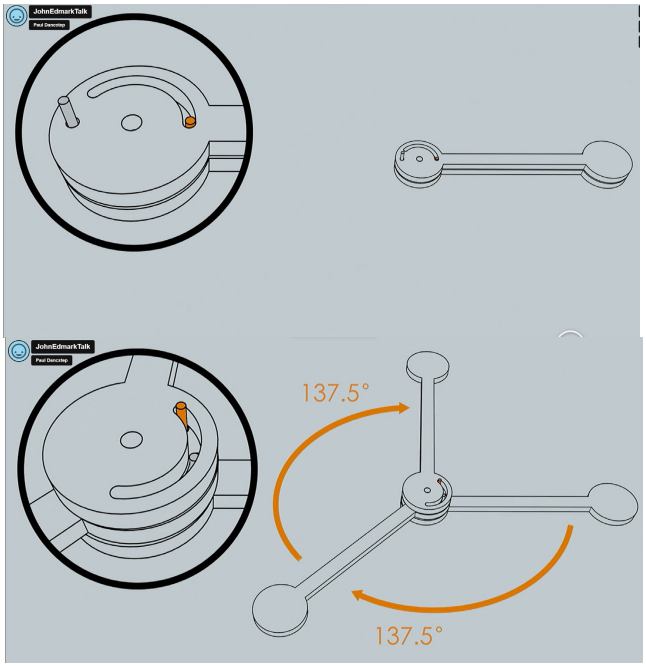
Different types of phyllotactic arrangement of leaves

Helicone - Process and model photos









Principle of how the model works

Application

Arrangement of leaves on the pinecone are arranged in sucha way that each one recieves equal amount of sunlight and hence this apporoach can be used for a building where green terraces are rotated at that angle to recieve maximum sunlight

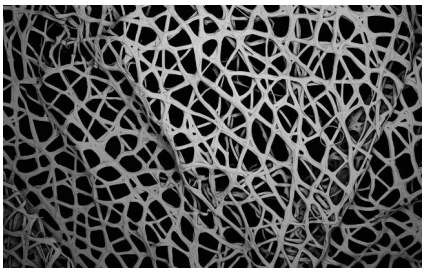
2. Silk Pavilion

Haashim Maricar, Likhith Rajesh, Sasikumar, Snehith Poojary, Tummala Pranesh

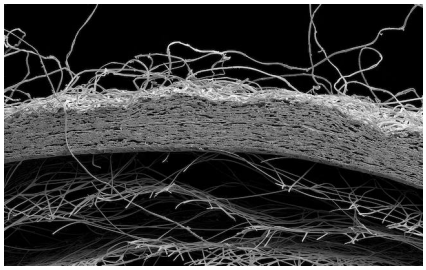
The Silk Pavilion explores relationships between digital and biological construction, proposing methods that unite the biologically spun and the robotically woven. Inspired by the silkworm's ability to generate a three-dimensional cocoon out of a single silk thread.

Constructed over three weeks with a flock of 6,500 live silkworms assisted by a robotic arm. Each silkworm spun a single silk thread filament that is about 1km long.

The silkworm is the larva (the active immature form of an insect) or caterpillar of the Bombyx mori moth. Silk has been made for at least 5000 years in China. Themoth is important because it makes silk. It is entirely dependent on humans, and it no longer lives in the wild. Silkworms eat mulberry leaves, and are native to Northern China.

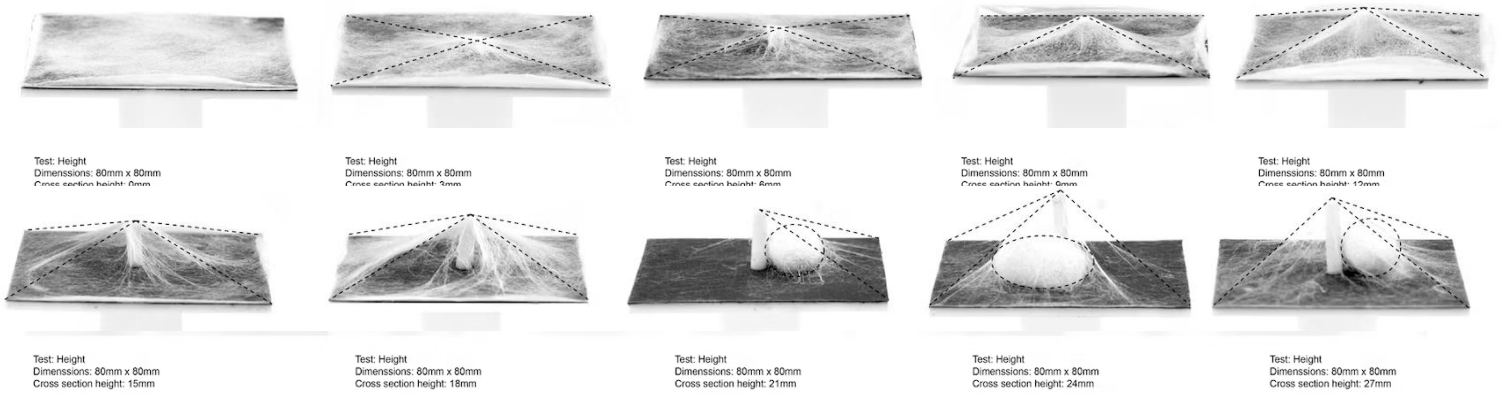


Intricate fiber layering created by the spinning



Section view of a silk cocoon

Silkworm templated response to height



Silk pavilion Model

PROTOTYPE I

PROTOTYPE II

3. Retaining Wall

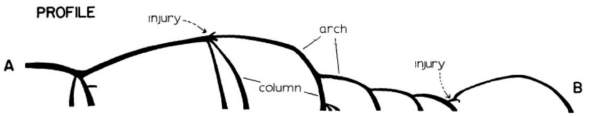
The red mangrove (Rhizophora mangle) is a coastal tree that grows in shallow estuaries throughout tropical regions. They grow in regions where storms and high winds are common and they are continually subjected to water currents and tidal forces. At the same time, they grow in waterlogged and shallow silt that is continually moving and so they are unable to anchor themselves using their roots the way trees growing on land can.

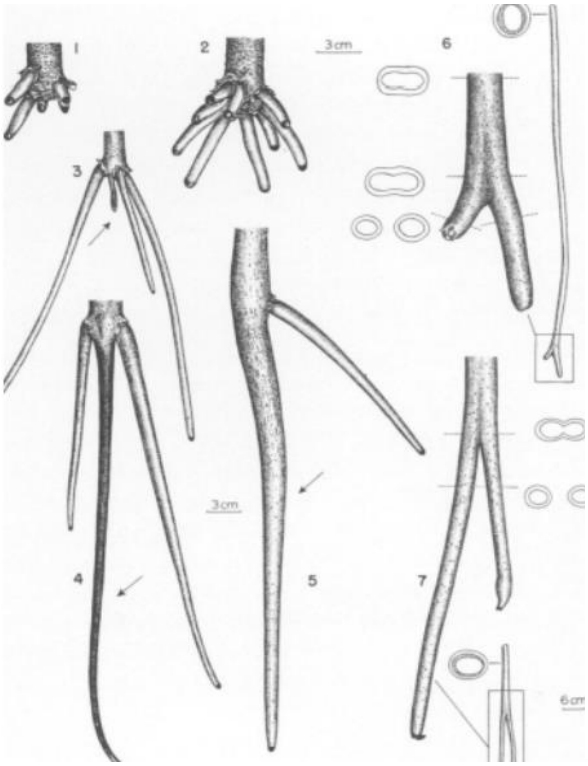
Soil pressure Some retaining walls, like brick walls, can't withstand severe soil pressure. This can lead to brick breakage or foundation failure.

Temperature and pressure Retaining walls can develop vertical fissures in the poured concrete due to severe pressure or drastic temperature changes.

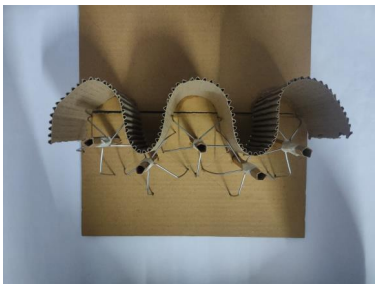
Water Retaining walls that are not properly maintained can allow water to seep in and contaminate the soil. This can negatively impact the health of plants and animals in the area.

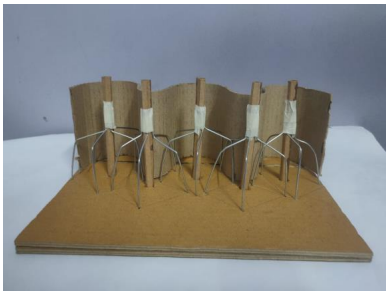
Aerial roots - emerges from the single stem, multiple branching radially.
secondary aerial roots - always dichotomous (branches in twos)
Subterranean roots- relatively thicker, mo branching from aerial roots

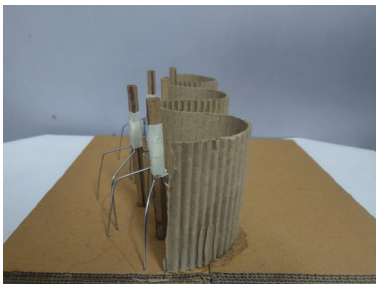


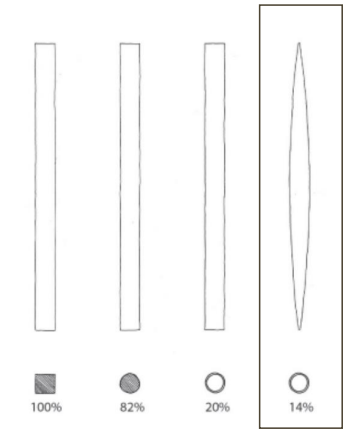


Creating: retaining wall scheme inspired from the roots of red mangrove trees









Efficiency in cross section

4. Frisky Mesh

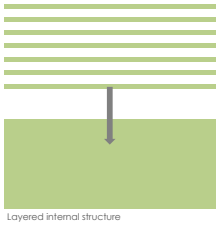
Aniruddh Muvva, Dhanyashree M , Janvi Singhania,
Kulsum Fatima

Venus Flower Basket :
Marine structure found underwater,100 to 300 mm tall,Also known as glass sponge.

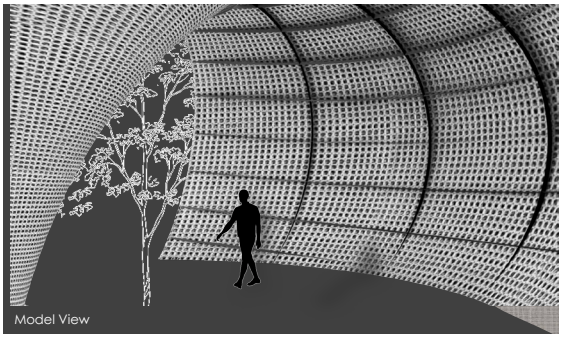
Venus flower basket or 'Glass sponge'

Two separate but overlapping lattices make up the main frame.These lattices can still move relative to one another, the skeleton can be flexible while it's growing. The squares of the lattice are reinforced by struts that run vertically, horizontally, and diagonally.

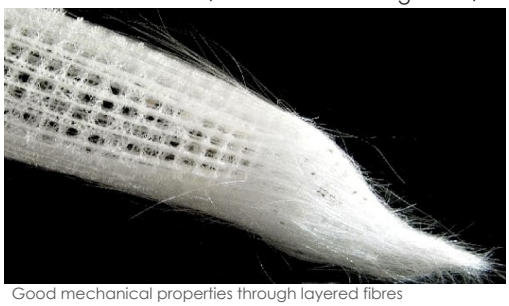
The sponge's glass skeleton is made up of spicules, tubule structures of concentric layers of amorphous hydrated silica separated by thin organic layers. But these thin organic layers go a long way to impart the spicules with considerable toughness. Silica layers are made up of colloidal spheres of silica about 50 to 200 nm in diameter, which are in turn made up of smaller spheres about 2.8 nanometers in diameter.



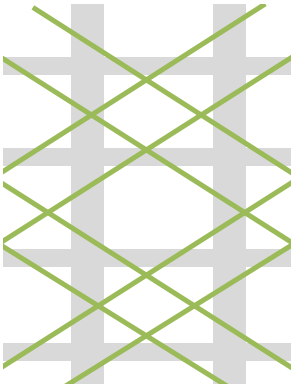
Layered internal structure



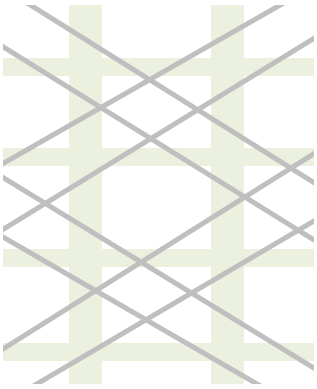
Model View



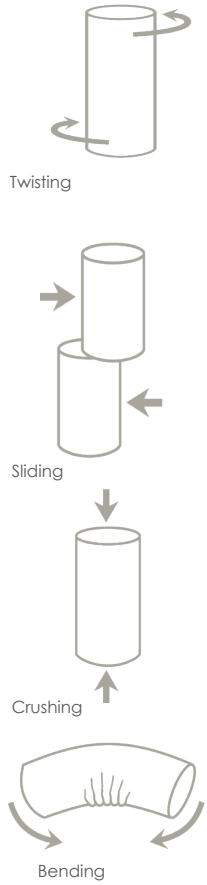
Good mechanical properties through layered fibres



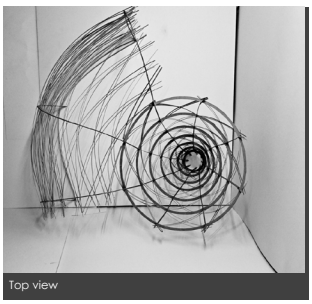
Lattice 1



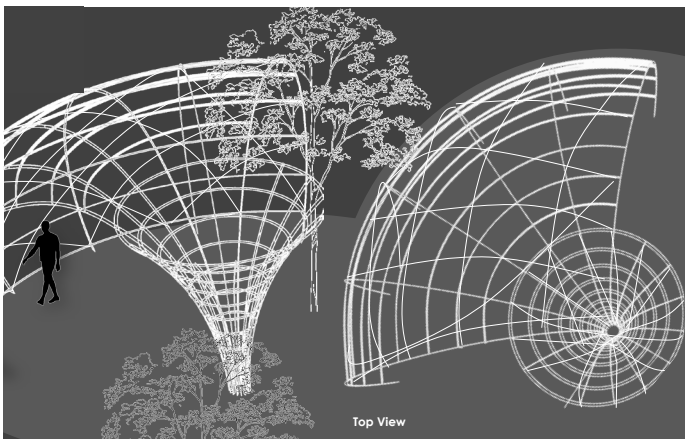
Lattice 2



Model view



Top view

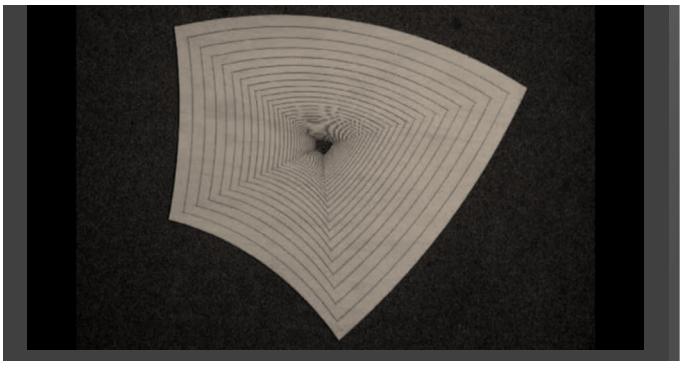


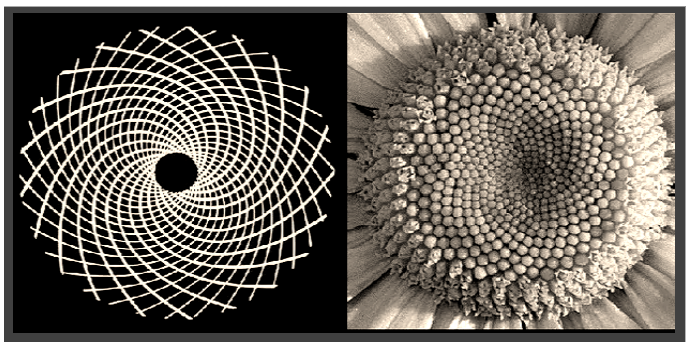
Top View

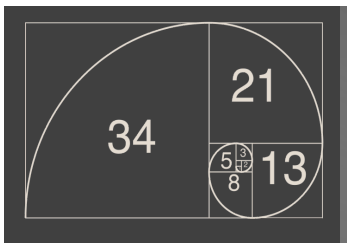
5. Golden Glow

Aniruddh Muvva, Dhanyashree M , Janvi Singhania,
Kulsum Fatima

The nesting principle was used to design this light fixture that can be viewed as a spiral when stood under it. A complicated pattern such as
the spiral can be broken down to simple fractals as seen in the drawings.It has been installed in a double height space such as in the well of a spiral staircase.The extent of the spiral chandelier in plan is 2 m x 1.5 m x 4 m

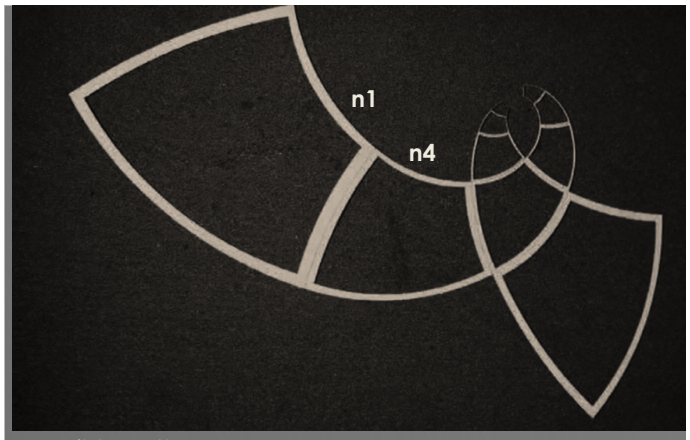




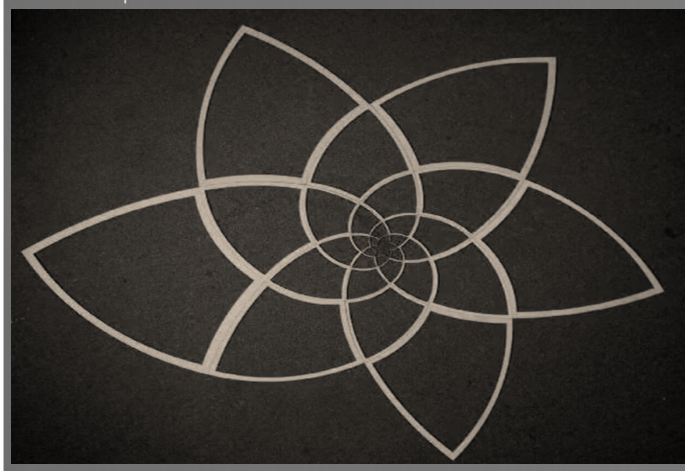


FIBONACCI SERIES
The Fibonacci sequence starts like this: 0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55 and so on forever. Each number is the sum of the two numbers that precede it.
It's a simple pattern, but it appears to be a kind of built-in numbering system to the cosmos

$n =$	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	...
$x_n =$	0	1	1	2	3	5	8	13	21	34	55	89	144	233	377	...



Possible patterns


Fibonacci Spiral

NESTING FRAMES
SPIRAL TILING
All of these frames are cut from a single piece of wood. They are similar, and logarithmically scaled. Their shape was designed to allow them to be combined to form a spiral tiling


Model View