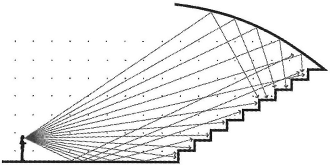
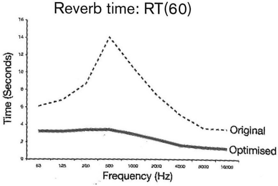
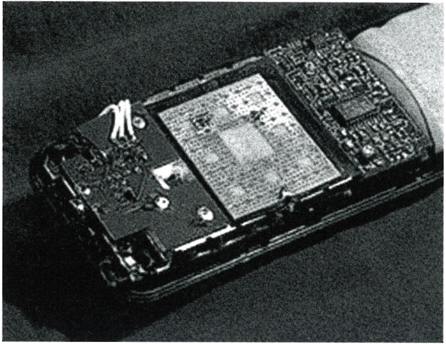
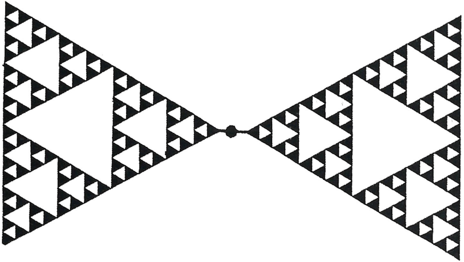
Acoustic optimization





Acoustic optimization is a very qualitative process, despite the contribution of measurement and quantitative analysis. Two positions in a room may give equivalent measures, but still sound different subjectively. A performance space needs to be designed with several different acoustics in mind, from the seating acoustic (which varies significantly from point to point in the space), to the platform acoustic for the performers, to the recording and broadcasting acoustic. Sound experience is also highly subjective, and will not necessarily reflect even the most accurate measurements taken when the listener is in the built space. The three principal measurements are clarity, reverberation and loudness. Clarity depends on the length of early time delay; the ear collects the sound received in approximately the first 80 milliseconds and reinforces the initial sound. Reverberation received outside this time starts to be detected as loss of clarity. As sound travels 1m in roughly 3 milliseconds, there are critical dimensions of halls that determine the arrival of the first reflection.





12-55. (Left) Fractal antenna in a cell phone in the form of a square Sierpiński carpet (see plate 12-33). Courtesy Fractal Antenna Systems, Bedford, Massachusetts.

(Right) Fractal antenna in the form of a triangular Sierpiński carpet, in Nathan Cohen and Robert G. Hohlfeld, "Self-Similarity and the Geometric Requirements for Frequency Independence in Antennae," *Fractals* 7, no.1 (1999): 79–84. © 2011 World Scientific Publishing Company. Used with permission.

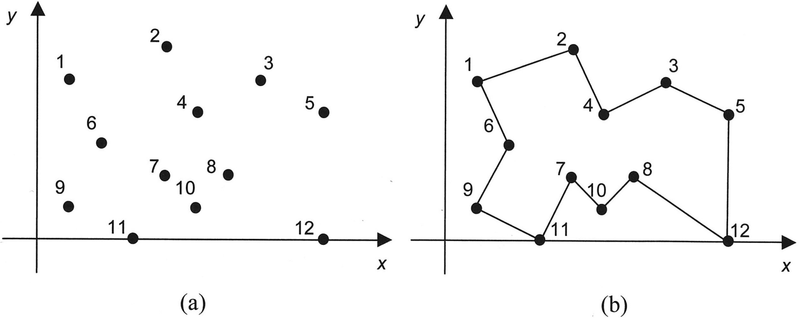
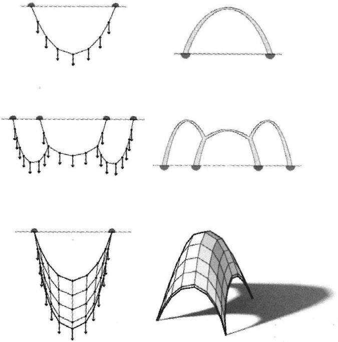


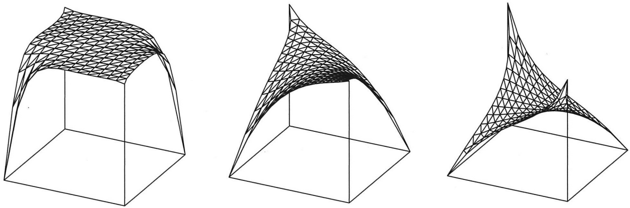
Figure 5.4: A simple instance of the TSP. (a) A set with 12 cities. (b) A minimal route connecting the cities.

Catenary models



The catenary is a mathematical curve, which, when rotated around its X-axis, gives the catenoid, or minimal surface. The word 'catenary' is derived from the Latin *catena*, meaning 'chain'; indeed, the catenary is the shape taken up by a chain fixed at both ends and hanging under its own weight. As luck would have it, when reflected in the X-axis, it also perfectly describes the line of force in a masonry arch supporting its own weight. An arch built in this shape can act in pure compression, as the chain acts in pure tension. This has led to a number of inspired designers, notably Gaudí, finding the shape for their masonry structures from hanging or funicular models. The parabola is a close approximation to the catenary. (Galileo believed it to be the shape of the hanging chain.) It has a simpler formula and is easily constructed by finding points equidistant from a point and a line.

Dynamic relaxation



Dynamic relaxation is a method of computational modelling for the form-finding of cable and fabric structures. In the example of the roof for the British Museum's Great Court (p. 122), this method had to be used to find the structural subdivision of the complex, curved dome into glazed facets. It assumes that all the mass is concentrated at the structural nodes. The system oscillates about the equilibrium position under the influence of loads. The iterative process is achieved by simulating a pseudo-dynamic process in time. At each iteration, the geometry (node position) is updated, using Newton's second law, where force is equal to the product of mass and acceleration. This is doubly integrated to give a relation between speed, geometry and residual force. Gradually the forces acting on each individual node are equilibrated. Finally, the friction component tangential to the surface at each of the structural nodes via imaginary strings to its four nearest neighbours converges at zero.

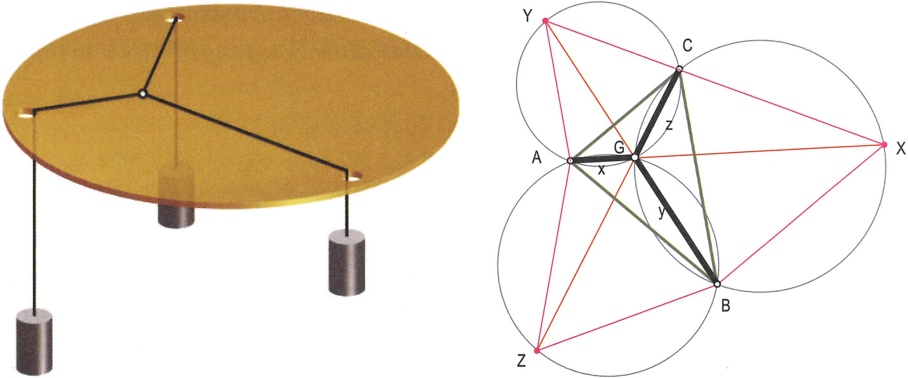
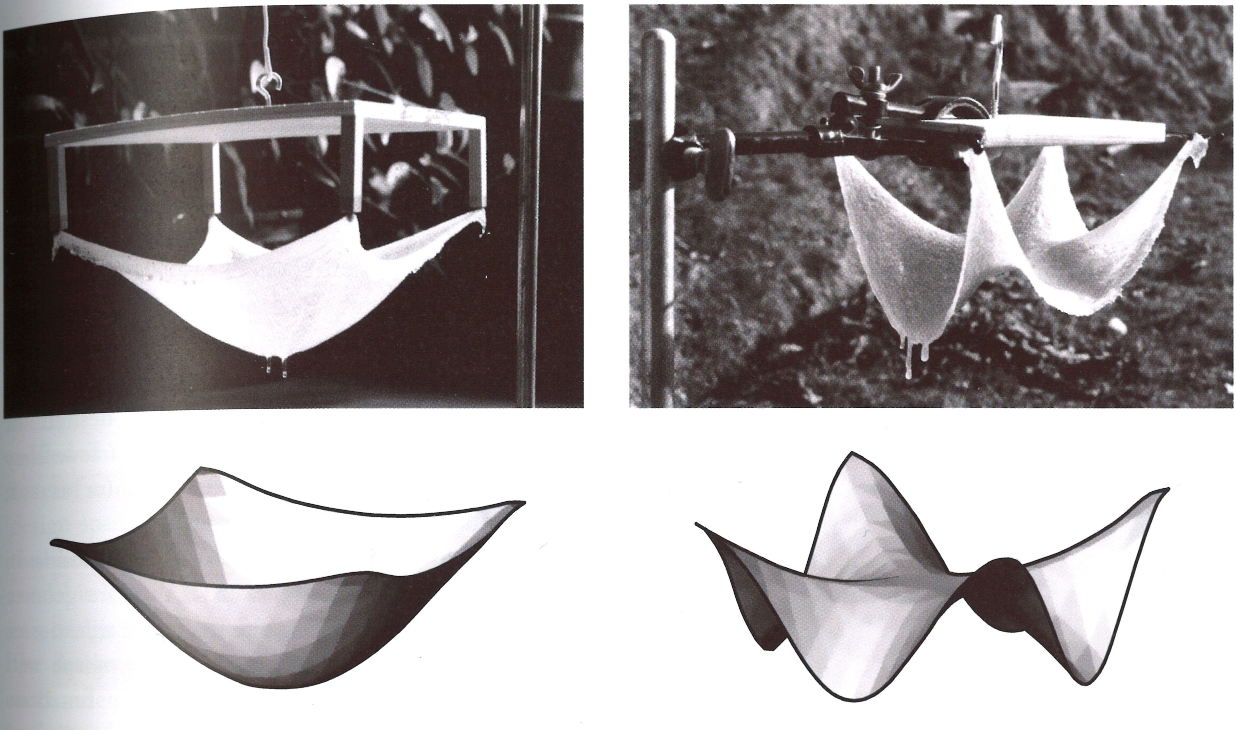


Abb. 1.16 Der Fermatsche Punkt



(a) (b)

Figure 5.2 Ice and polyester experiments by Heinz Isler versus numerical hanging models. Negative and positive curvature by modifying the angle of material anisotropy, either (a) parallel, or (b) diagonally aligned to the edge

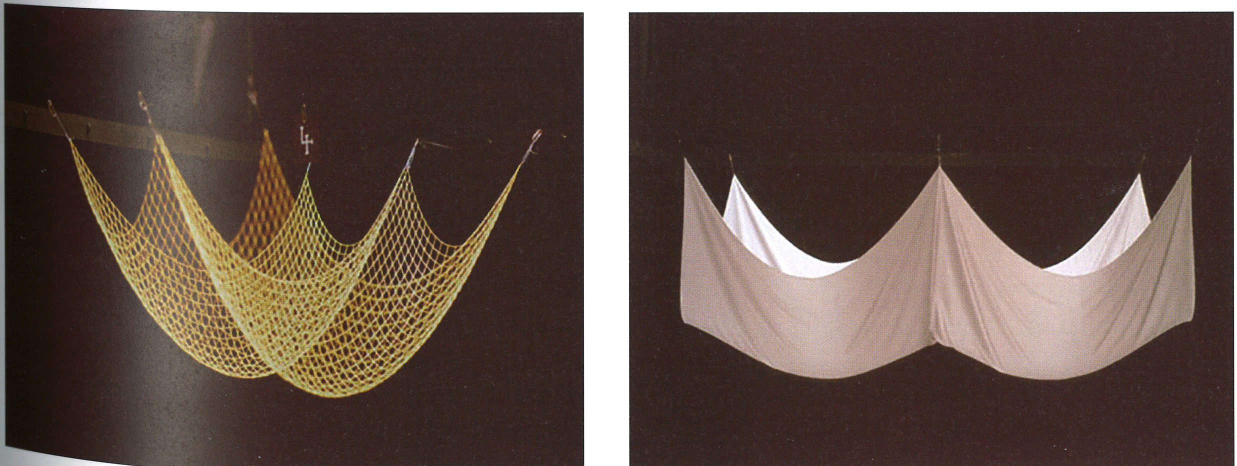
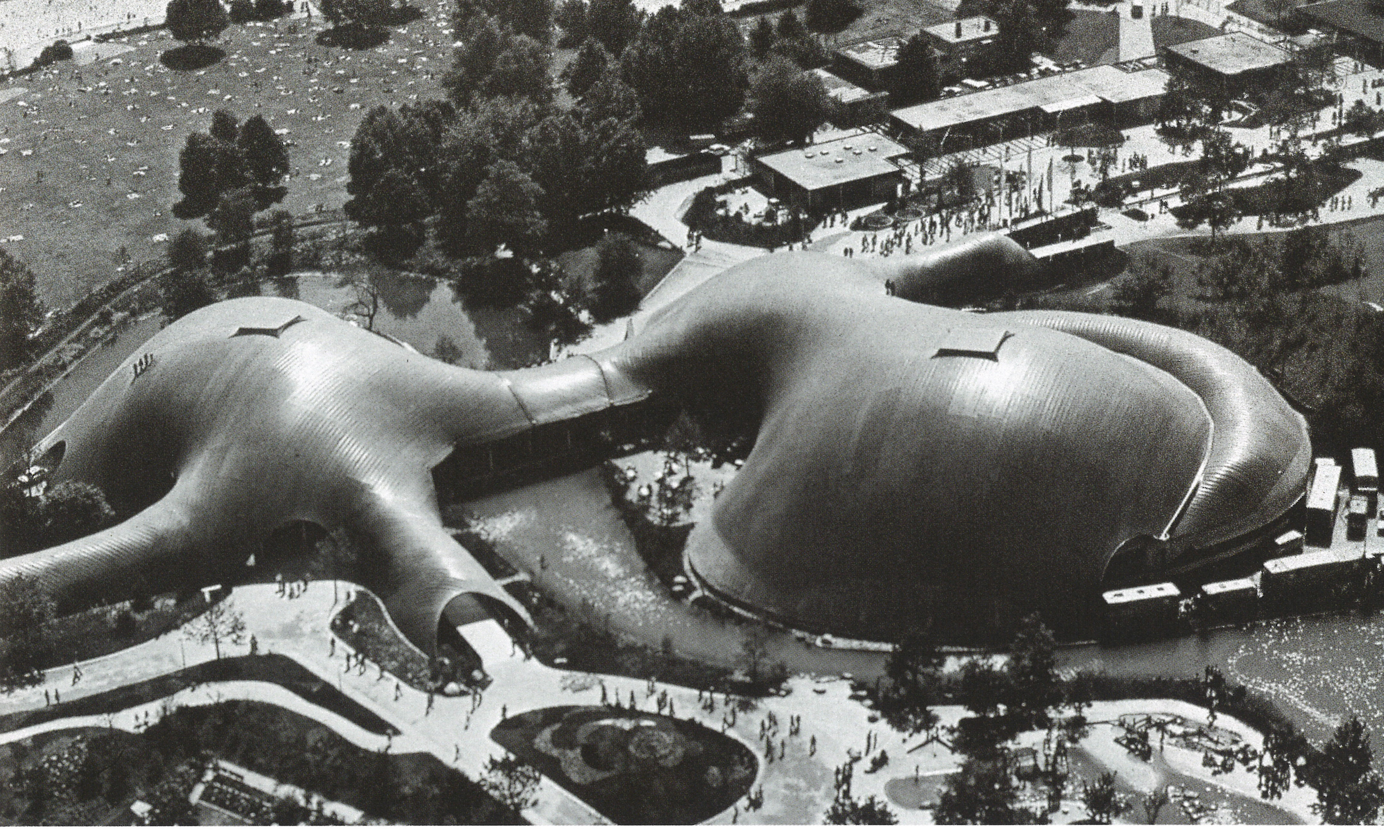
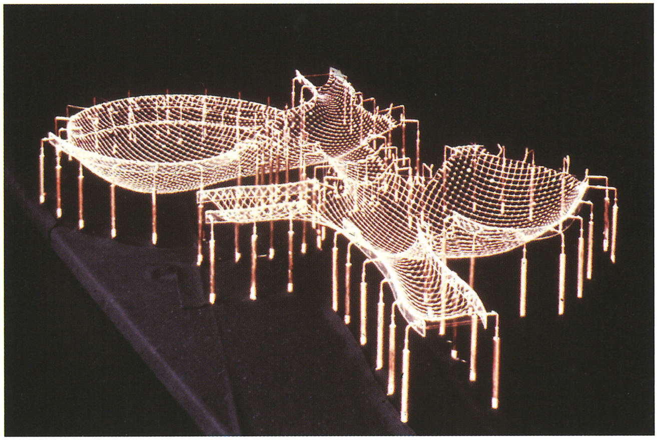


Figure 5.3 Hanging model experiments from IL



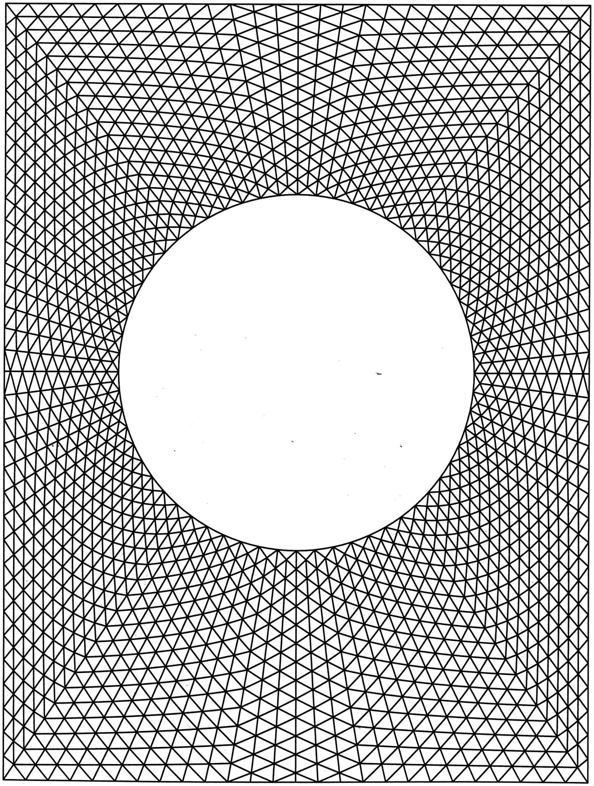
691



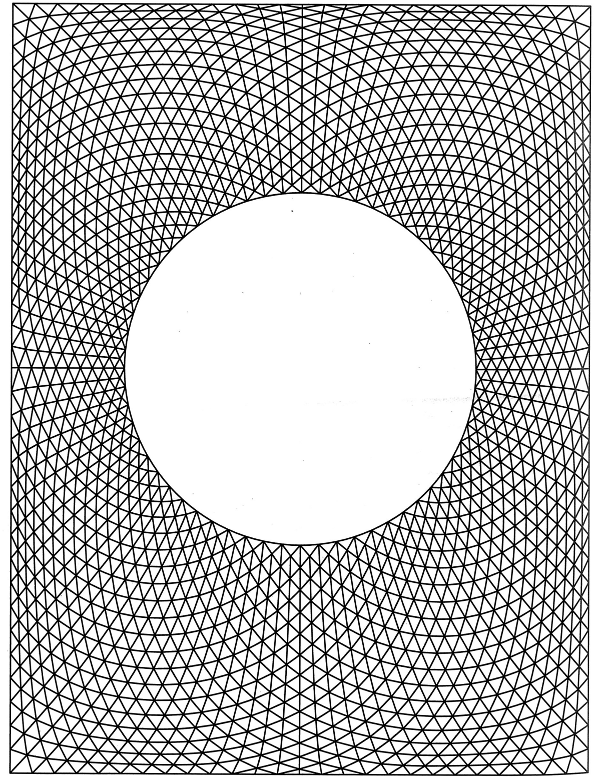
692

691 Exhibition building for the Garden Festival, Mannheim, Germany, 1975. Engineers: Ove Arup & Partners with Frei Otto; architect: Carlfried Mutschler and Partners. 692 Garden Festival building. Hanging chain model used to find the form for the timber grid shell.

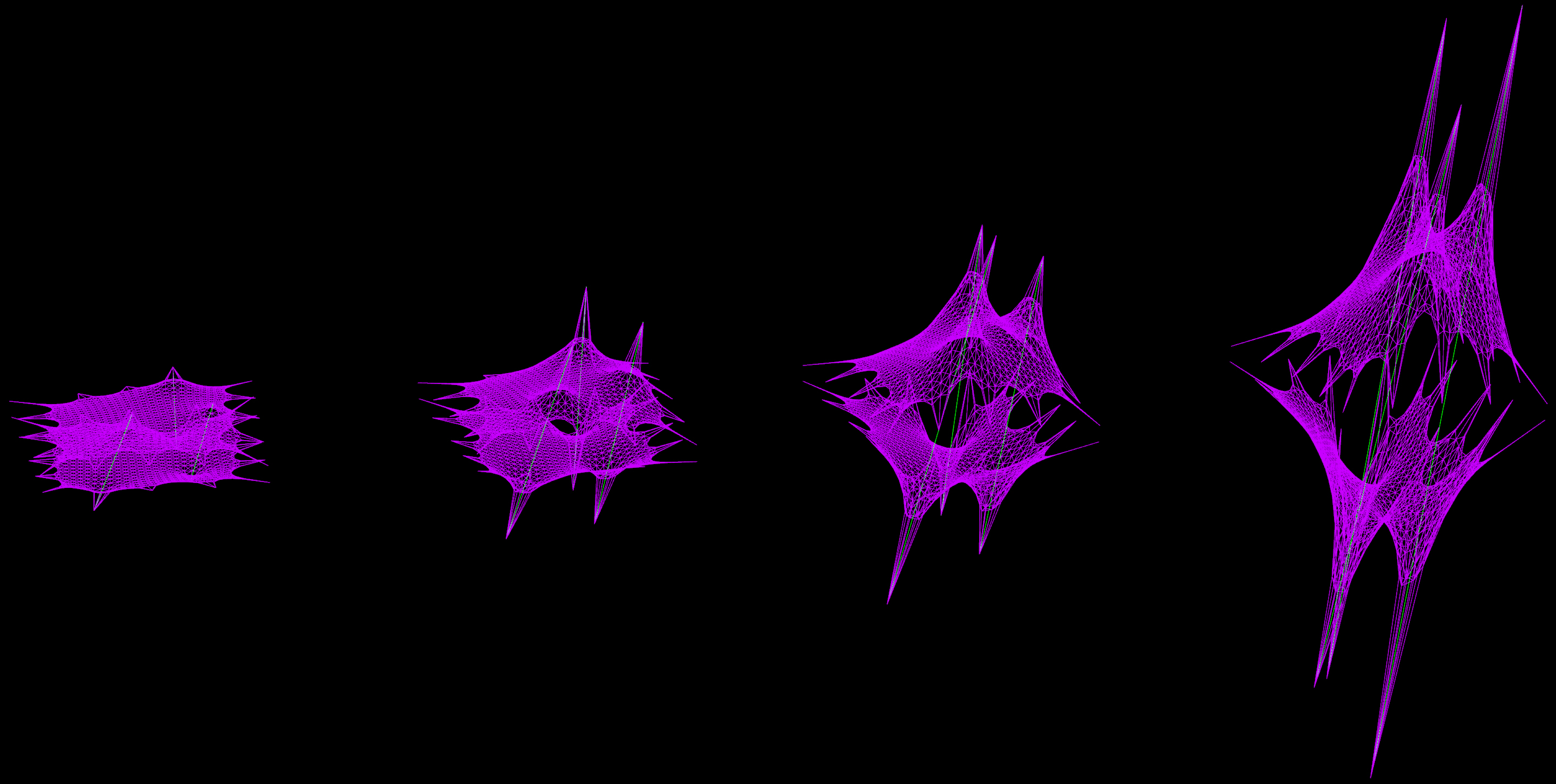
mesh before relaxation

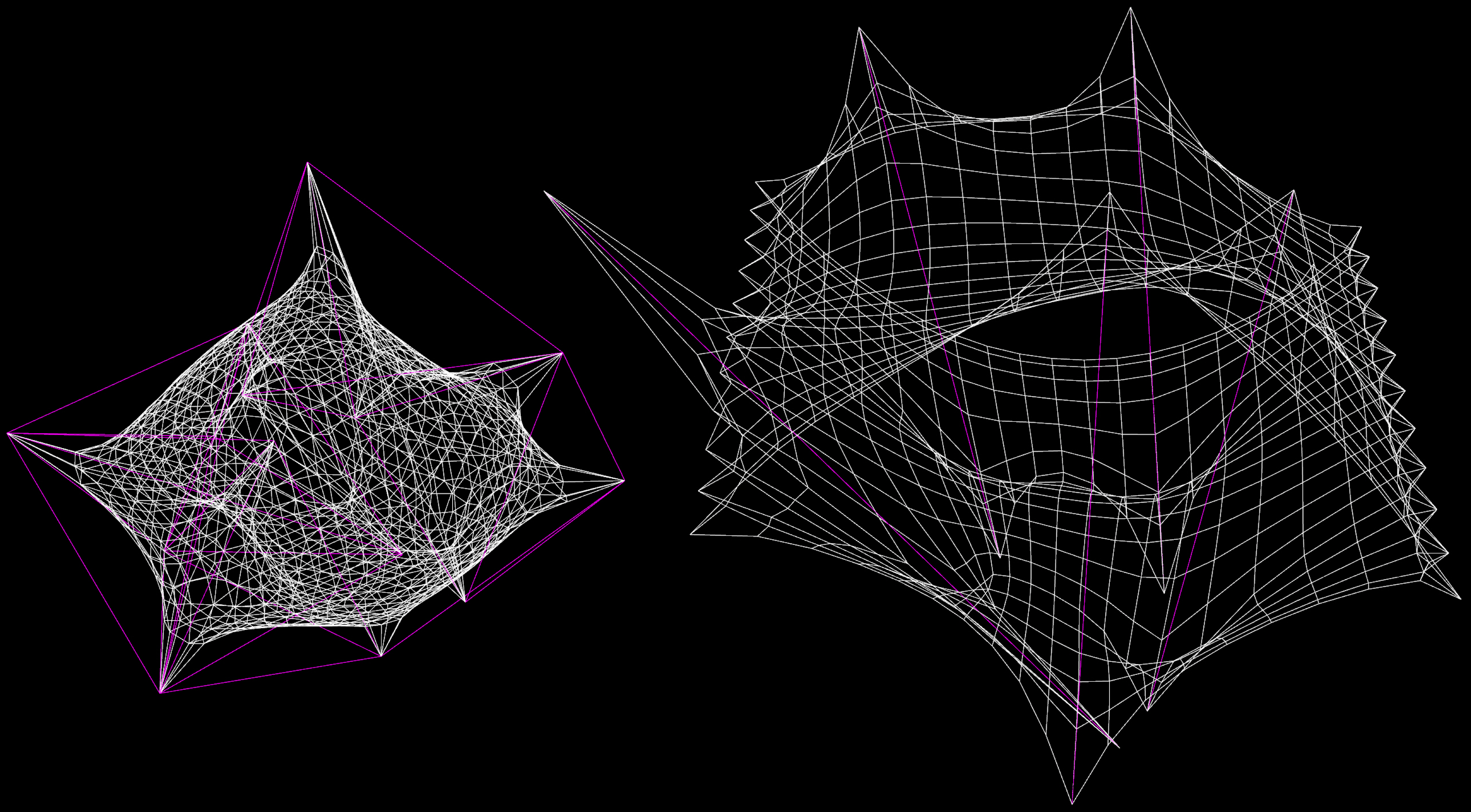


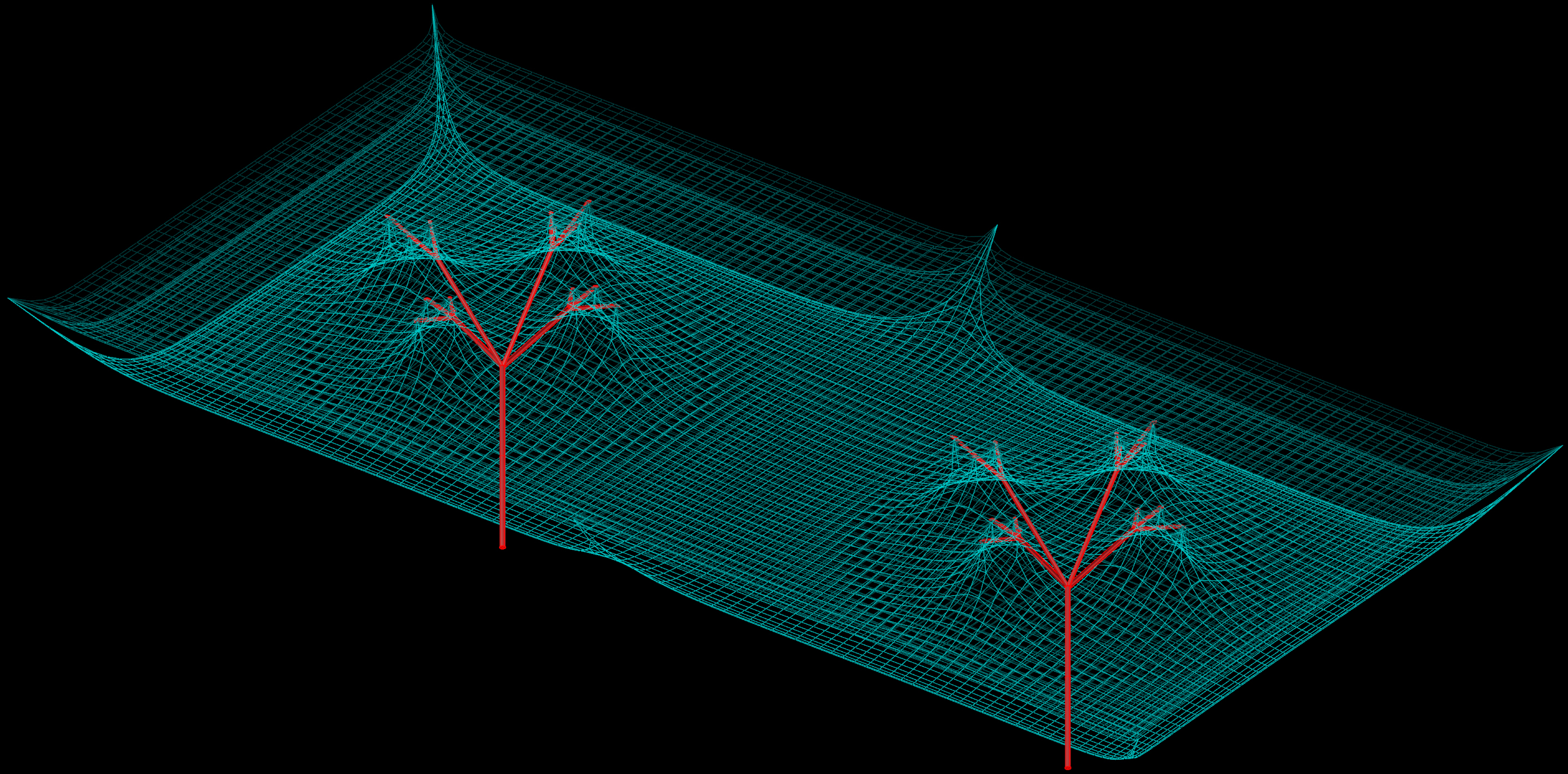
mesh after relaxation

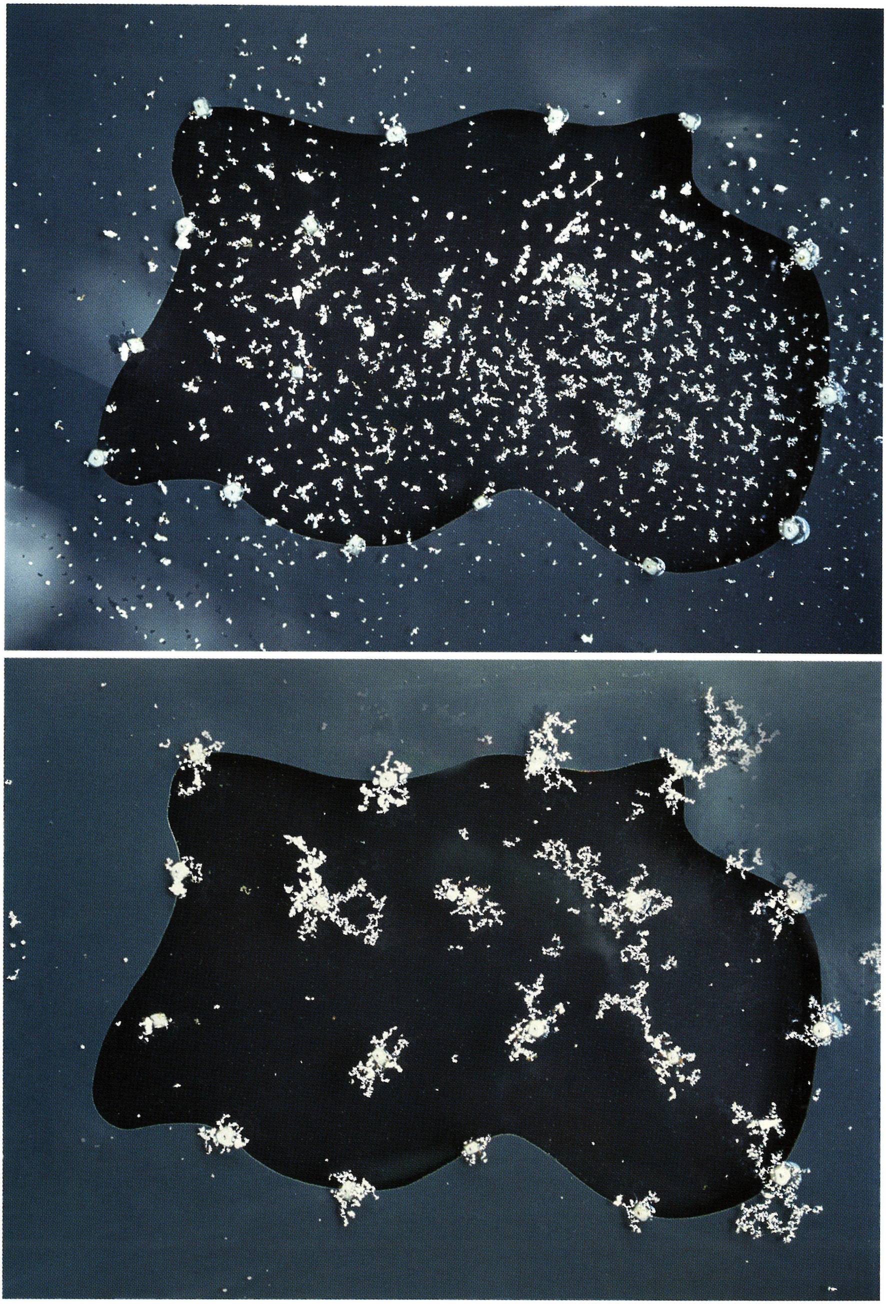



ELIZABETH II AD 2000 THIS GREAT COURT









Frei Otto, occupation with simultaneous distancing and attracting forces, Institute for Lightweight Structures (ILEK), Stuttgart, Germany, 1992. Analogue models for the material computation of structural building forms (form-finding) are the hallmark of Frei Otto's research institute. The same methodology has been applied to his urban simulation work. The model shown integrates both distancing and attractive occupations by using polystyrene chips that cluster around the floating magnetic needles that maintain distance among themselves. © Frei Otto.

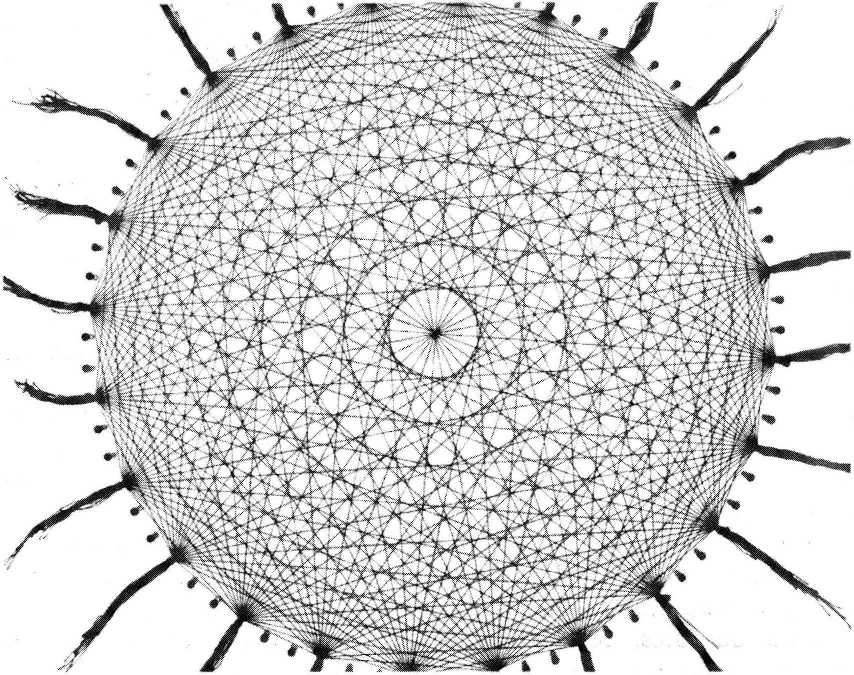


Figure 16.1a: Frei Otto, Wool Thread Models, Stage 1 (dry and taut) produced at the ILS Institute for Light-Weight Structures, University of Stuttgart. Image credit: Images courtesy of ILEK Institut für Leichtbau Entwerfen und Konstruieren Universität Stuttgart.

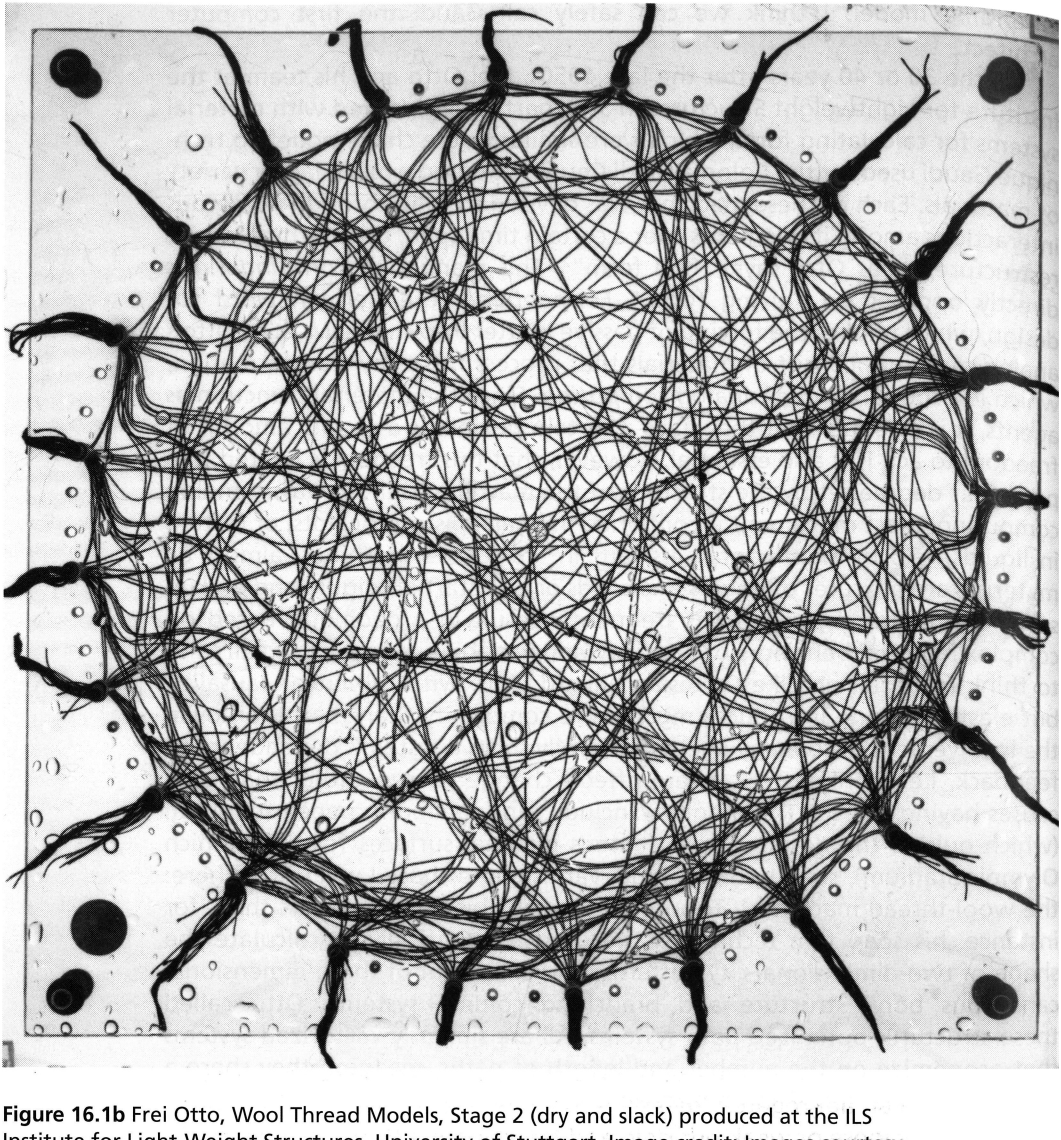


Figure 16.1b Frei Otto, Wool Thread Models, Stage 2 (dry and slack) produced at the ILS Institute for Light-Weight Structures, University of Stuttgart. Image credit: Images courtesy of ILEK Institut für Leichtbau Entwerfen and Konstruieren Universität Stuttgart.

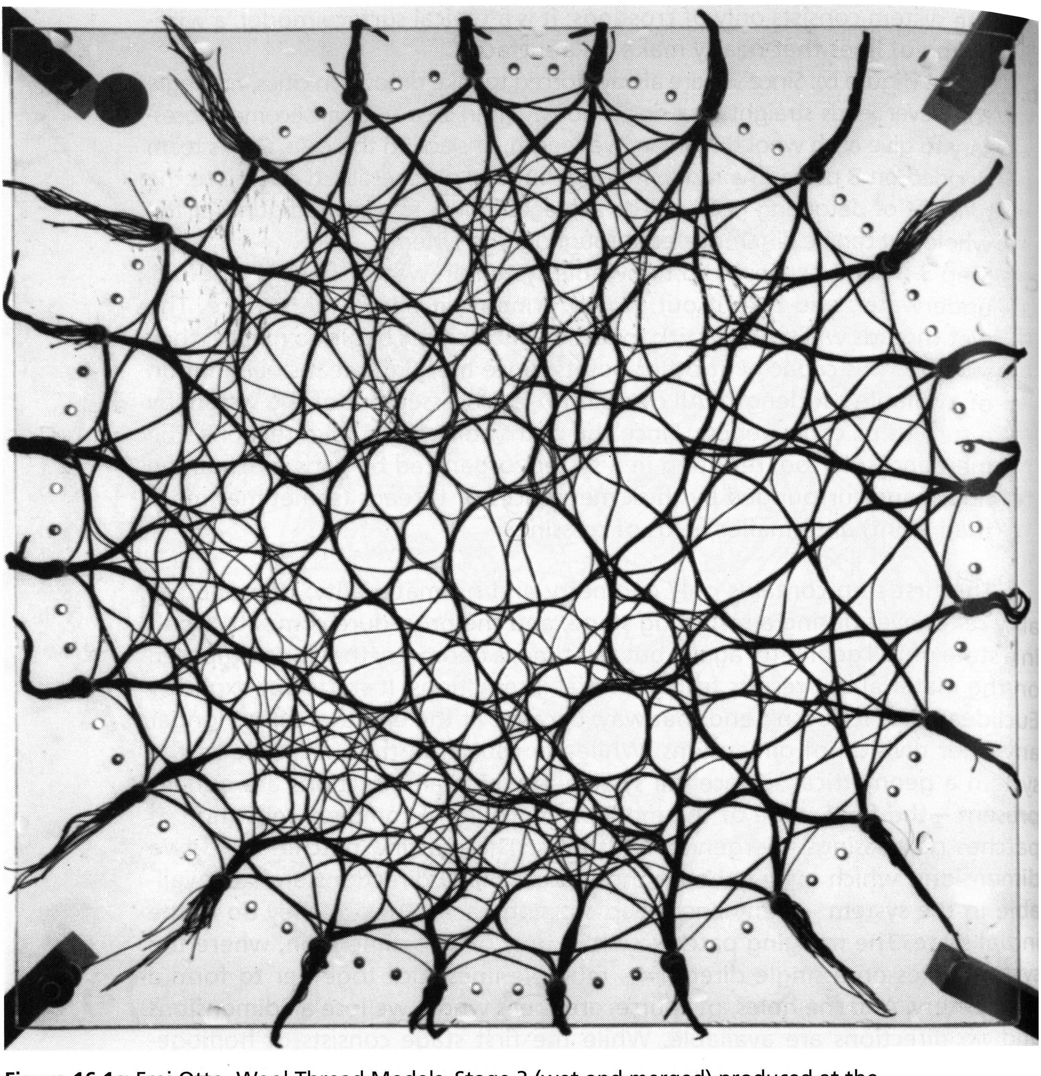
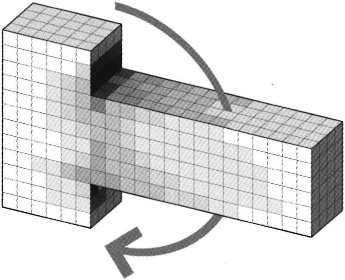


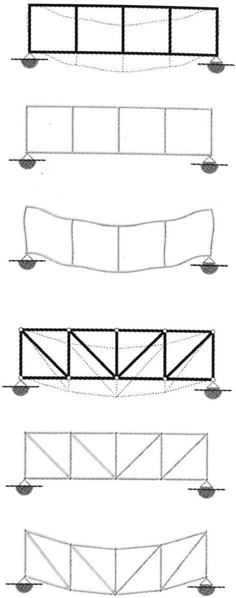
Figure 16.1c: Frei Otto, Wool Thread Models, Stage 3 (wet and merged) produced at the ILS Institute for Light-Weight Structures, University of Stuttgart. Image credit: Images courtesy of ILEK Institut für Leichtbau Entwerfen und Konstruieren Universität Stuttgart.

Finite-element analysis



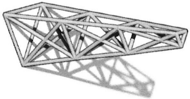
Finite elements are like tiny cubic blocks that make up the whole. They can be very small, their size a balance between the grainyness or pixellation of the form at low resolution and the computing time, which increases very steeply with the reduction of element size. Each element is impacted by the forces transferred from its immediate neighbours, and this type of analysis uses these forces.

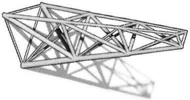
Vierendeel truss

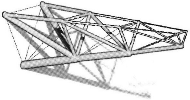


The Vierendeel truss is one in which the members are not triangulated; the openings in the truss are polygonal, but not triangular. The frame has fixed joints that are capable of transferring and resisting bending moments. This contrasts with more commonly used trusses that are assumed to have pin joints with no bending moments at the jointed ends. The Vierendeel truss is named after engineer Arthur Vierendeel (1852–1940), who developed the design in 1896, and is sometimes referred to as a strong-joint, weak-member elastic structure.

Arup optimizer







For both the Water Cube (p. 86) and the Melbourne Rectangular Stadium (p. 134), an Arup in-house application was used to individually size the members in the steel structures. In contrast to the traditional engineering method of deriving member sizes for stressed elements from tables and charts, it allowed iterative evaluation of the most appropriate member size for each structural element individually. The optimizer works on the very simple principle of constraint satisfaction, which carries out design-strength checks for each individual member in a group. One constraint is active when a series of checks is being carried out. The system is very input-sensitive; it is important to select appropriate starting values for the member sizes to avoid finding local, rather than global, minima. It takes approximately 30 minutes to calculate the whole structure by considering the case of each individual member in turn.

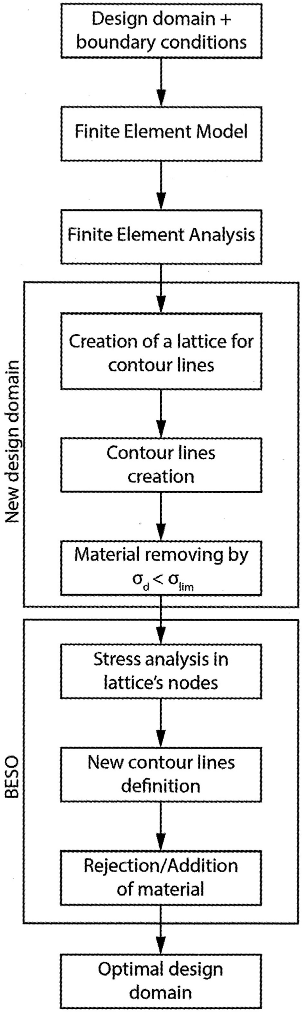


FIGURE 10.10

Extended evolutive structural optimization flowchart.

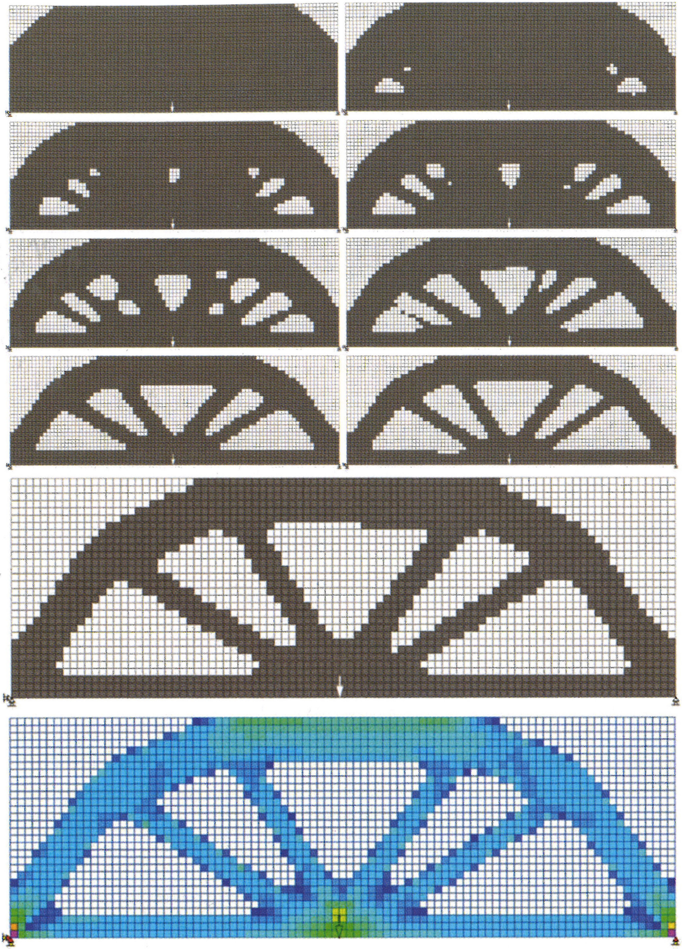


FIGURE 10.9

MBB beam optimization and Finite element analysis of the optimized beam.

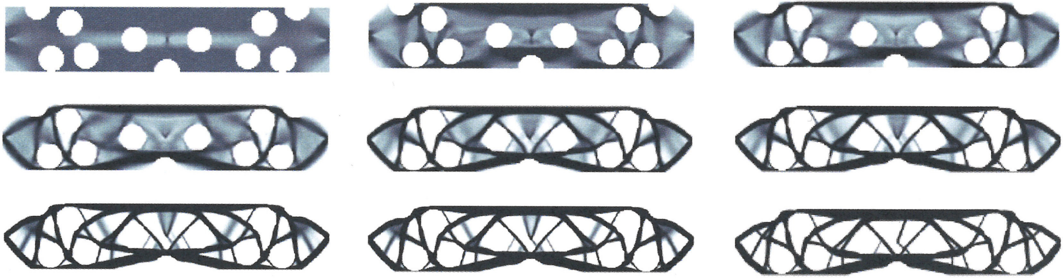


Fig. 2 Topology optimisation process of a beam structure: from the initial generation to the end results

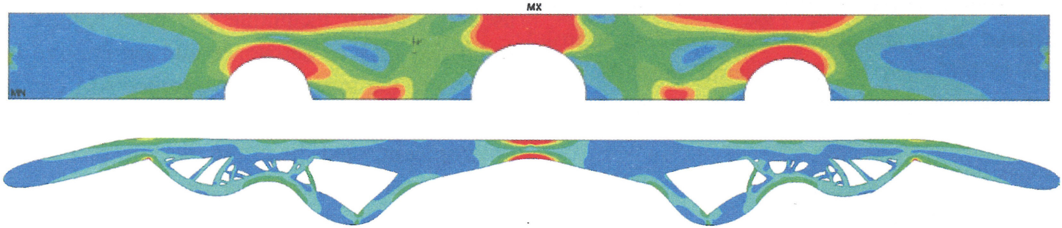
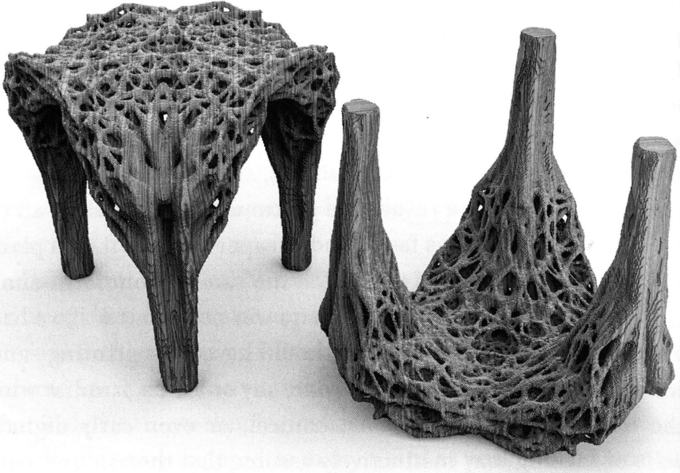


Fig. 1 FEA analysis for an initial shape (*top*) and an optimal shape (*bottom*), both were designed for the same loads and boundary condition



2.19
Daniel Widrig, *Degenerate Chair*, Frac Centre Collection (2012). Author's rendering.

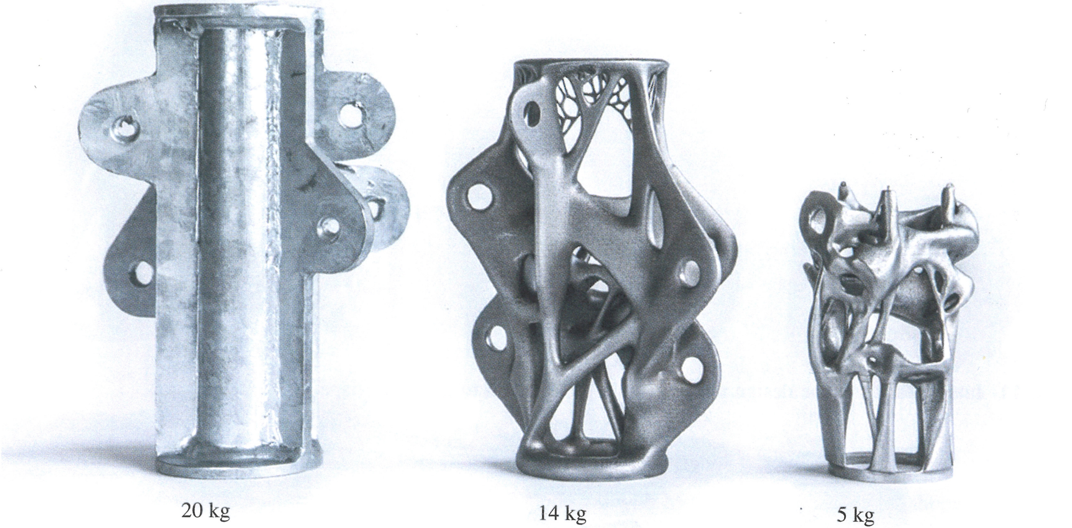
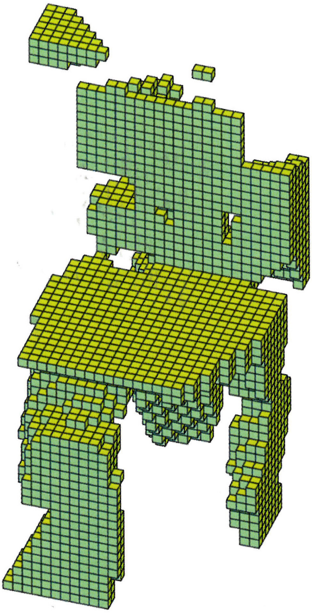
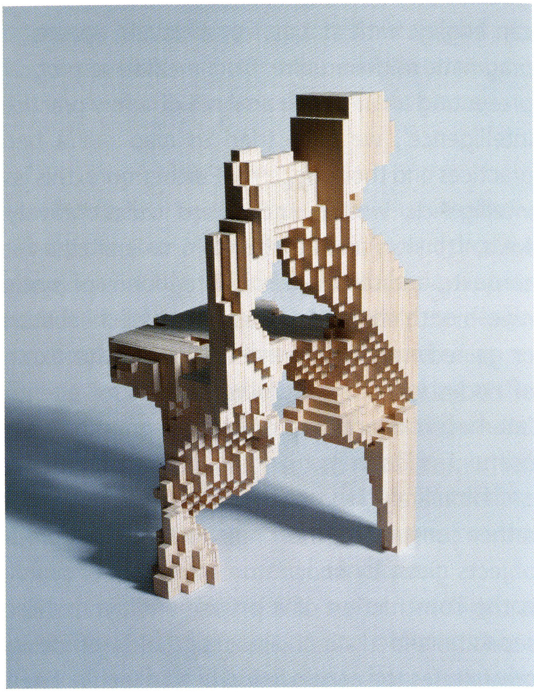
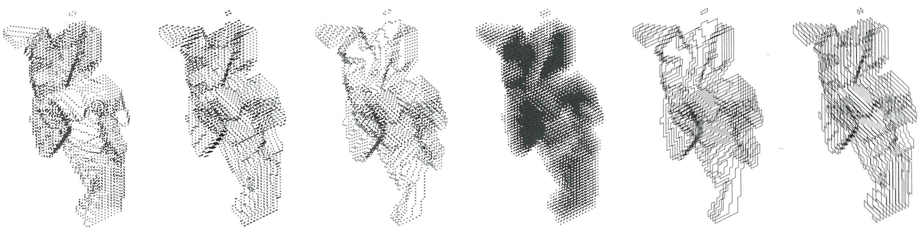


Fig. 13 Comparison of three steel nodes. *Left* to *right* Traditional node, AM node 1.0, and AM node 2.0, all with the same functional and structural performances



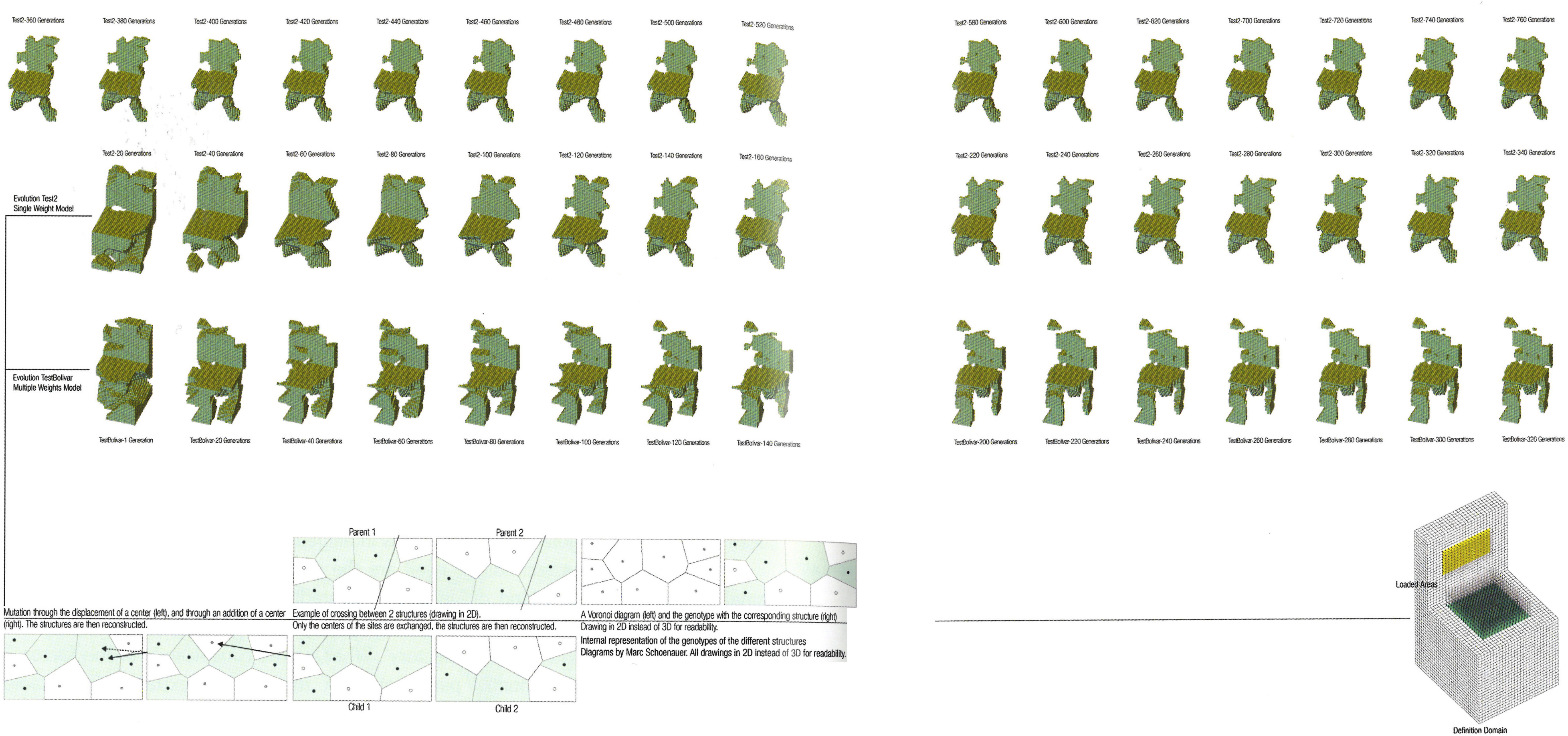




top left: EZCT Architecture & Design Research with Hatem Hamda and Marc Schoenauer, studies on optimisation: computational chair design using genetic algorithms, 2004. The 'Bolivar' model is evaluated for a multiple load strategy (it is always stable, whatever way the seat is positioned). This model (prototype and drawings) is part of the Centre Pompidou Architecture Collection. © Philippe Morel (original drawings © Centre Pompidou).

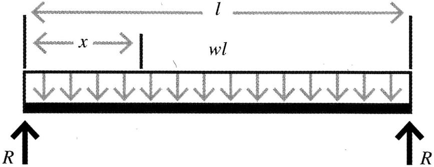
top right: Philippe Morel/EZCT Architecture & Design Research, chair 'Model T1-M', after 860 generations (86,000 structural evaluations). Courtesy Philippe Morel © Ilse Leenders.

above: EZCT Architecture & Design Research with Hatem Hamda and Marc Schoenauer, Studies on optimisation: computational chair design using genetic algorithms, 2004. Data analysis, 'Bolivar' model, Mathematica drawings. Because the data was structured for mutations and evaluation via finite element methods, it needed to be rearranged for fabrication. Mathematica was therefore used for writing different algorithms in order to ease pricing, cutting and assembling. The drawings are part of the Centre Pompidou Architecture Collection. © Philippe Morel (original drawings © Centre Pompidou).



above: EZCT Architecture & Design Research with Hatem Hamda and Marc Schoenauer, studies on optimisation: computational chair design using genetic algorithms, 2004. The process sheet shows seven chairs optimised through a mono-objective optimisation strategy, two chairs optimised through a multi-objectives strategy, and the optimisation process for Model 'Test2'. The sheet shows the crossing-over internal representation based on Voronoi diagrams. This high-level representation strategy, developed by Marc Schoenauer, allows for a better correspondence between the genotype representation and the phenotype of the real chairs. © Philippe Morel.

2.1.2 Analytical formulae

Problem to be solved	Example formula
Compute moment in a simple beam, uniformly loaded	M_{max} (at center) . . . . $= \frac{wl2}{8}$ 
Flow resistance of air through a small opening in an exterior wall	$S_h(V) = \frac{p}{0{,}845 \cdot A^2} \cdot V$ where S_h is the flow resistance [Pa · m³/s] p is the density of the air [kg/m³] A is the area of the hole [kg/m²]
Required capacity of rainwater downpipes and gutters	Qh = (a × i) × (ß × F) a = the reduction factor for the rain intensity for flat roofs a = 0.60 flat roof with ballast of gravel a = 0.75 for the other flat roofs As flat roofs discharge the water at a slower pace, for all other cases (therefore all pitched roofs) applies a = 1, i = rain intensity and is 1.8 (litre/minute)/m² ß = reduction factor for the roof width is determined by the pitch roof F = surface of the roof

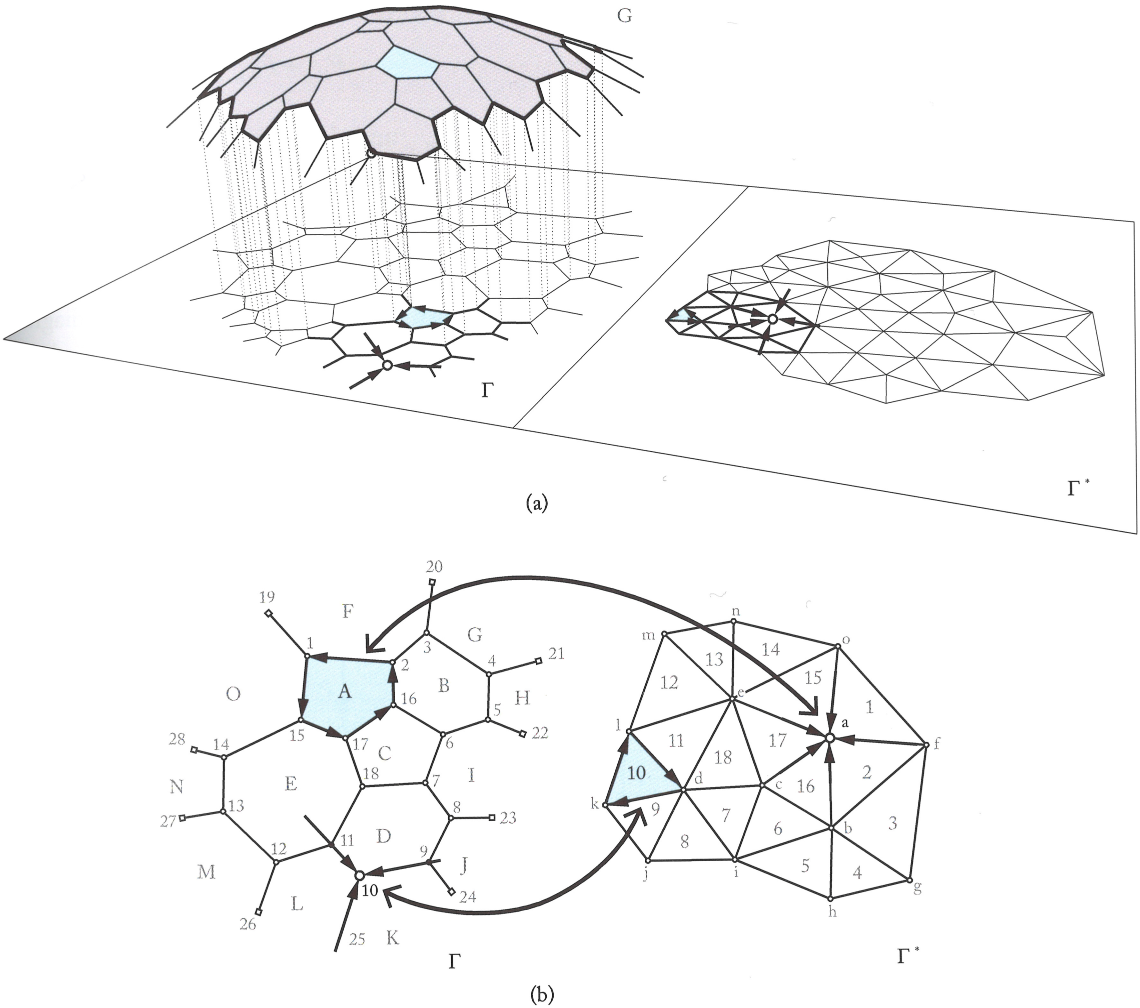


Figure 7.5 (a) Relationship between the thrust network **G**, its planar projection, the form diagram Γ and the reciprocal force diagram Γ* and (b) the reciprocal relation between Γ and Γ* using Bow's notation to label corresponding elements

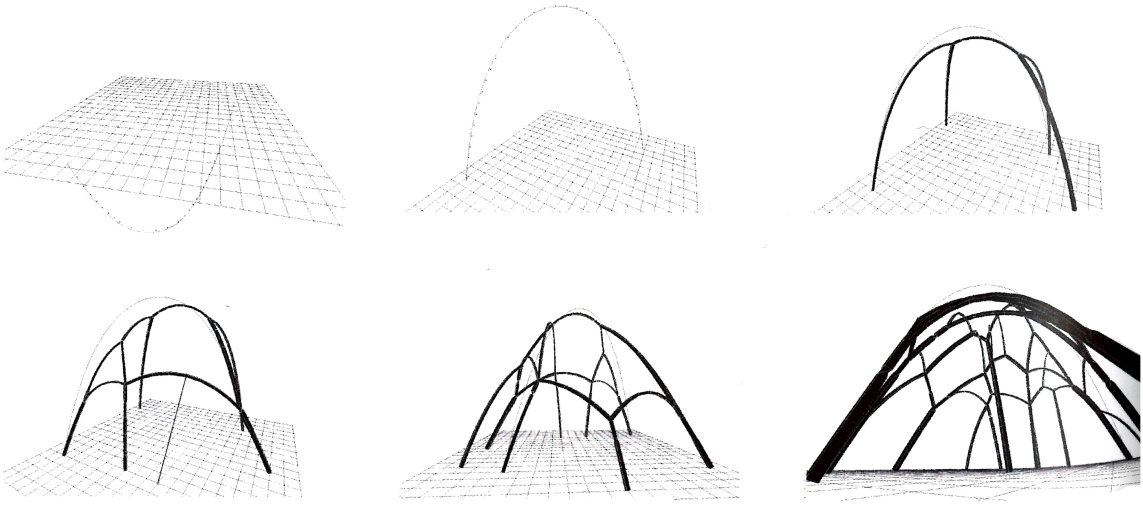
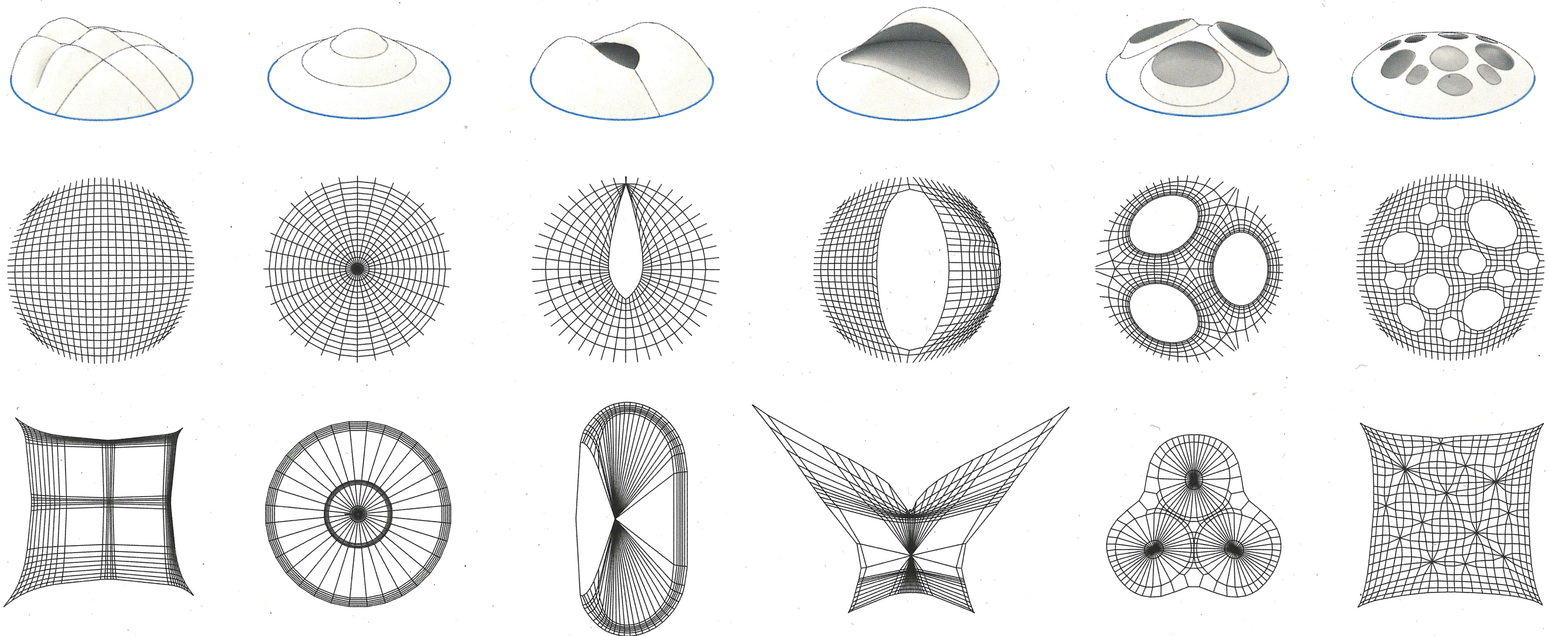
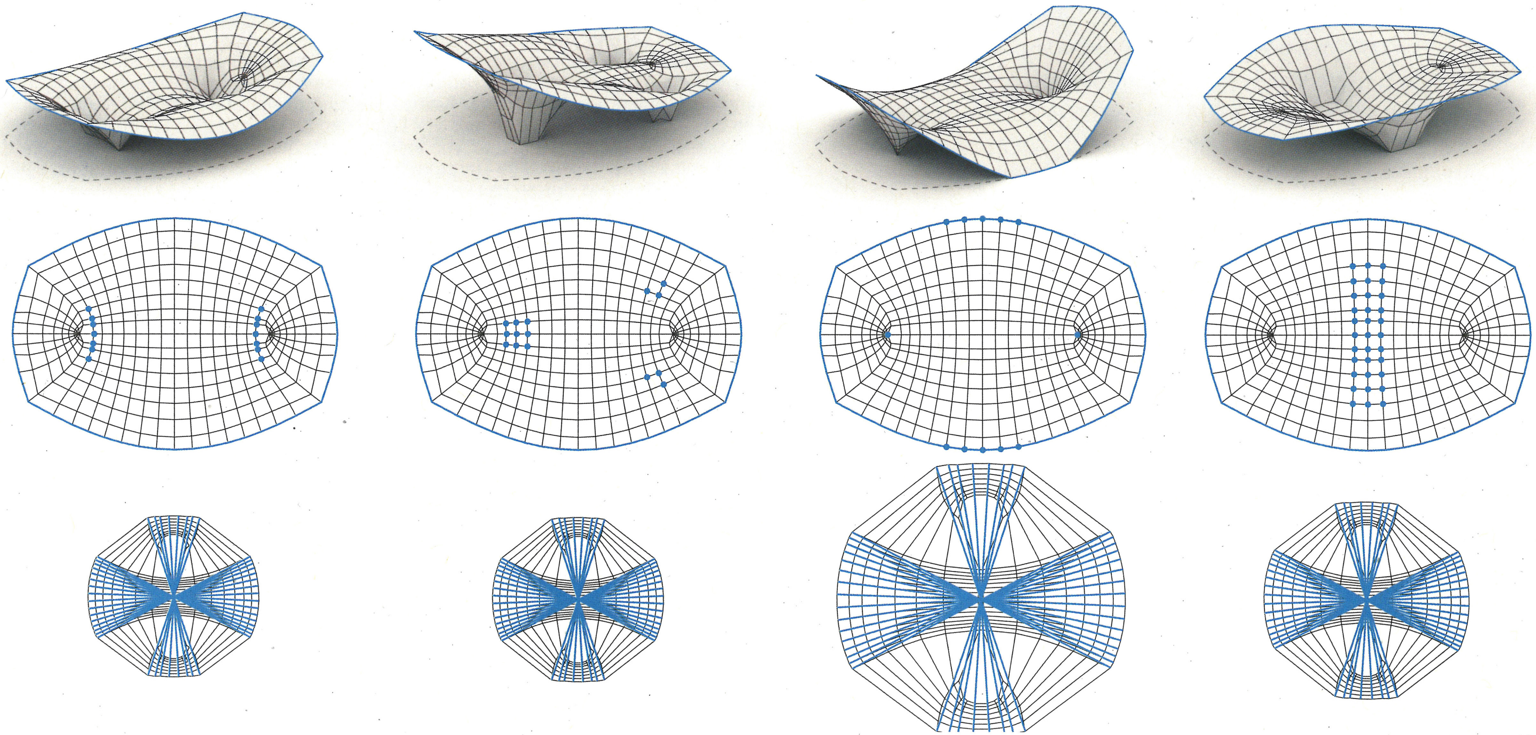


Figure 11.7 A topology created iteratively by manually adding more and more chain segments to an initial single arc



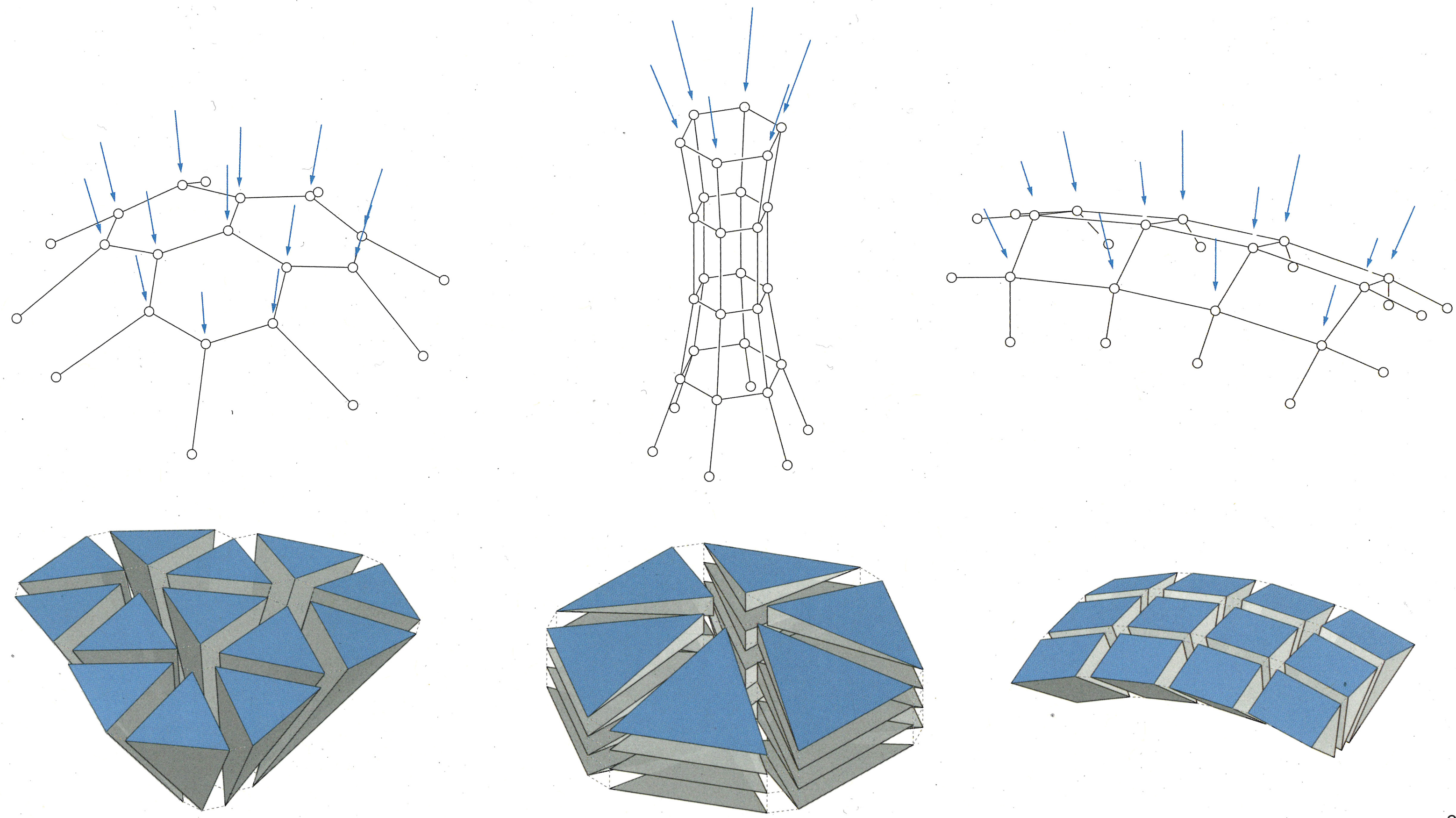
4

(4) Six different compression networks/surfaces for a given circular boundary condition, (marked in blue) for self-weight loading. The figure shows the compression surface on the top, the form diagram representing the layout of the forces in plan in the middle, and the force diagram representing the distribution of horizontal forces in the system at the bottom. | Sechs verschiedene druckbeanspruchte Schalenformen für eine gegebene kreisförmige Randbedingung (blau hervorgehoben). Die Abbildung zeigt die Schalenoberfläche oben, den Lageplan mit der Anordnung der Kräfte im Grundriss (Mitte) und den Kräfteplan mit der Verteilung der Horizontalkräfte im System unten, Zurich | Zürich, 2014 © Block Research Group, ETH Zurich



5

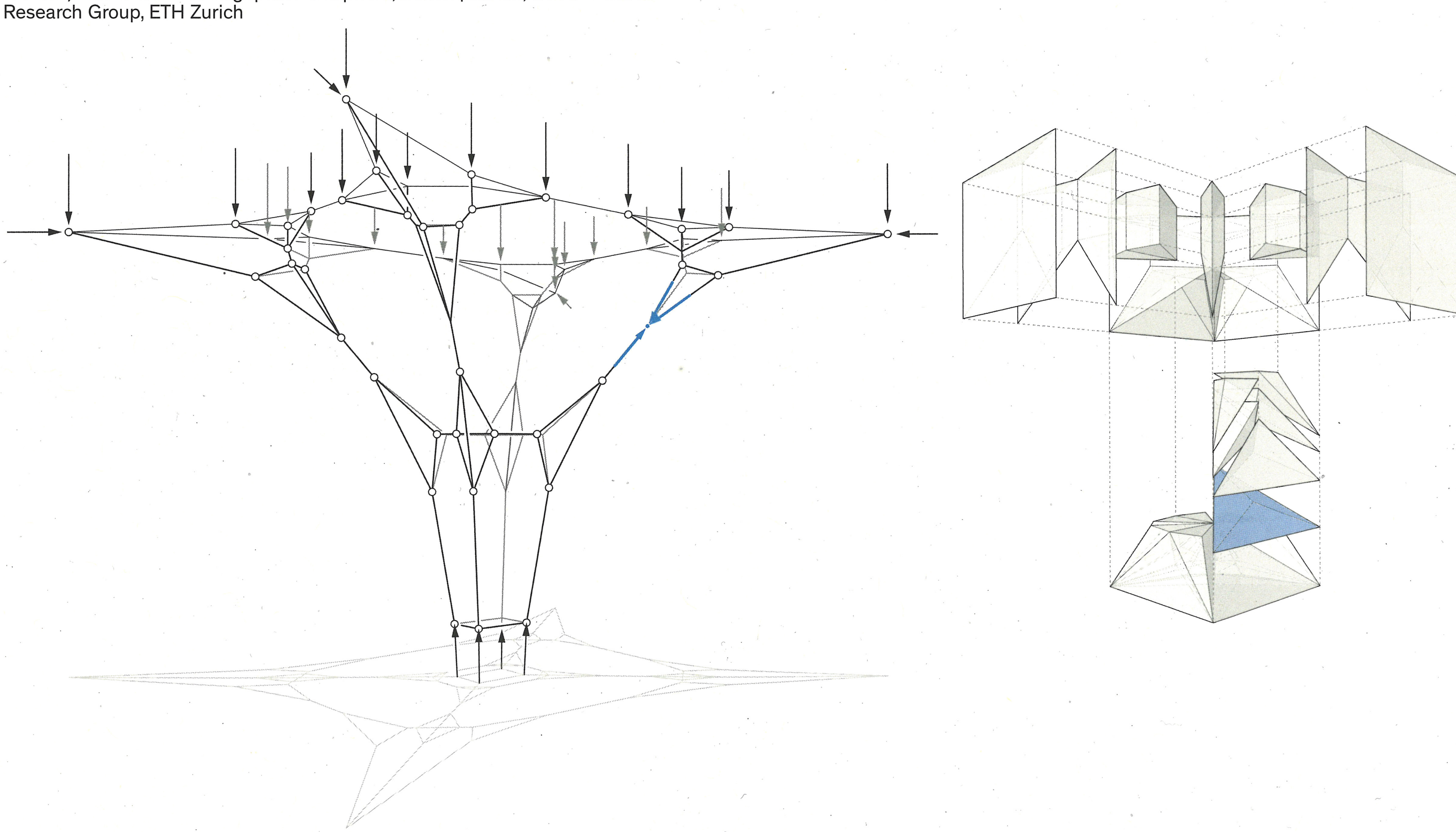
(5) Design exploration of various funicular funnel shells which are defined as compression-only shells with a tension ring (highlighted in blue) along their boundaries. By changing the definition of free or fixed support nodes (marked with blue dots) and the overall magnitude of the horizontal thrusts in each structure, represented by the overall scale of the force diagram, very different equilibrium solutions, all with the same horizontal projection, are obtained. | Entwurfsfindung verschiedener rein druckbeanspruchter trichterförmiger Druckschalen mit einem Zugring am Rand (blau hervorgehoben). Durch Änderung der Definition freier und fester Auflagerknoten (letztere durch blaue Punkte hervorgehoben) und der Gesamtgröße der Horizontalkräfte jedes Tragwerks, dargestellt durch die Ausdehnung des jeweiligen Kräfteplans, entstehen ganz unterschiedliche Gleichgewichtslösungen, die alle dieselbe Horizontalprojektion im Lageplan aufweisen, Zurich | Zürich, 2013 © Block Research Group, ETH Zurich



6

(6) By aggregating polyhedrons to form a 3D force diagram (bottom), one can quickly design expressive, spatial, funicular networks (top). Each polyhedron represents the equilibrium of forces at a node in the network, with the areas of its faces proportional to the magnitude of forces in the corresponding (perpendicular) elements in the form diagram. | Durch die Aggregation von Polyedern zu einem 3D-Kräfteplan (unten) lassen sich rasch ausdrucksstarke räumliche Seilnetze entwickeln (oben). Jedes Polyeder repräsentiert das Kräftegleichgewicht an einem Knoten des Netzwerks, wobei sein Flächeninhalt der Größe der Kräfte in den entsprechenden (senkrechten) Elementen des Lageplans entspricht, Zurich | Zürich, 2015 © Block Research Group, ETH Zurich

(7) Combining aggregation of polyhedral cells and internal subdivision, very spatial compression or tension-only support structures can be discovered. The force equilibrium of the node highlighted in blue is represented by the closed polyhedral cell. | Durch Verbindung von Polyederaggregation und innere Unterteilung lassen sich räumliche rein druck- oder rein zugbeanspruchte Tragwerke entwerfen. Das Kräftegleichgewicht des blau hervorgehobenen Knotens wird durch die geschlossene Polyederzelle repräsentiert, Zurich | Zürich, 2015 © Block Research Group, ETH Zurich



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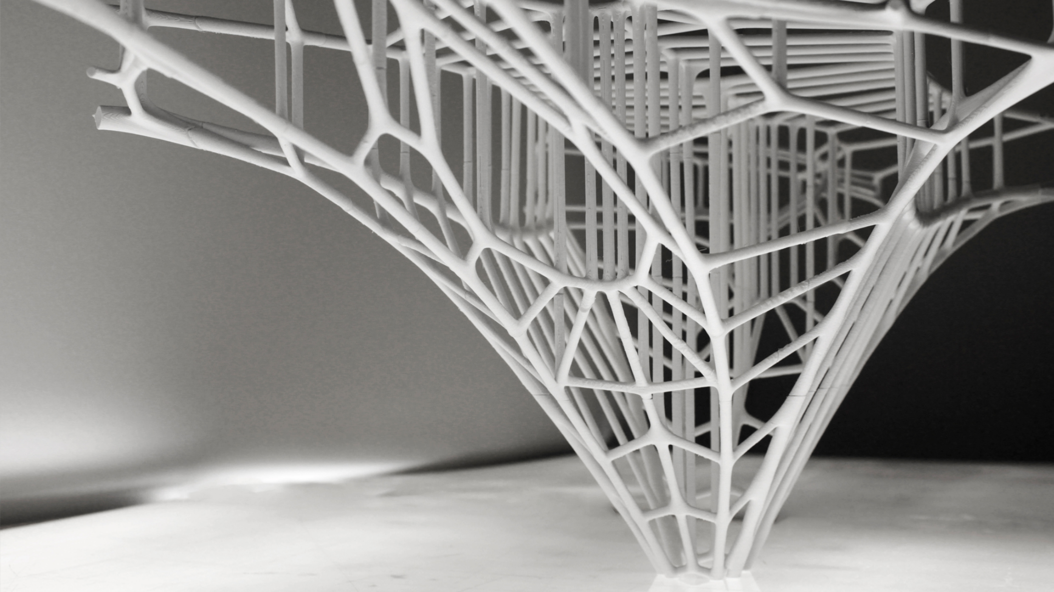
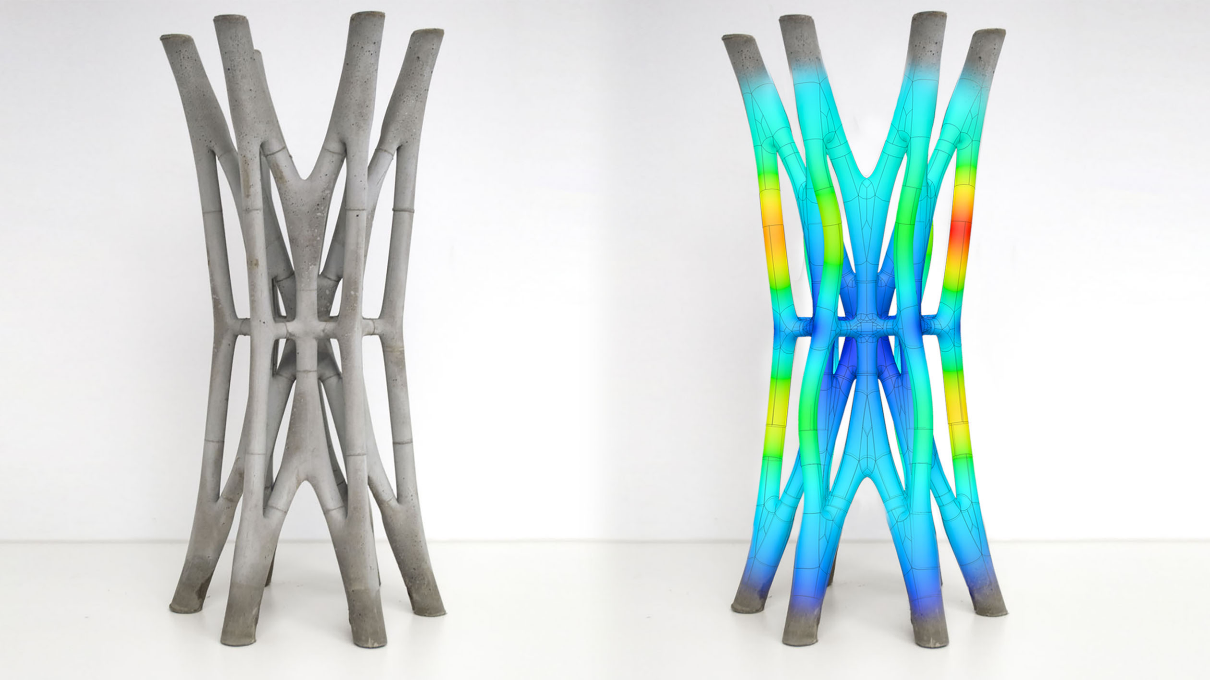
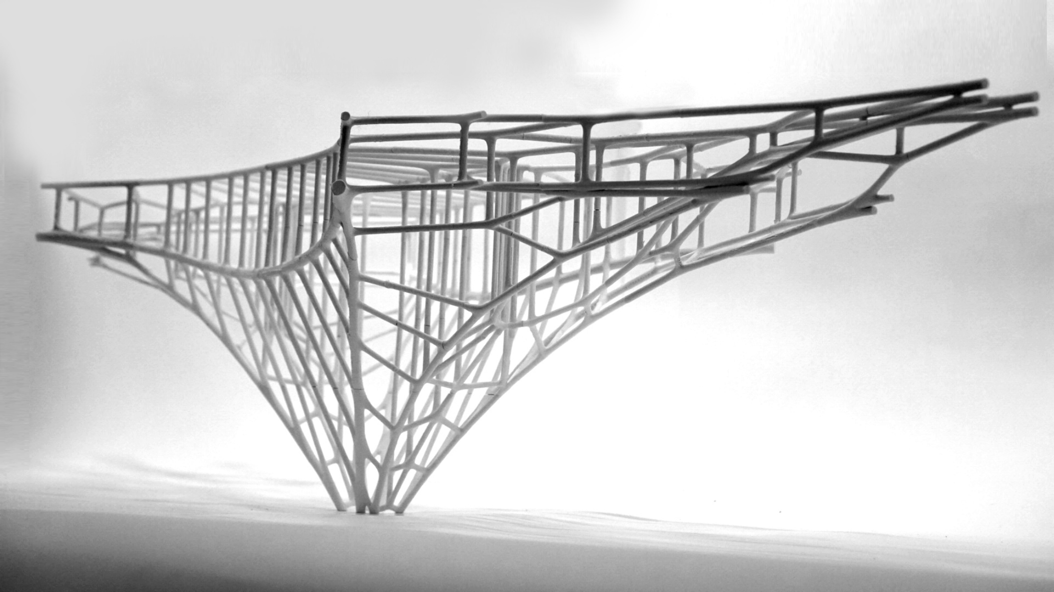
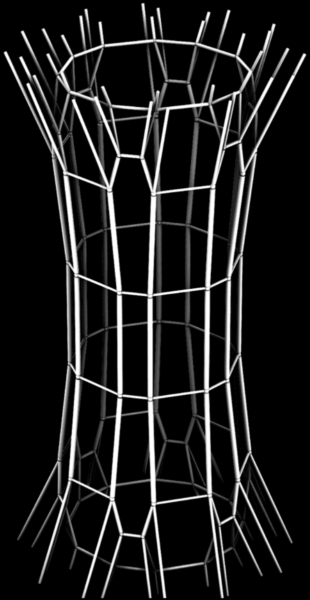
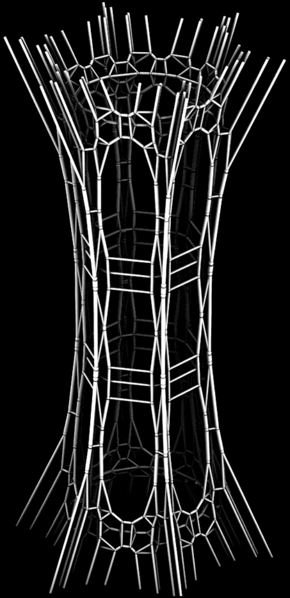




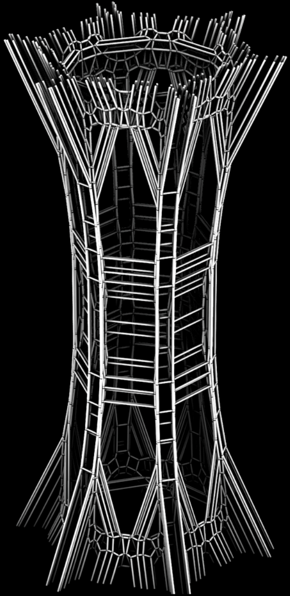




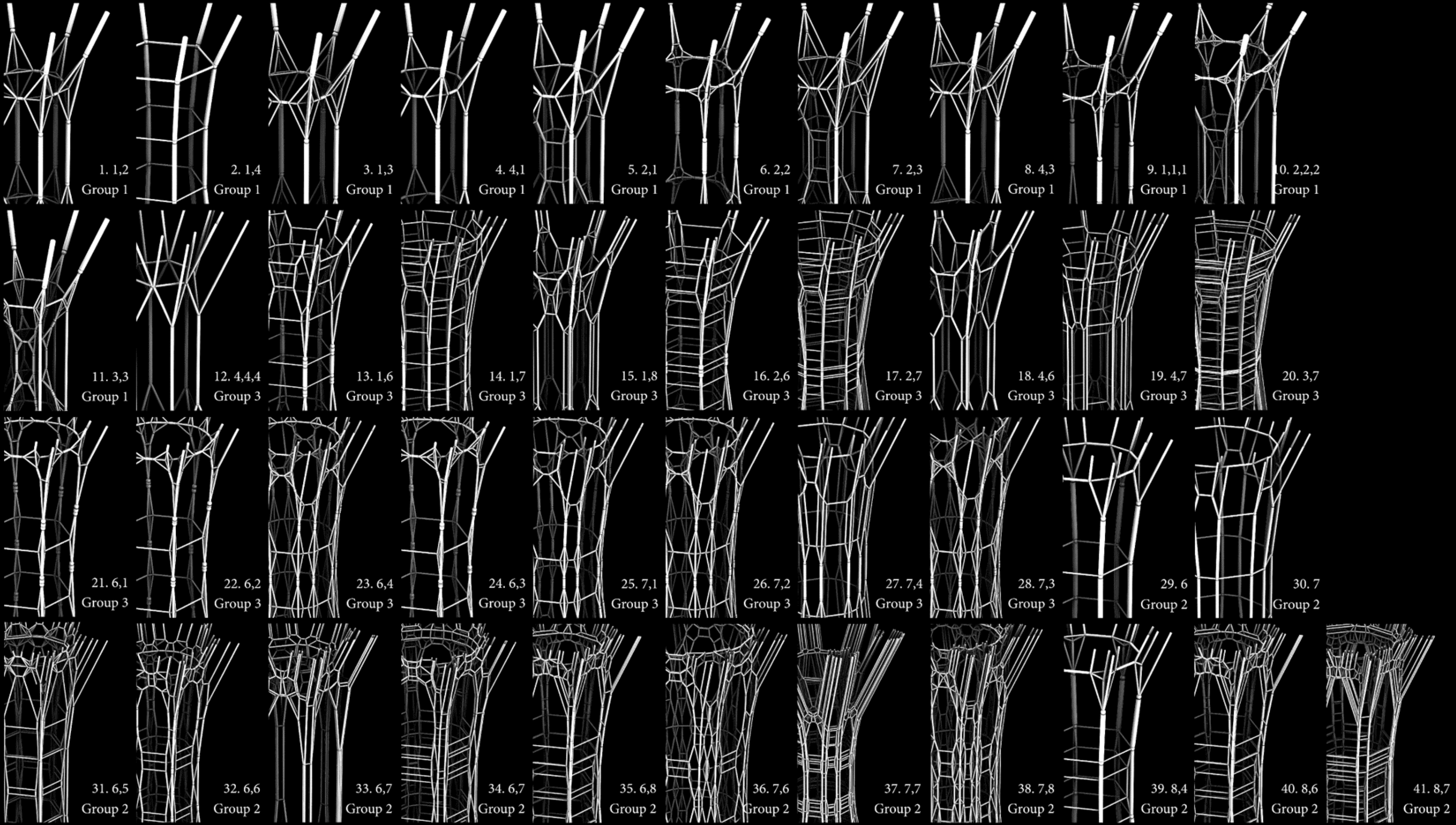
Specimen: 30
Subdivisions: 8

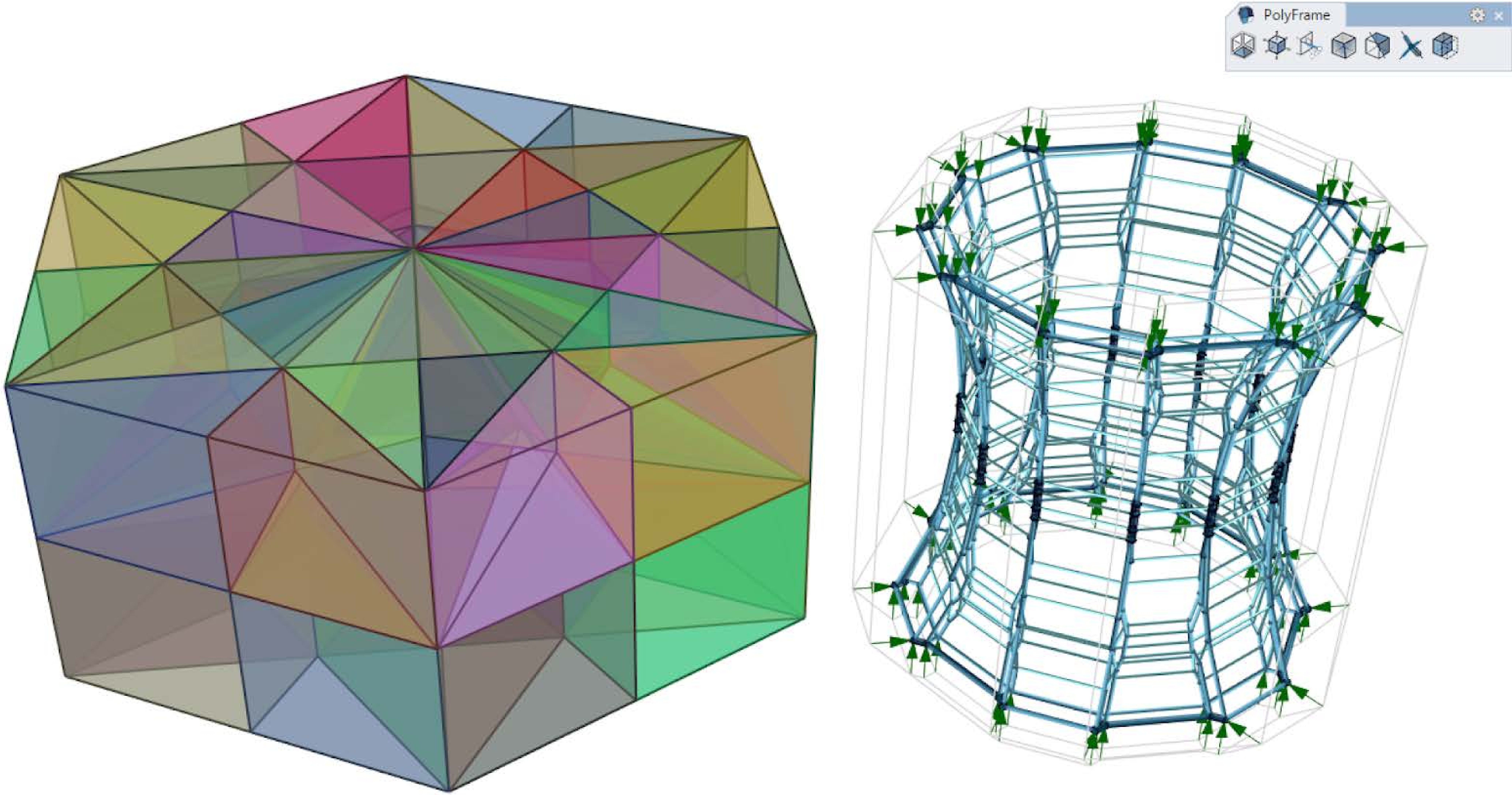


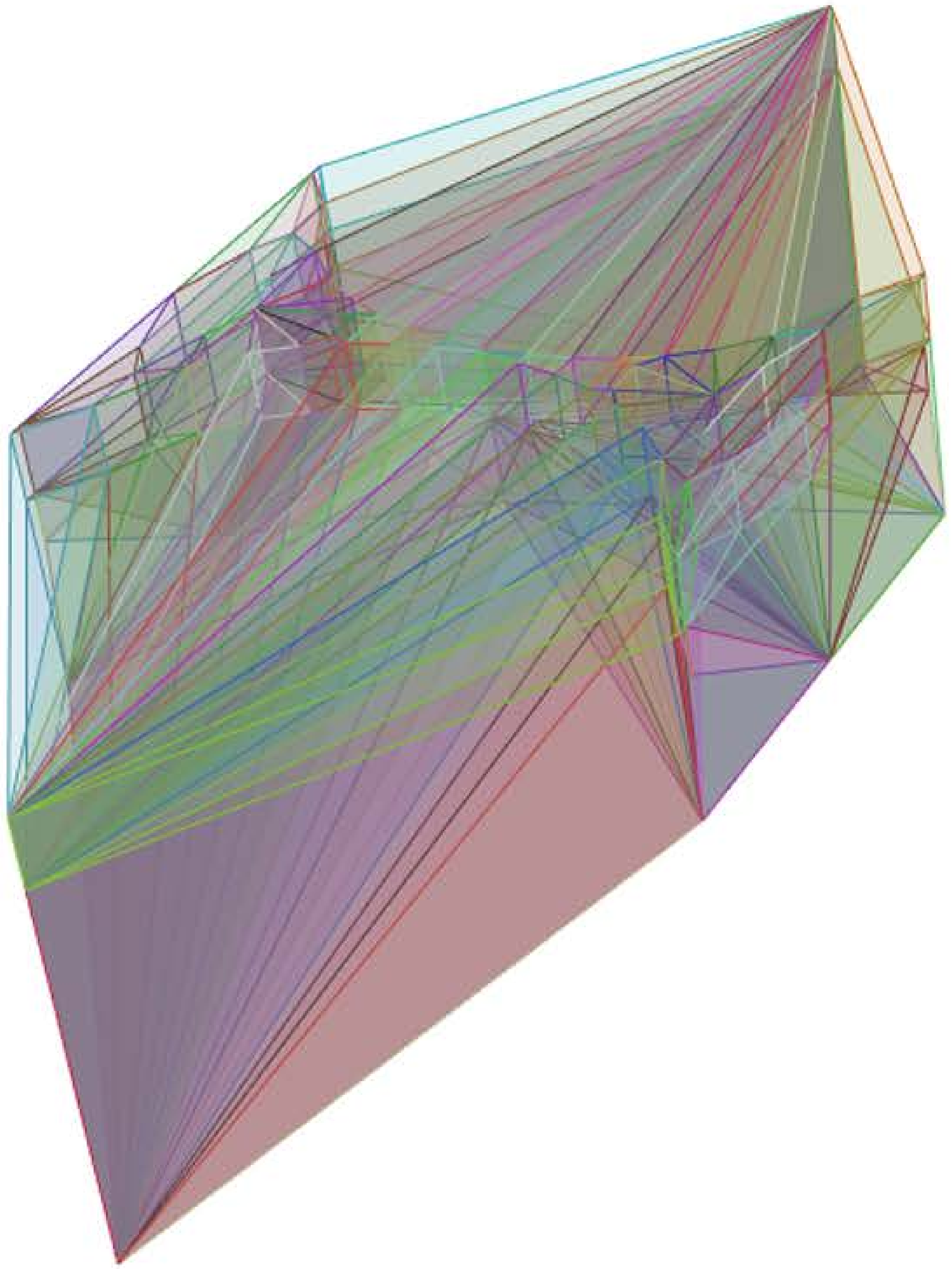
Specimen: 32
Subdivisions: 7,7

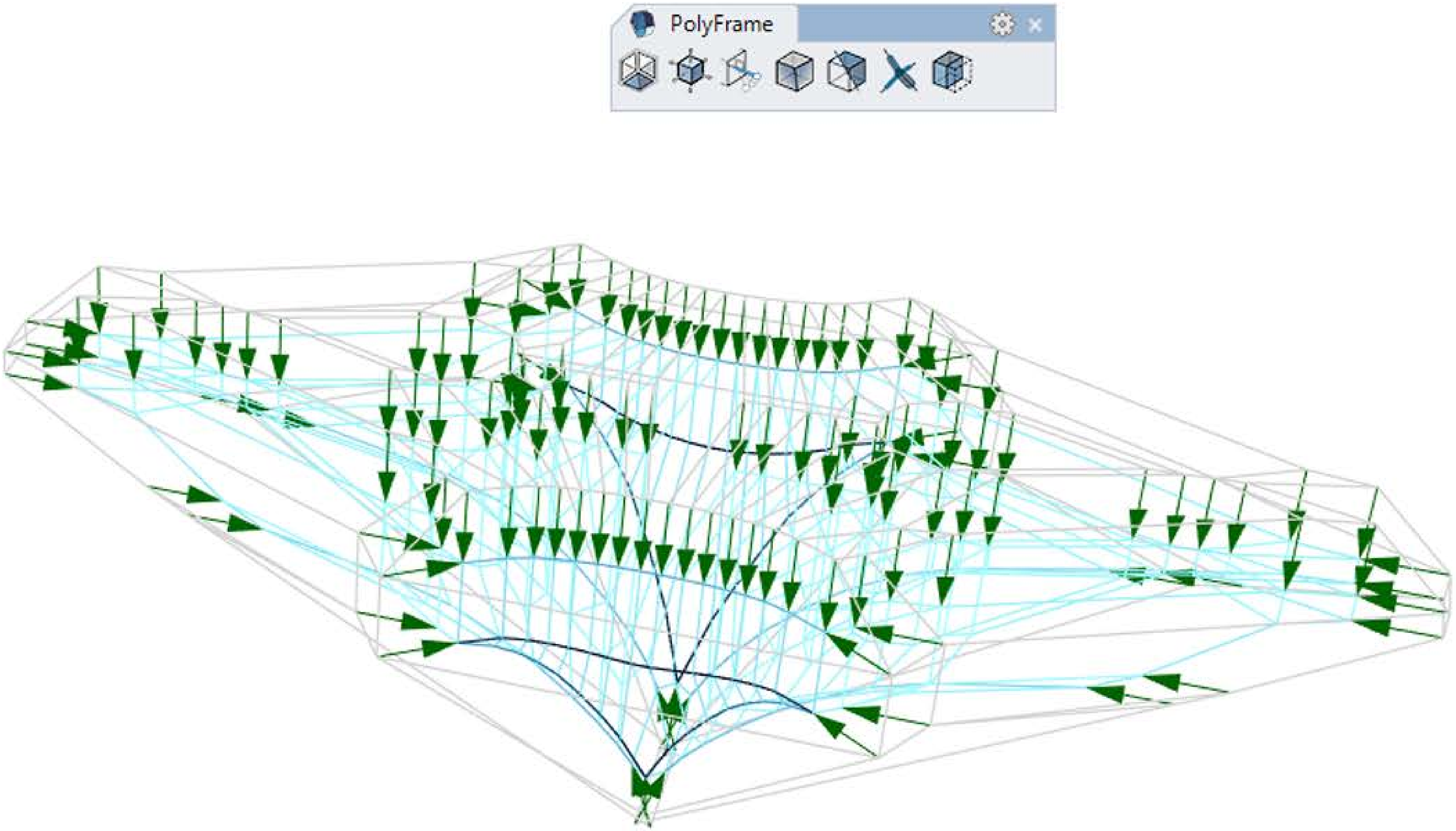


Specimen: 41
Subdivisions: 9,8


1. 1,2
Group 1
2. 1,4
Group 1
3. 1,3
Group 1
4. 4,1
Group 1
5. 2,1
Group 1
6. 2,2
Group 1
7. 2,3
Group 1
8. 4,3
Group 1
9. 1,1,1
Group 1
10. 2,2,2
Group 1
11. 3,3
Group 1
12. 4,4,4
Group 3
13. 1,6
Group 3
14. 1,7
Group 3
15. 1,8
Group 3
16. 2,6
Group 3
17. 2,7
Group 3
18. 4,6
Group 3
19. 4,7
Group 3
20. 3,7
Group 3
21. 6,1
Group 3
22. 6,2
Group 3
23. 6,4
Group 3
24. 6,3
Group 3
25. 7,1
Group 3
26. 7,2
Group 3
27. 7,4
Group 3
28. 7,3
Group 3
29. 6
Group 2
30. 7
Group 2
31. 6,5
Group 2
32. 6,6
Group 2
33. 6,7
Group 2
34. 6,7
Group 2
35. 6,8
Group 2
36. 7,6
Group 2
37. 7,7
Group 2
38. 7,8
Group 2
39. 8,4
Group 2
40. 8,6
Group 2
41. 8,7
Group 2

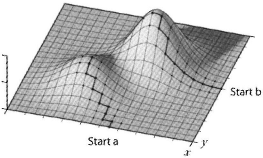

PolyFrame



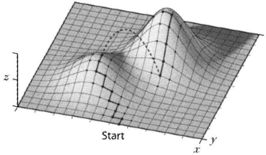

PolyFrame

Hill climbing

Hill climbing



Simulated annealing



Hill climbing is a generic name for a technique in computer science that searches locally and progressively for better solutions to a function until it can find no further improvement, at which point it stops. There is no guarantee that the programme will find the optimum solution, and it is susceptible to getting stuck at a local maximum. Hill climbing has been used in architecture to search for 'best fit' geometrical and structural solutions in a constrained design context.

Function	$z = e^{-(x^2 + y^2)} + 2e^{-[(x-1.7)^2 + (y-1.7)^2]}$
Point visited	●
Point considered	•
Path	———
Transition	---------

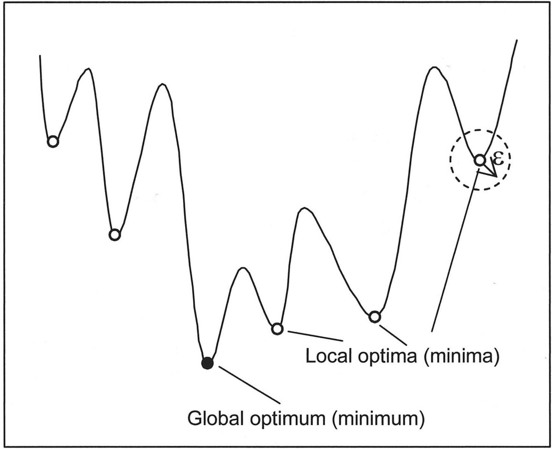


Figure 3.1: Illustration of global and local minima of an arbitrary function. Dark circle: global minimum; White circles: local minima.

```
procedure [x] = hill-climbing(max_it,g)
  initialize x
  eval(x)
  t ← 1
  while t < max_it & x != g & no_improvement do,
      x' ← perturb(x)
      eval(x')
      if eval(x') is better than eval(x),
            then x ← x'
      end if
      t ← t + 1
  end while
end procedure
```

Algorithm 3.1: A standard (simple) hill-climbing procedure.

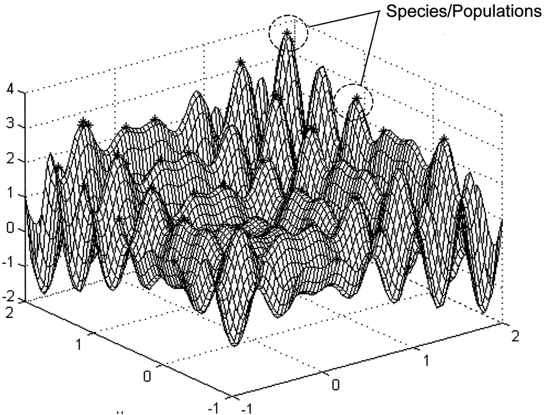


Figure 3.12: An example of an adaptive landscape. The topographic map (landscape or surface) corresponds to the different levels of adaptation of the populations (points in the landscape) to the environment. The populations or individuals at each peak are assumed to be reproductively isolated, i.e., they only breed with individuals in the same peak, thus forming species inhabiting distinct niches.

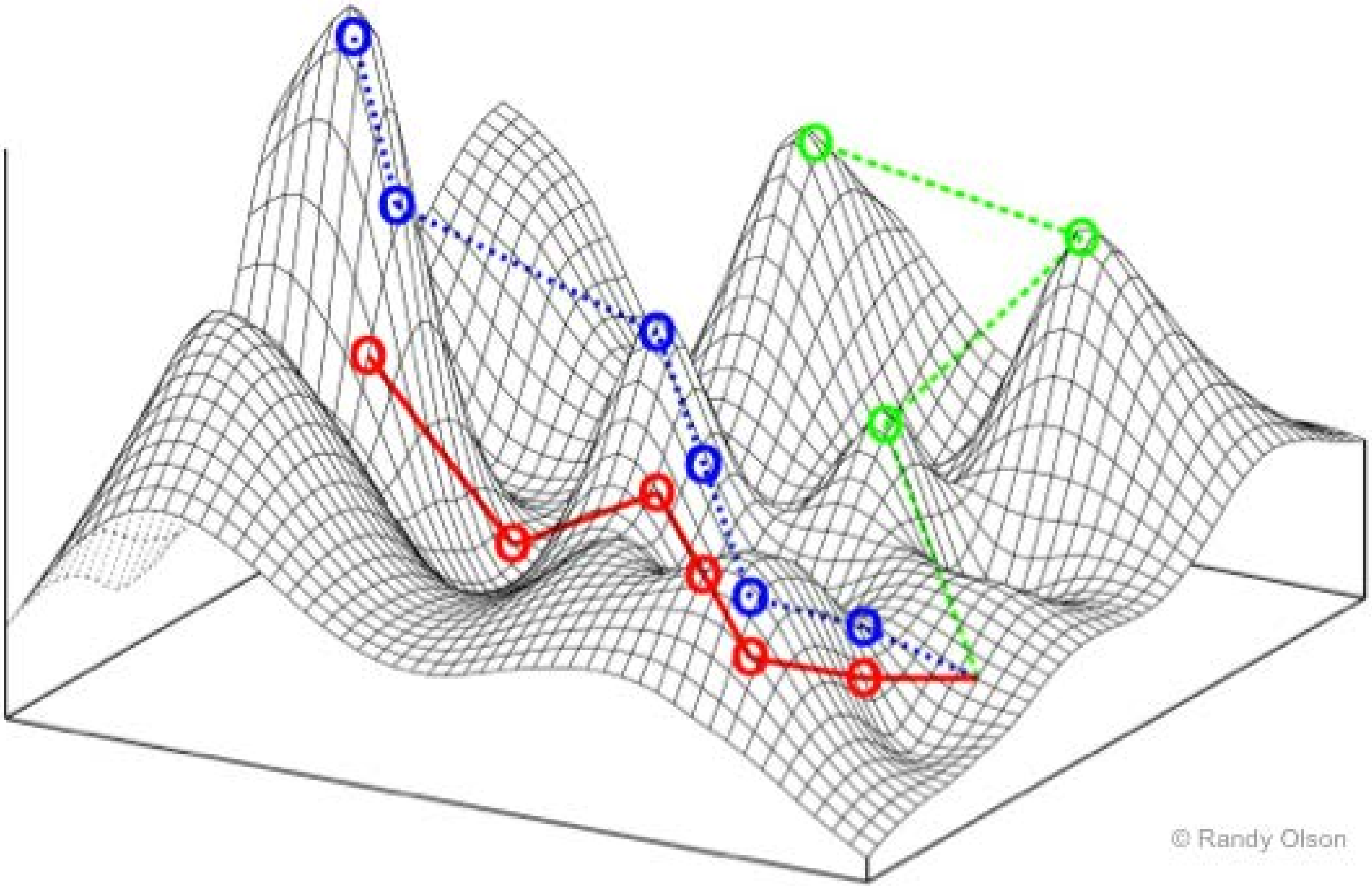
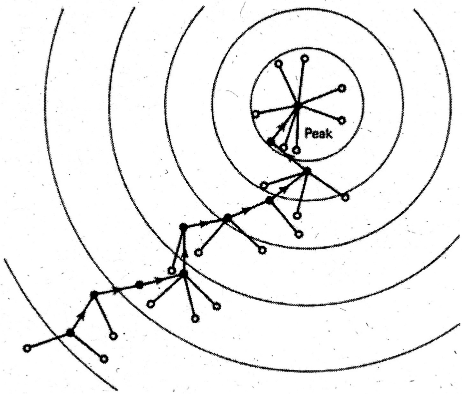
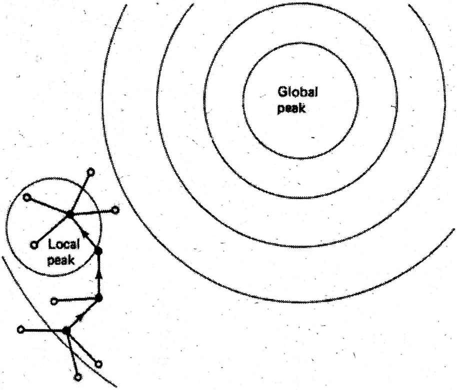

© Randy Olson

Figure 13.12
A simple improvement procedure for finding the peak of a hill. (a) Typical path generated by a simple improvement procedure for finding a peak. (b) Where more than one peak exists in the neighborhood the procedure may only find a local peak.



(a)



(b)

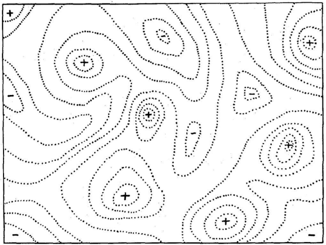


FIGURE 2.—Diagrammatic representation of the field of gene combinations in two dimensions instead of many thousands. Dotted lines represent contours with respect to adaptiveness.

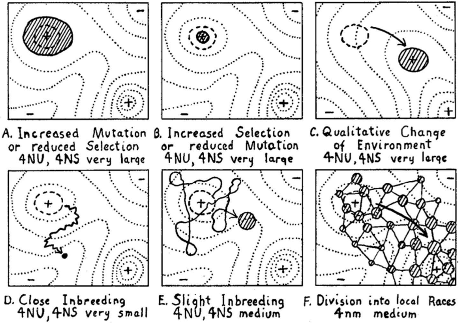
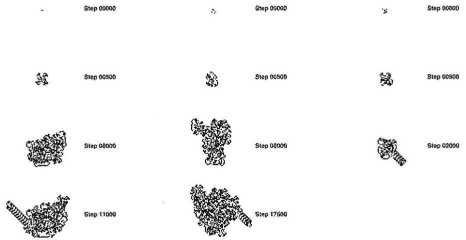


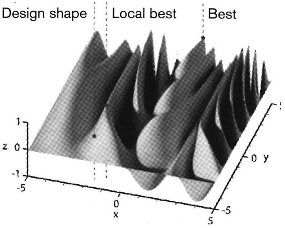
FIGURE 4.—Field of gene combinations occupied by a population within the general field of possible combinations. Type of history under specified conditions indicated by relation to initial field (heavy broken contour) and arrow.

Emergence

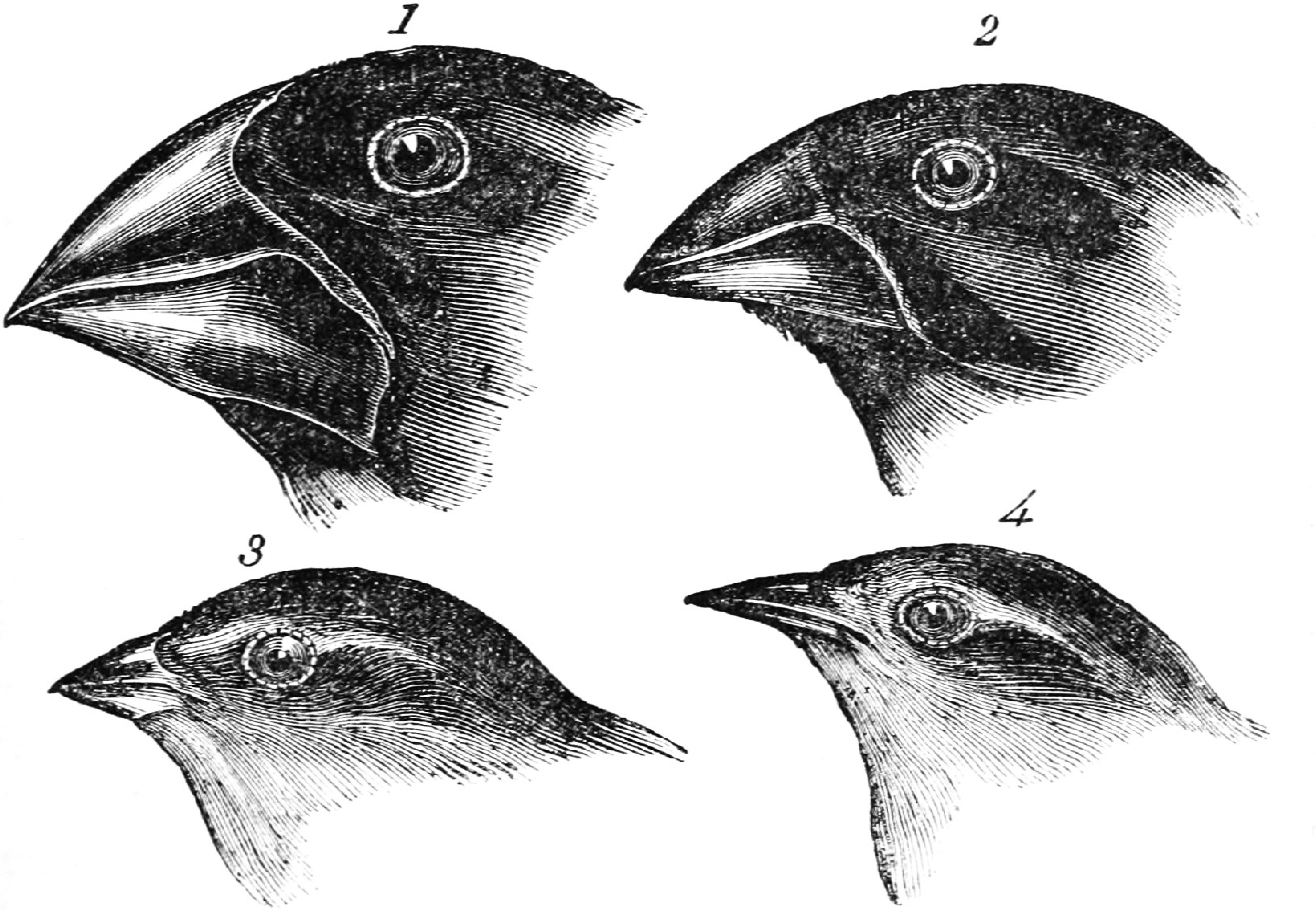


In mathematics, emergent properties are those that are global, topological properties of the whole, rather than the properties of the component parts. In architecture, emergence is thought of similarly, though less rigorously, as spontaneous order appearing within a system that cannot necessarily be inferred or predicted from the simple components of the system and their basic relations, but has resulted from their interaction. Contrast this with top–down ordering. In nature, the ant colony is often cited as the archetypal example of emergent behaviour and form. The queen does not give direct orders. Instead, each ant reacts individually and spontaneously to chemical scents, in turn leaving scents for the other ants. This is effectively a recursive behaviour that results in orderly patterns of movement, construction, searching and disposal at a macro-level. It results in the recognizable typology of the termite mound, and even solves such geometrical problems as finding the site furthest from all the entry points to the nest or search zones of constant radius from the colony.

Evolutionary shape optimizer



Evolutionary shape design by means of sensitivity analysis is the exercise of coming to understand how local and more global shape changes affect the mechanical performance of the structure in terms of its efficiency and low-strain energy. The strain energy is generally minimized when most of the loads are transmitted axially in the structural members, and there is very little bending. A global minimum may represent the most structurally efficient shape, but other local minima may represent very good solutions that are much closer to the design shape and to meeting all the other design criteria. Sensitivity analysis is the study of how variation (uncertainty) in the output of a mathematical model can be apportioned, qualitatively or quantitatively, to different sources in the input of a model. The aim is to identify the relative weighting of sources of uncertainty. This understanding of the response to changes in its inputs is often obscured in mathematical models, but it is important in making correct and meaningful use of the model.



1. Geospiza magnirostris.
2. Geospiza fortis.
3. Geospiza parvula.
4. Certhidea olivasea.

Box 1 Darwin's Five Major Theories of Evolution

1. The nonconstancy of species (the basic theory of evolution).
2. The descent of all organisms from common ancestors (branching evolution).
3. The gradualness of evolution (no saltations, no discontinuities).
4. The multiplication of species (the origin of diversity).
5. Natural selection

Box 2 Rejection of Some of Darwin's Theories by Early Evolutionists

The following table shows the composition of the evolutionary theories of various evolutionists. All of these authors accepted a fifth theory, that of evolution as opposed to a constant, unchanging world. They differed in accepting or rejecting some of Darwin's four other evolutionary theories.

	Common Descent	*Gradualness*	*Populational Speciation*	*Natural Selection*
Lamarck	No	Yes	No	No
Darwin	Yes	Yes	Yes	Yes
Haeckel	Yes	Yes	?	In part
Neo-Lamarckians	Yes	Yes	Yes	No
TH Huxley	Yes	No	No	No
de Vries	Yes	No	No	No
TH Morgan	Yes	No	No	Unimportant

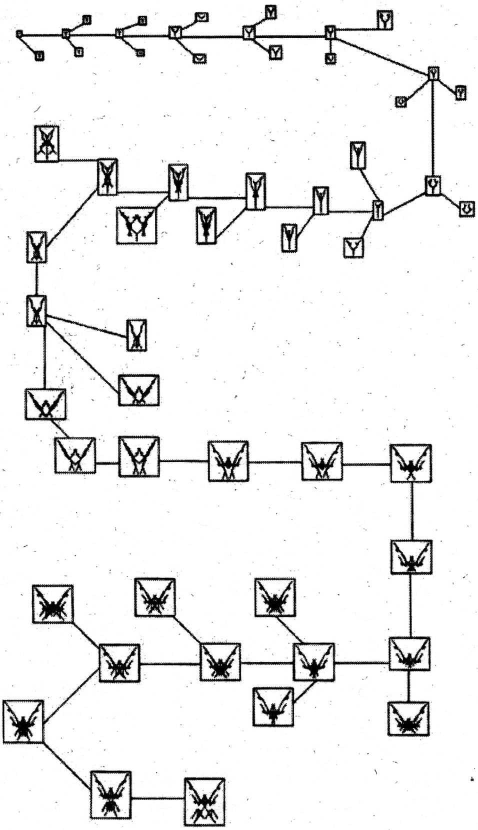
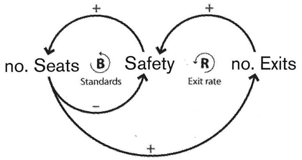
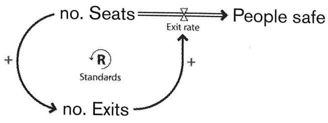


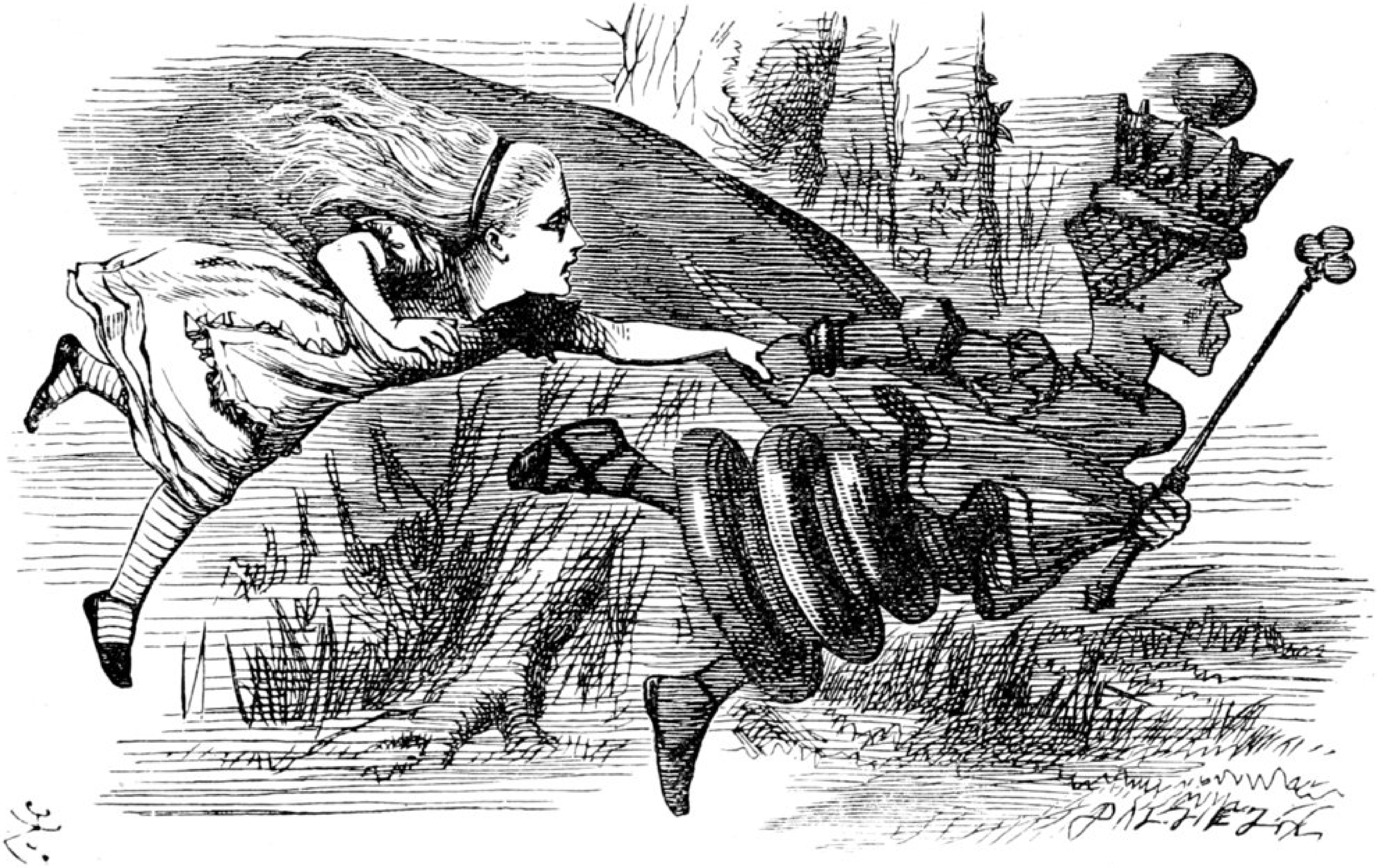
Figure 6.2: Starting from one Biomorph (represented by a dot) Dawkins evolves an insect-like individual after only 29 generations.

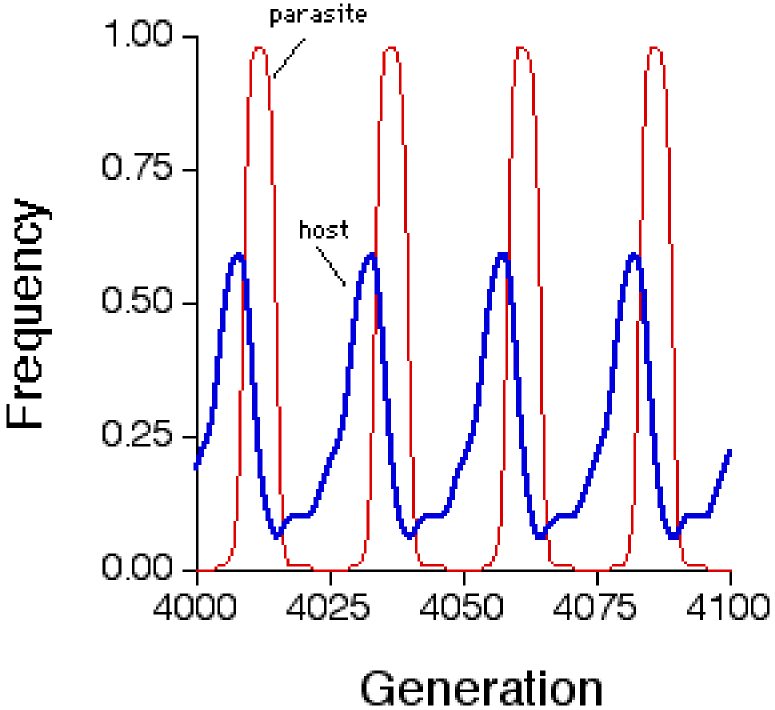
System dynamics



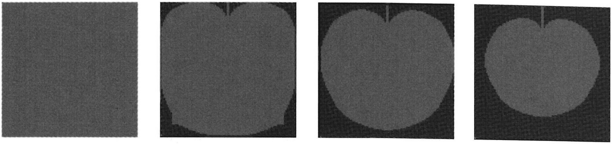


System dynamics is the study of the behaviour of complex systems over time. It takes into account that changes in the parts of system impact elsewhere, so a change in A may result in a change in B that in turn affects A. For instance, the cost estimate for a building exceeds the budget, so the programme is reconsidered and the building redesigned to reduce the overall volume. This results in a building with a higher cost per square metre, which in turn has implications for the budget. By building relational and simulation models, it is possible to observe the dynamics of the system when changes are made, to explore 'what if' scenarios. If the number of seats in a theatre are increased, how will this impact the number and position of fire exits, air handling, space needed front of house, etc? In architecture, such models that encompass multiple aspects of the building design, procurement and management are still in their infancy.

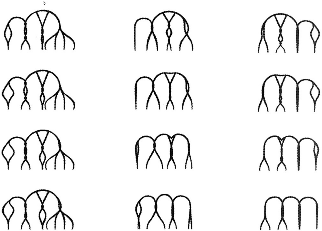



parasite
host
Frequency
1.00
0.75
0.50
0.25
0.00
4000
4025
4050
4075
4100
Generation

Evolutionary structural optimization



Evolutionary structural optimization was originally proposed in 1992 by Mike Xie and Grant Steven. It is a recursive iterative routine that uses finite-element analysis to discover the von Mises stress or strain energy in each element in a structure. A starting 'cube' of virtual finite elements is given some real material properties, say those of stone, steel or concrete, and some loads and constraints are applied: gravity, support points, etc. After analysis, the elements recording stress below a certain threshold, say the least stressed 1 per cent, are removed. The analysis and removal of the lowest stressed elements is then repeated on the residual form recursively many times over (50 to 100 in this example). This method will optimize a structural form to use the least material The software was developed by Xie and his researchers to evolve tension-only structures, such as steel cable structures or compression-only structures like masonry, and a combination of the two. They have also developed bidirectional ESO or BESO, whereby elements are both subtracted and added during the evolution of the form. This is poetically close to such processes observed in nature as bone growth.



Left Henri Labrouste, Ste.-Geneviève Library, Paris (1851). *Right* NOX, Columnar figures for the design of the Jalisco State Library, Guadalajara (2005).

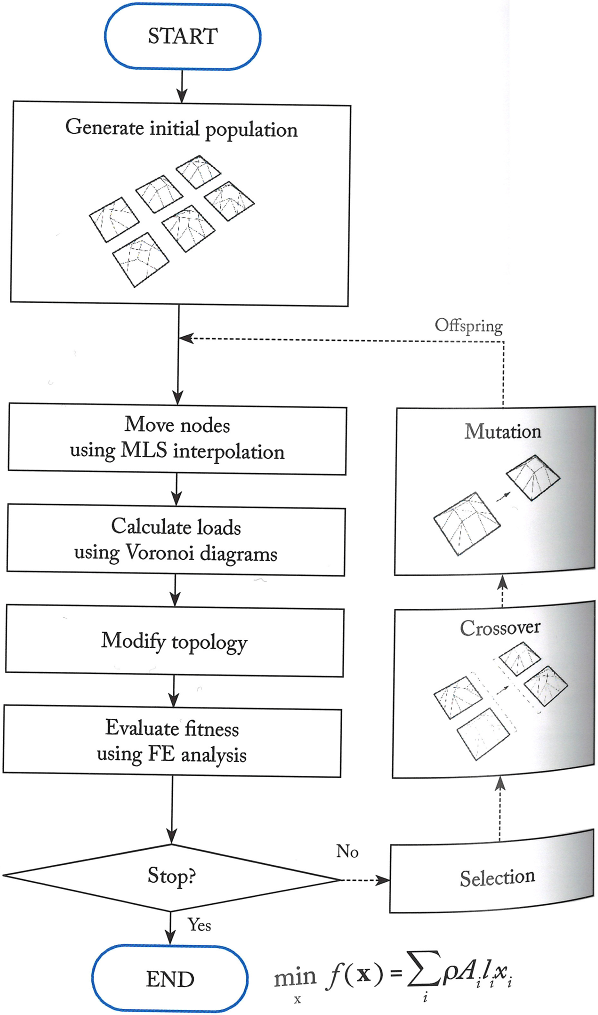
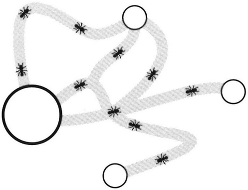
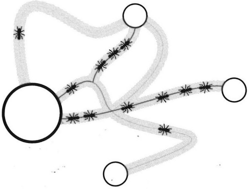


Figure 14.2 Genetic algorithm applied to gridshells

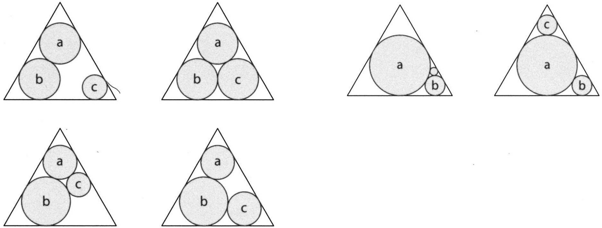
Multi-objective optimization





Architects are generalists. Architectural design is concerned with bringing things together and with synthesis. One area of design research that is very pertinent in this respect is multi-objective optimization, in which optimal values for two or more conflicting objectives are looked for (maximizing the penetration of sunlight into a building in the winter, and passively regulating the internal temperature in the summer, for example). The striking foraging patterns of ants, apart from being a top exemplar of geometrical and organizational emergence, also provide an empirical testing ground for the mathematics of multi-objective optimization. It seems that the ants have optimized the amount and combinations of types of food they can gather relative to the energy expended, despite the fact that different food categories require different foraging patterns.

Pareto optimization



A solution where no element of the solution can be significantly improved without negatively affecting the other elements (circles in triangles, for example). A solution can be considered optimal if none of the circles can grow without shrinking the others. Named after Vilfredo Pareto (1848–1923), an economist, sociologist and philosopher who was fascinated by the inequality of income distribution in the population, Pareto optimization is a measure of efficiency. The significance for architecture is that it is possible to identify an optimal range of solutions in the middle of the graph where all variables perform relatively well, but a slight shift will improve one at the expense of another. An example might be the trade-off between natural light and thermal performance as the percentage of external glazing is varied. An outcome of a game is Pareto optimal if no other outcome makes every player at least as well off and at least one player strictly better off. That is, a Pareto optimal outcome cannot be improved upon without hurting at least one player. A Nash equilibrium is often not Pareto optimal, implying that the players' payoffs can all be increased.

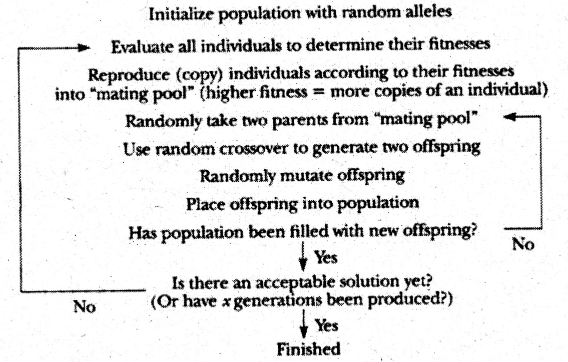
The Four Areas of Evolutionary Computation

Genetic algorithms

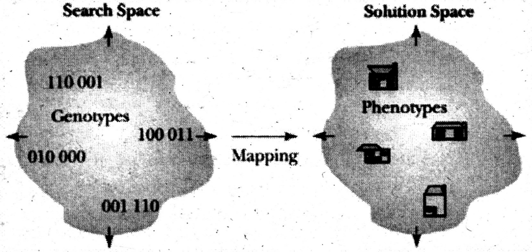
Evolutionary programming

Evolution strategies

Genetic programming



The simple genetic algorithm.



Mapping genotypes in the search space to phenotypes in the solution space.

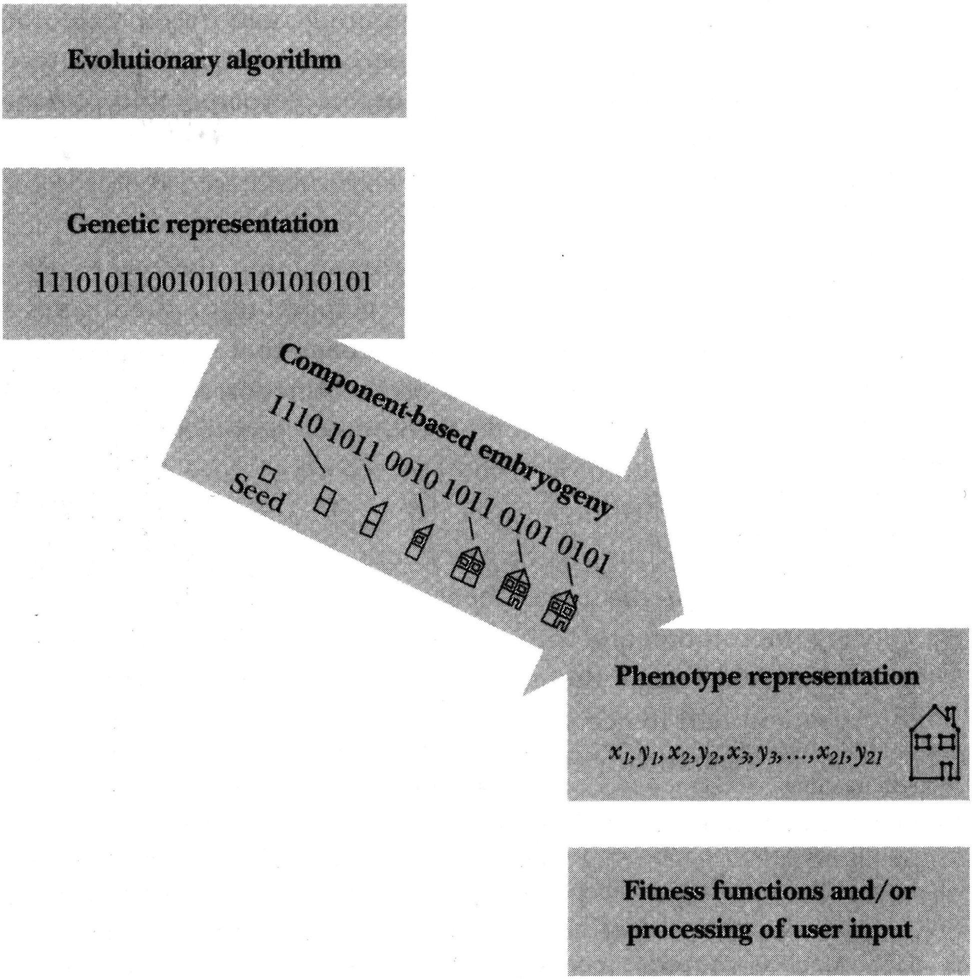


Figure 1. The five elements of the framework for creative evolutionary systems. Peter Bentley and David Corne. Image from original publication. Reprinted by permission of Elsevier Books. © Elsevier Books.

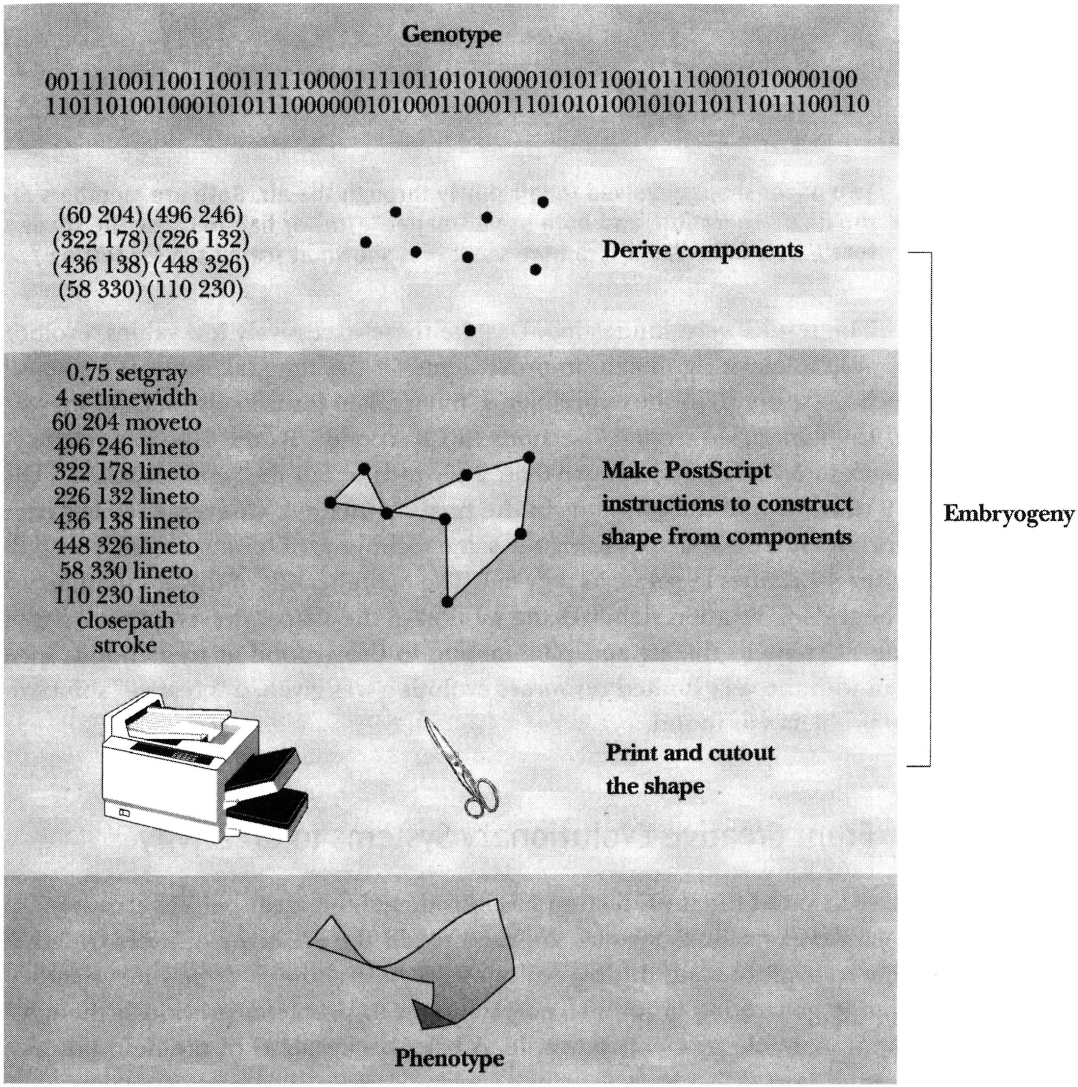
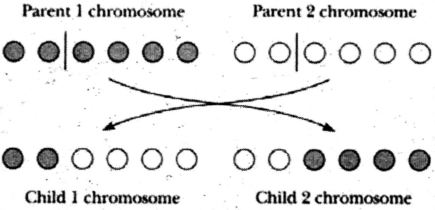
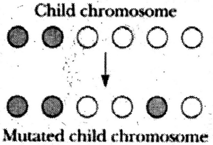


Figure 2. The paper fall application uses eight vertices as its components. These are extracted from the genotype and transformed into real paper shapes by the use of a 'connect the dots and fill the shape' embryogeny (and someone to print and cut out the shape). Peter Bentley and David Corne. Image from original publication. Reprinted by permission of Elsevier Books. © Elsevier Books.



The behavior of the crossover operator. The vertical line shows the position of the random crossover point.



The behavior of the mutation operator.

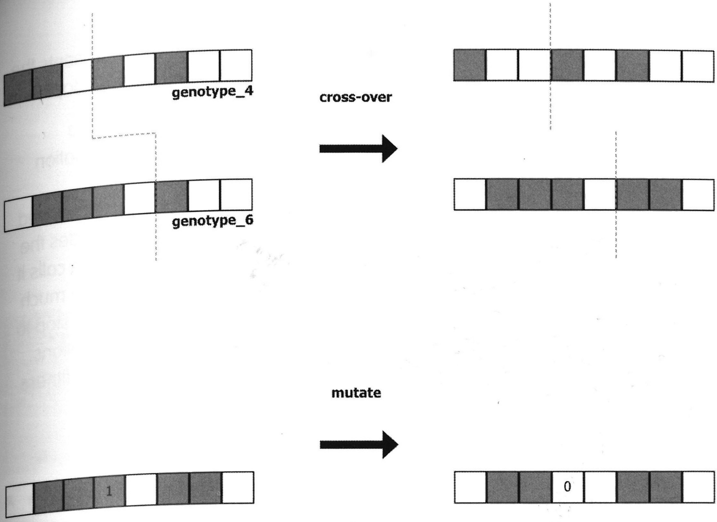


Fig 1 Genetics: the process of cross-over and mutation

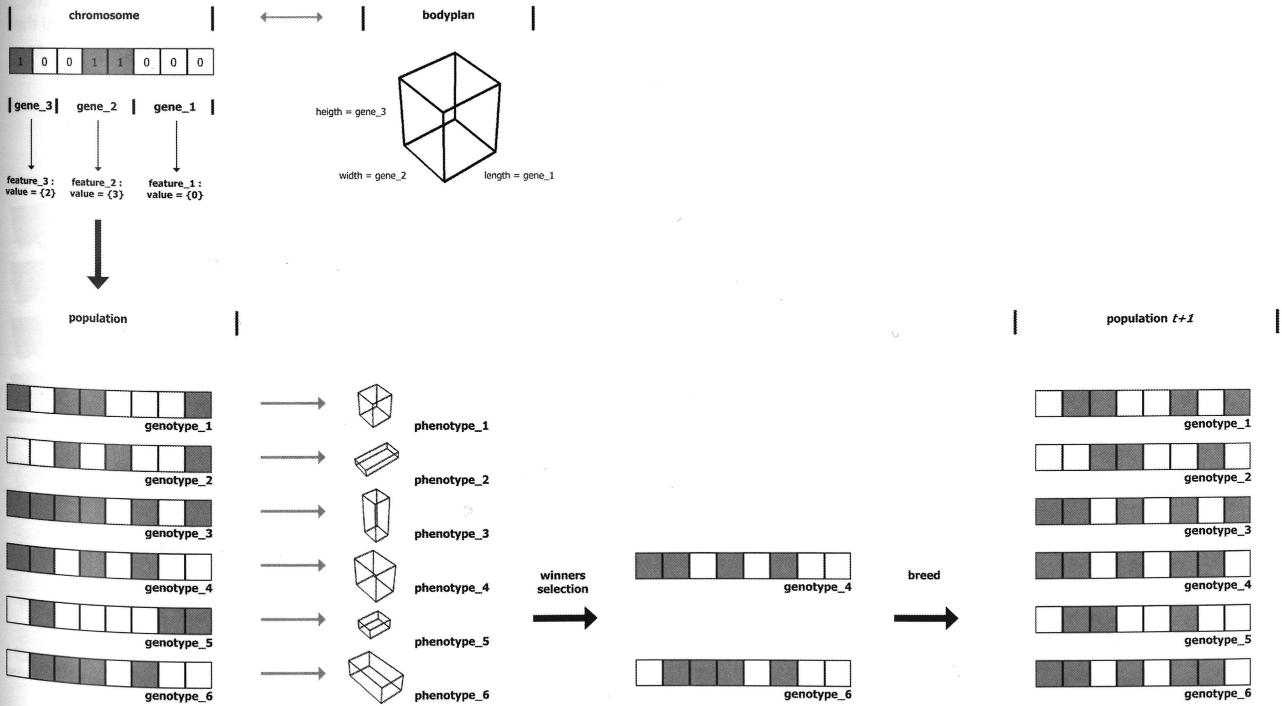
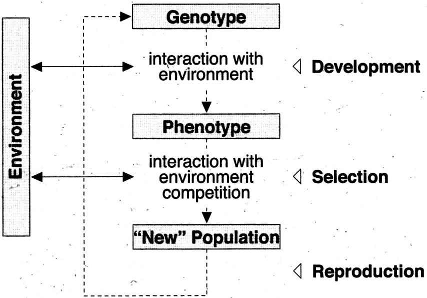


Fig 2 The embryology and development process

a.



b.

encoding	development	selection	reproduction
• binary	• no development (phenotype = genotype)	• "roulette wheel"	• mutation
• many-character	• development with and without interaction with the environment	• elitism	• crossover
• real-valued		• rank selection	
		• tournament	
		• truncation	
		• steady-state	

Figure 6.3: Overview of the process of evolution. (a) The main components. The genotype is translated into a phenotype through a process of development. The phenotypes compete with one another in their ecological niche, and the winners are selected (selection) to reproduce (reproduction), leading to new genotypes. (b) Evolutionary algorithms can be classified according to a number of dimensions: encoding scheme, nature of developmental process, selection method, and reproduction (genetic operators). Mitchell (1997, pp. 166-175) discusses the pros and cons of these various methods in detail.

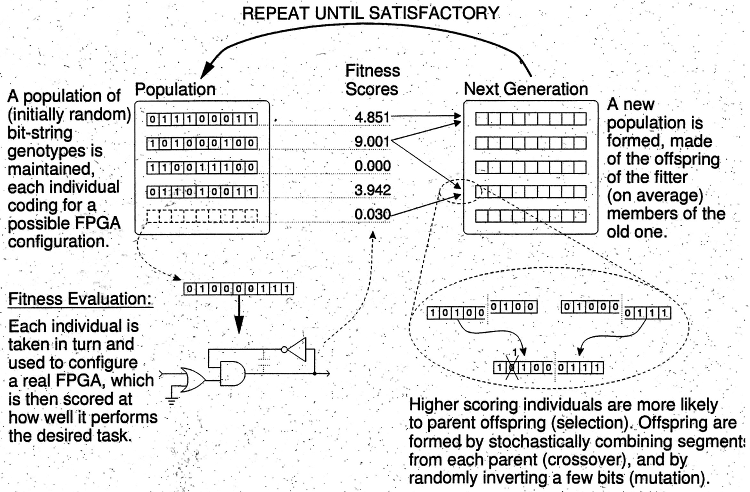
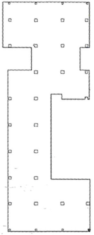
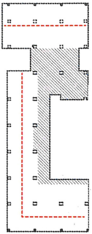


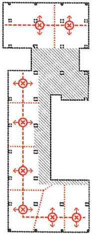
Figure 6.14: Evolving an FPGA configuration using a simple genetic algorithm.



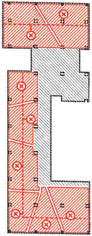
(0) Initial conditions.



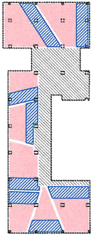
(1) Definition of fixed / non-generative zones and central spine for organizing neighborhoods.



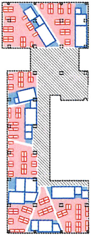
(2) A variable number of neighborhoods are seeded along spine, and given a parameterized range of motion.



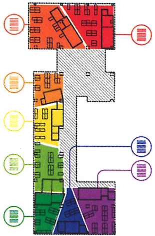
(3) Optimization algorithms shift seeds along the spine creating angular divisions.



(4) One edge from each neighborhood is selected to generate zone for amenity clusters.



(5) Automated "test fit" generates amenity rooms from space matrix and desk layout.



(6) Teams are assigned by best-fit algorithm. Neighborhood amenities are assigned by team preferences.

(7) Evaluation engine simulates and scores each design, and returns results to genetic algorithm.

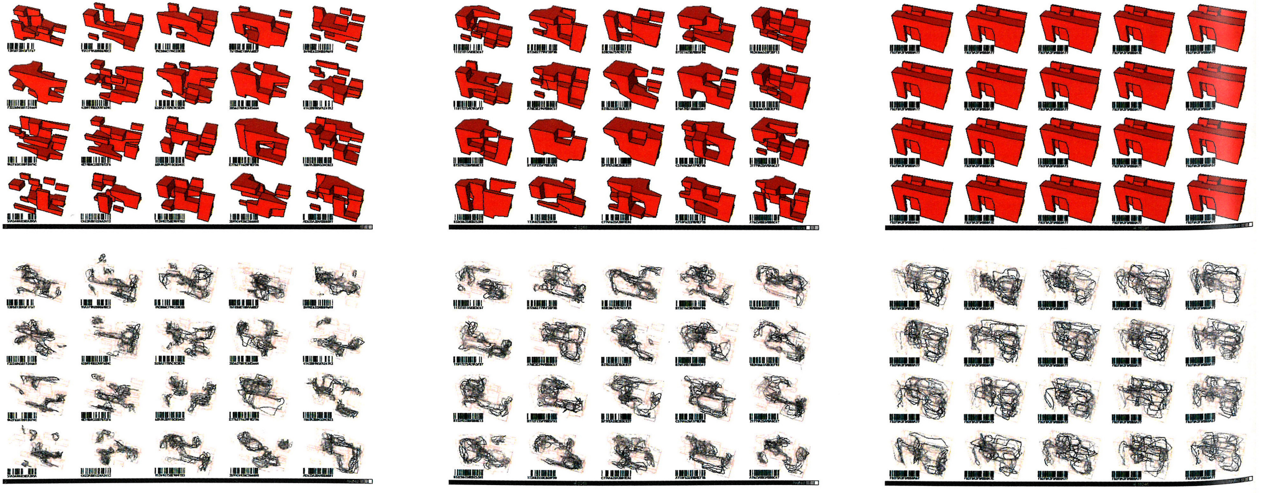
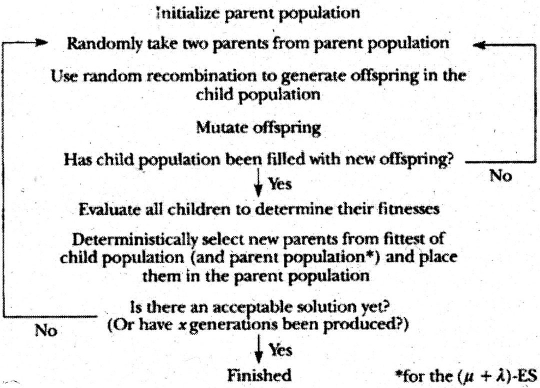


Fig 3 Experiment 1: three stages of a converging population of Boolean spaces (all bar-coded) towards 'good' fitness. Boolean spaces are shown above; agent traces, part of a network analysis system, are shown below



The evolution strategy.

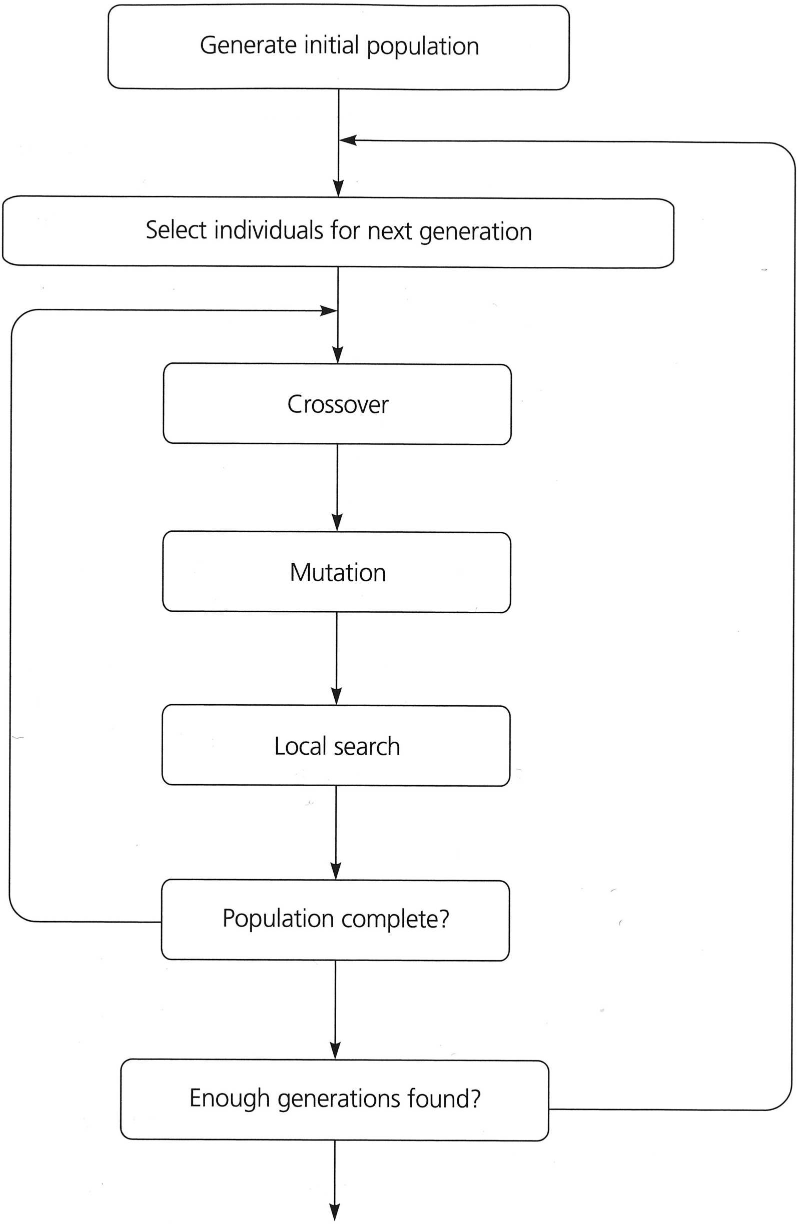
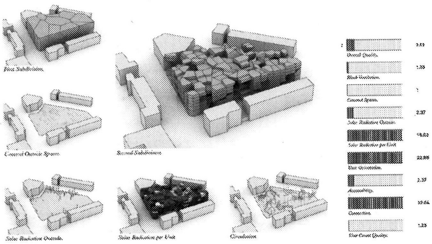
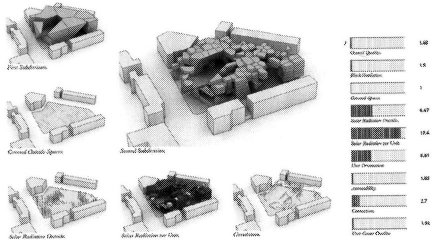


Figure 5.17 Steps in Burke and Smith's memetic algorithm (an evolutionary algorithm with local search). (From Burke and Smith, 1999.)

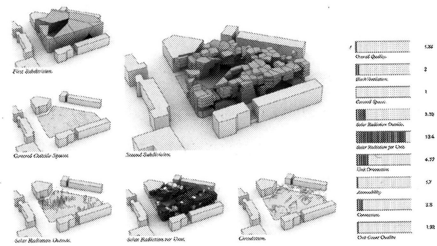
Experiment 01: *Evolution Cycle A*



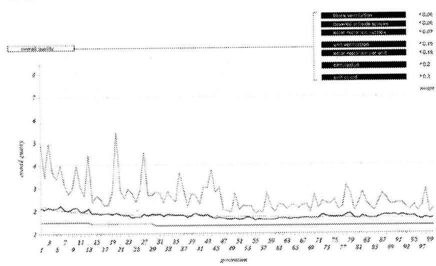
experiment 1, generation 00, individual 07



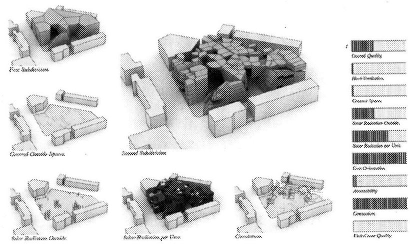
experiment 1, generation 40, individual 10



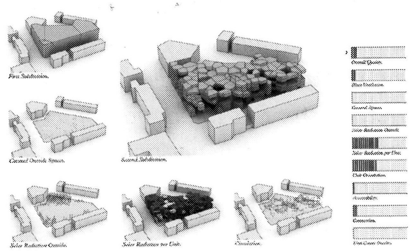
experiment 1, generation 99, individual 0



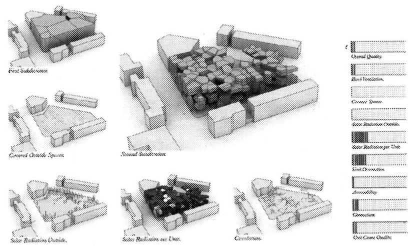
Experiment 02: *Evolution Cycle B*



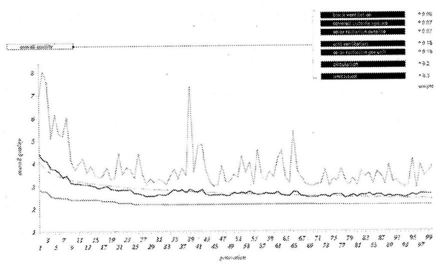
experiment 2, generation 00, individual 07



experiment 2, generation 40, individual 13



experiment 2, generation 99, individual 00



Florian Krampe, Christopher Voss, Integrated Urban Morphologies, ICD Stuttgart University (Prof. Achim Menges, Sean Ahlquist), Stuttgart, 2011. The project implements an Evolutionary Algorithm to negotiate constraints for spatial and circulatory organization with potentials for climatic modulation in the deployment of an urban housing block. In this non-typologically based generative process, the methods evolve multi-performing morphologies as well as utilize scripted analyses to identify novel emergent spatial formations.

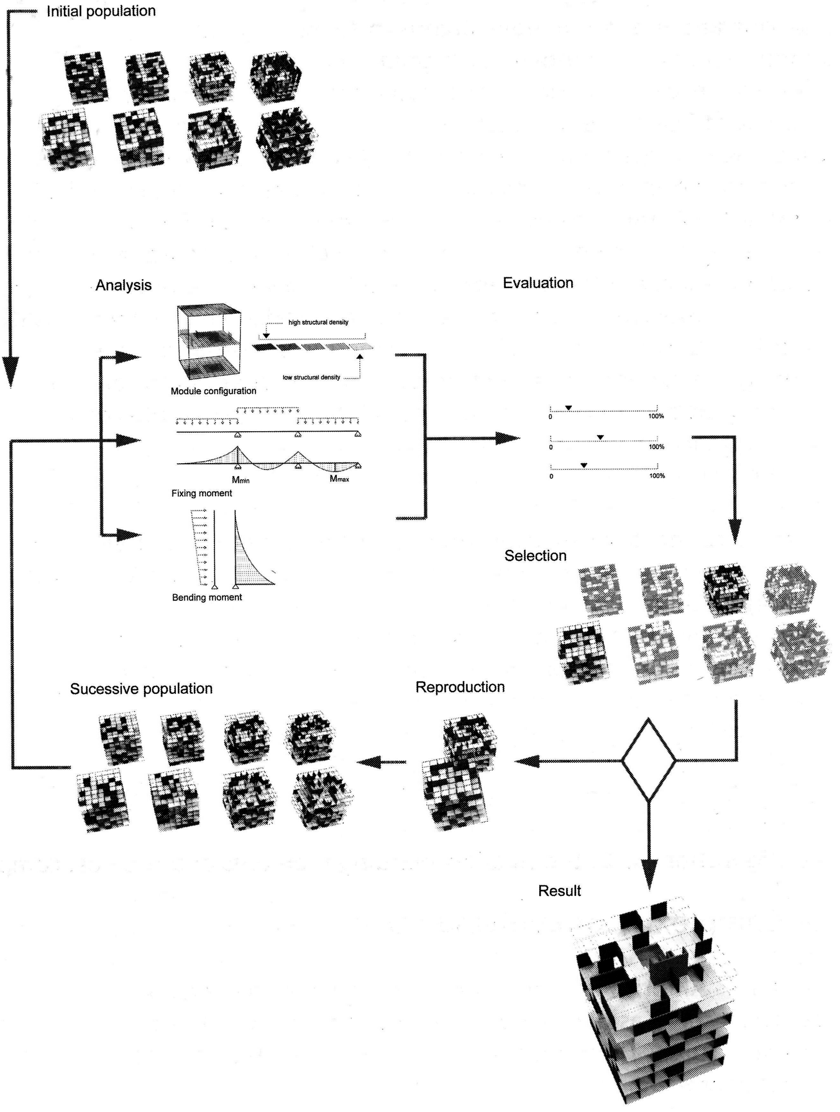
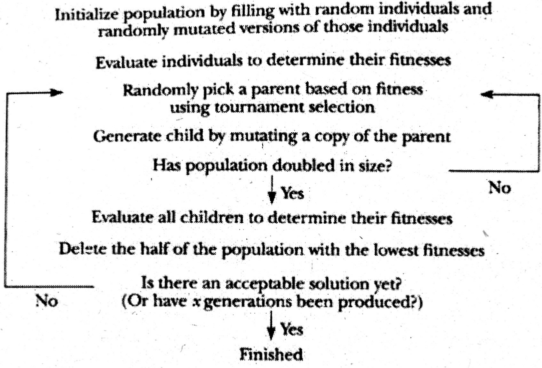
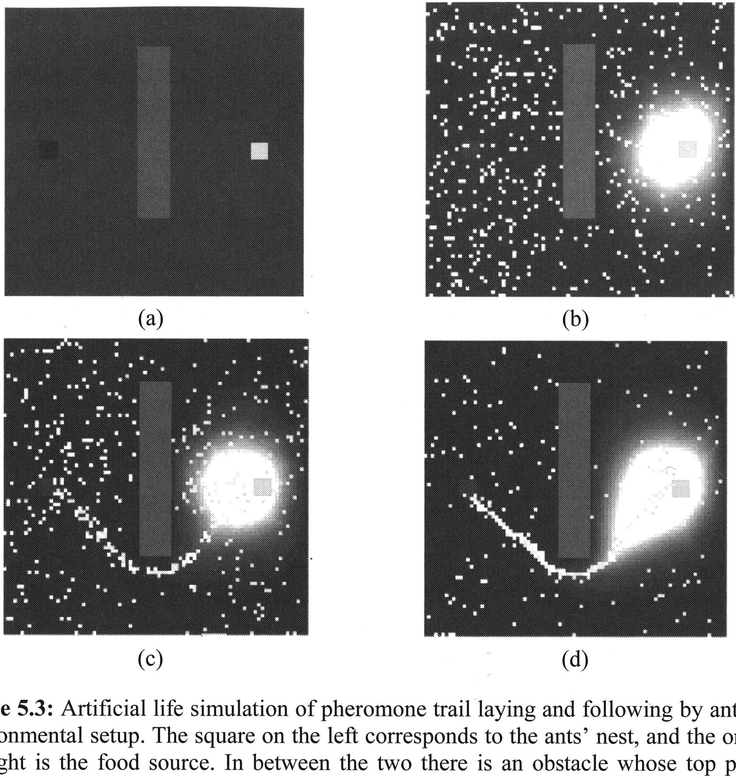


Figure 8.1: Diagram of the evolutionary algorithm. An initial population of random configurations gradually evolves until predefined properties are achieved. Image credit: Bollinger + Grohmann.

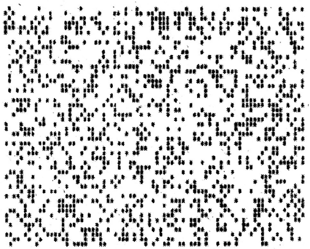


The evolutionary programming algorithm.

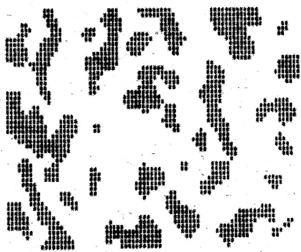


(a) (b) (c) (d)

Figure 5.3: Artificial life simulation of pheromone trail laying and following by ants. (a) Environmental setup. The square on the left corresponds to the ants' nest, and the one on the right is the food source. In between the two there is an obstacle whose top part is slightly longer than the bottom part. (b) 500 ants leave the nest in search for food, and release pheromone (depicted in white color) while carrying food back to the nest. (c) The deposition of pheromone on the environment serves as a reinforcement signal to recruit other ants to gather food. (d) A strong pheromone trail in the shorter route is established.



(a)



(b)

Figure 13.13
Application of an improvement procedure to a spatial arrangement problem. (a) Initial random field. (b) Result produced by transposition procedure. The system had reached effective stability after approximately 200,000 attempted transpositions for approximately 900 successes.

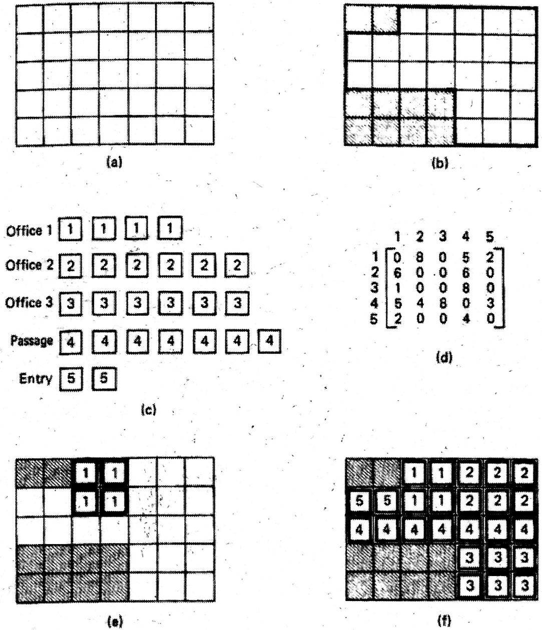


Figure 13.1
Floor plan layout as a quadratic assignment problem. (a) Grid of locations. (b) Building boundary within the grid. (c) Modules to be assigned. (d) Interaction matrix. (e) Preassigned space. (f) One of the many possible assignments of modules to locations.

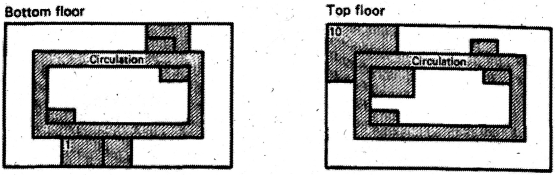
Number	Area (sq. ft.)	Area (10ft. X 10 ft. modules)
1	610	6
2	1537	15
3	2532	25
4	2417	24
5	1721	17
6	3321	33
7	1630	16
8	3239	32
9	2014	20
10	2024	20
11	2210	22

(a)

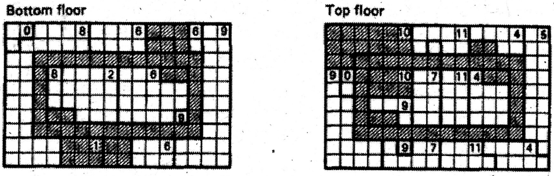
	1	2	3	4	5	6	7	8	9	10	11
1	X	A	D	B	D	D	D	C	C	D	F
2	A	X	D	C	D	D	D	D	D	D	D
3	D	D	X	D	D	C	C	D	D	B	C
4	D	D	D	D	B	D	D	D	D	D	D
5	C	D	D	A	X	D	D	B	D	D	B
6	D	D	B	D	D	X	A	D	D	D	D
7	B	C	D	D	B	D	X	D	C	D	D
8	D	C	D	D	C	D	D	X	D	D	D
9	B	D	D	C	D	D	D	D	X	C	D
10	D	D	D	D	D	D	D	D	D	X	C
11	F	D	D	D	D	D	D	D	D	C	X

Code	Interpretation
A	Absolutely essential to be located near department.
B	Essential to be located near department.
C	Important to be located near department.
D	Optional to be located near department.
F	Undesirable to be located near department.
X	No preference of department to itself.

(b)



(c)



(d)

Figure 13.10
Typical result produced by the ALDEP floor plan layout program (after Seehof and Evans (1967)). (a) Department areas. (b) Interaction matrix. (c) Building outline and preassigned departments (hatched). (d) Layout generated by a run of ALDEP.

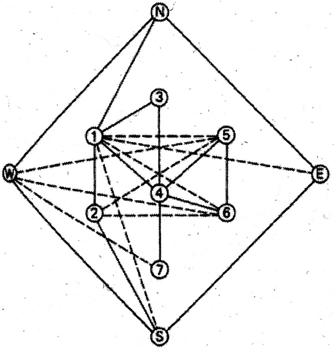


Figure 13.2
An adjacency requirements graph for a floor plan layout problem.

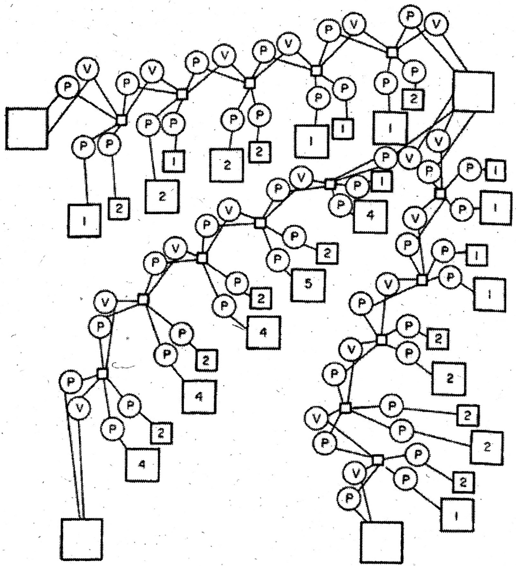


Figure 13.7
A constraint graph for a site layout problem (from Weizapfel and Handel (1975)). Squares represent housing units and other buildings, and the characters in the small circles are constraint labels. A label P indicates that the buildings linked by the constraint should be near to each other, and a label V that there should be visual access.

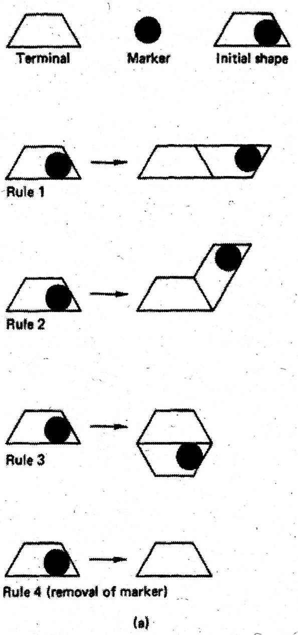
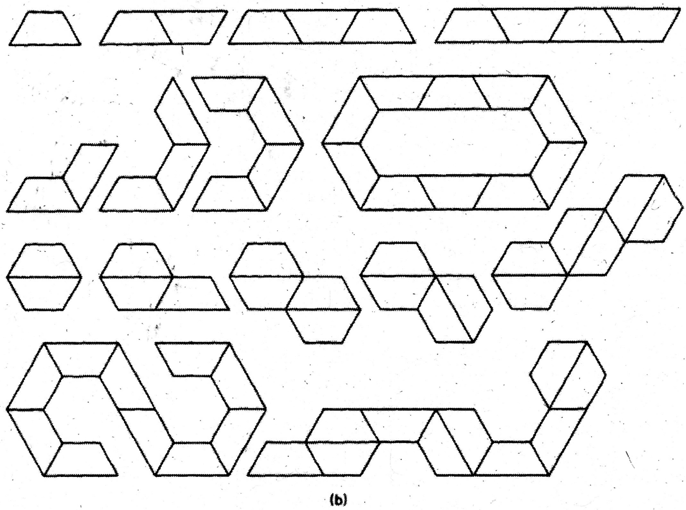
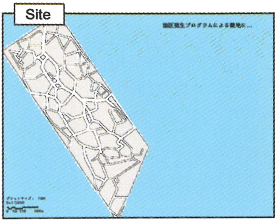


Figure 13.8
A shape grammar for arrangements of half-hexagon tables. (a) A shape grammar SG. (b) Some shapes in the language defined by SG.

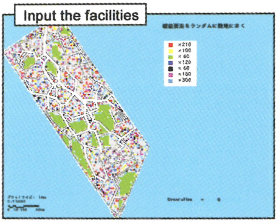


Structure of On-Demand City

Site

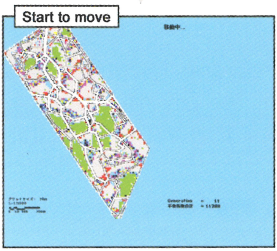


Input the facilities



Compare the mutual distances between all units with the matrix.

Start to move



If the mutual distances are acceptable, move the next unit.

Set the matrix

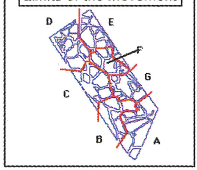
- office (red)
- convenience store (yellow)
- park (green)
- school (blue)
- hospital (black)
- commercial f. (purple)
- housing (light blue)

example facilities

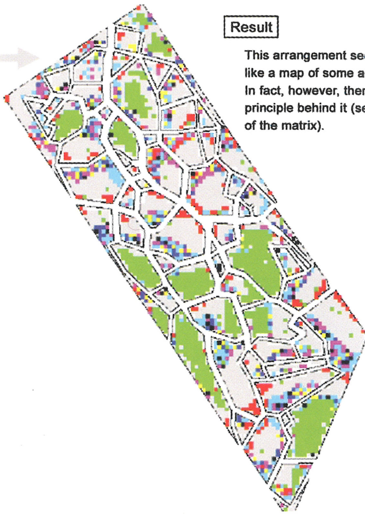
	office	convenience store	park	school	hospital	commercial f.	housing
office	12	10	8	14	18	10	20
convenience store	8	15	2	3	6	3	6
park	18	3	0	2	2	3	2
school	18	6	2	3	6	5	4
hospital	18	3	1	8	4	5	4
commercial f.	6	6	3	4	6	2	4
housing	20	6	2	2	5	10	4

The numbers indicate a desirable distance between functional units.

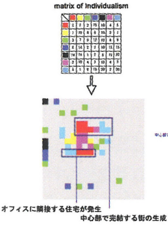
Limits of the movement

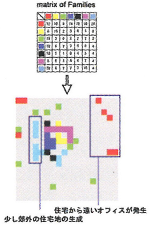


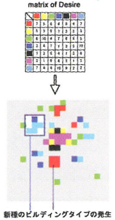
Result



This arrangement seems natural, like a map of some actual city. In fact, however, there is a clear principle behind it (set by means of the matrix).


matrix of Individualism
オフィスに隣接する住宅が発生
中心部で完結する街の生成


matrix of Families
住宅から遠いオフィスが発生
少し郊外の住宅地の生成


matrix of Desire
新種のビルディングタイプの発生

Artificial Life

Biological issues
- evolution
- origins of life
- synthesis of RNA/DNA

Principles of intelligent behavior
- emergence and self-organization
- distributed systems
- group behavior
- autonomous robots

Practical applications
- computer-animation
- computer games
- optimization problems
- design

Figure 1: The goals of Artificial Life.

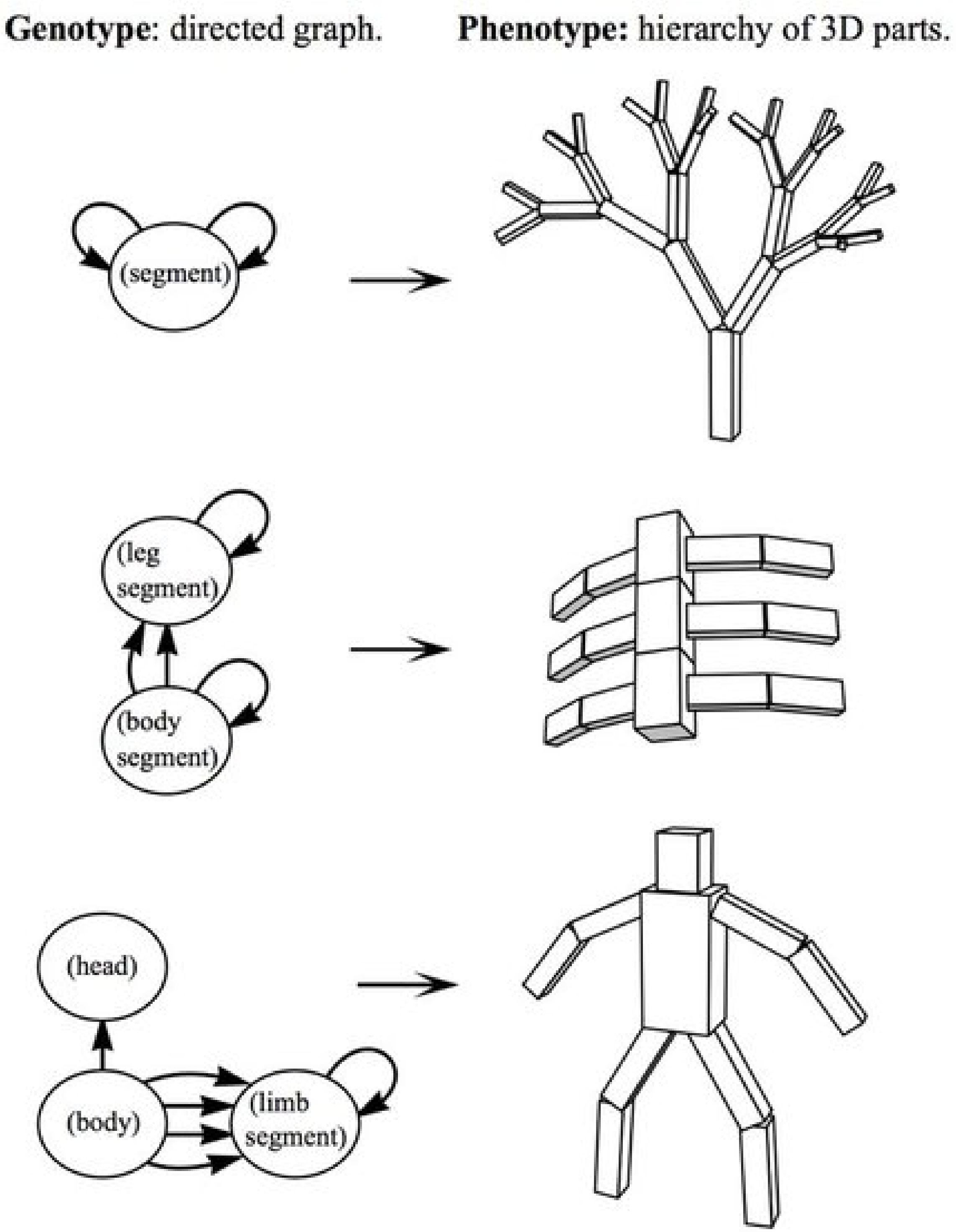


Figure 1: Designed examples of genotype graphs and corresponding creature morphologies.

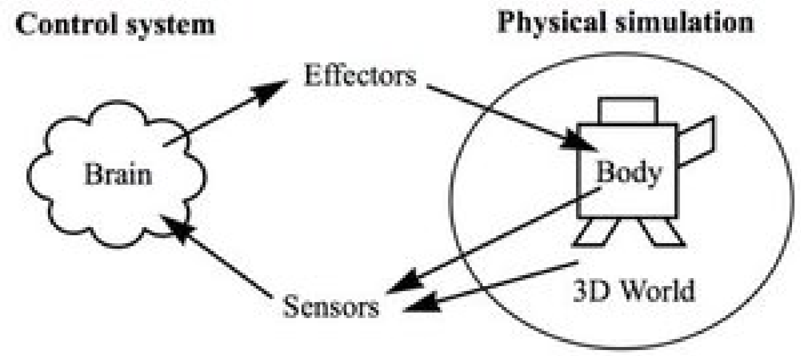


Figure 2: The cycle of effects between brain, body and world.

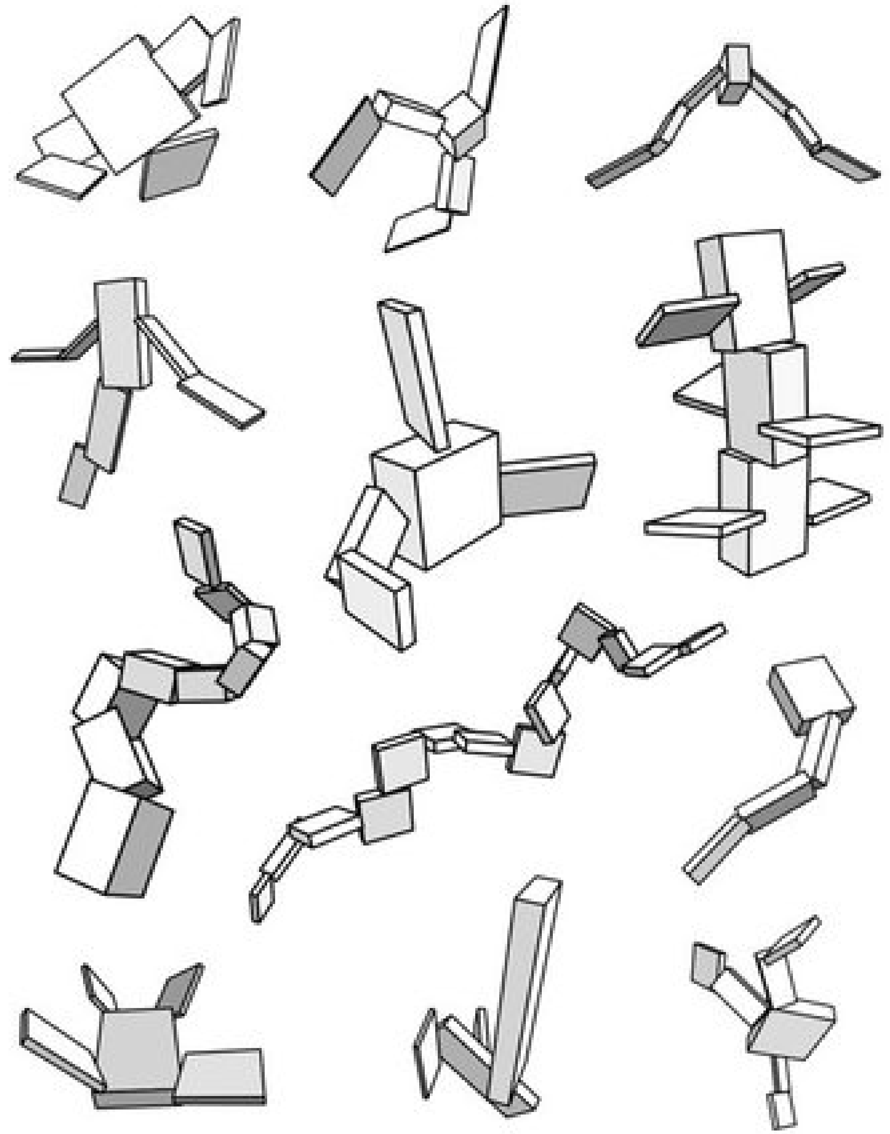


Figure 6: Creatures evolved for swimming.

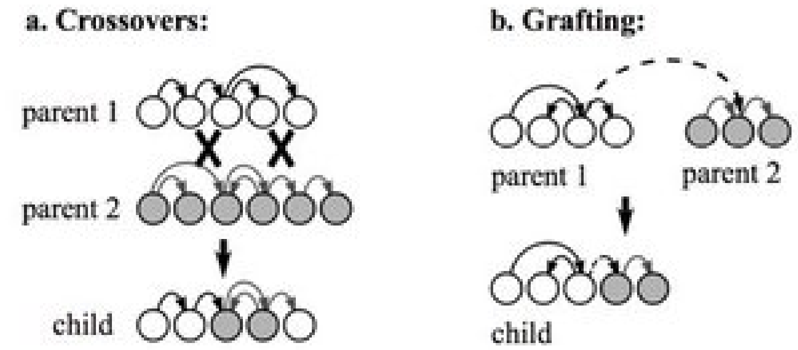


Figure 5: Two methods for mating directed graphs.

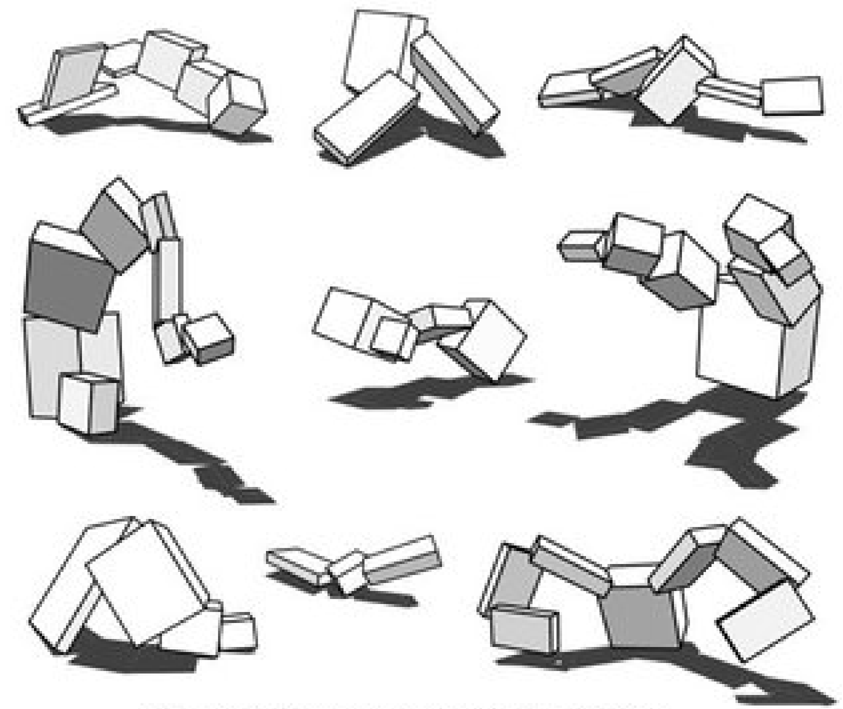


Figure 7: Creatures evolved for walking.

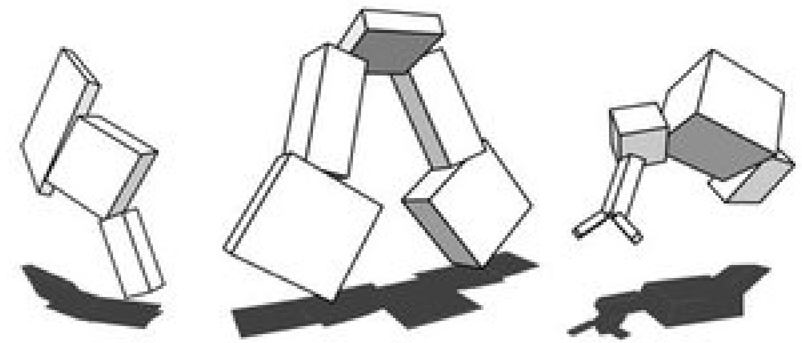
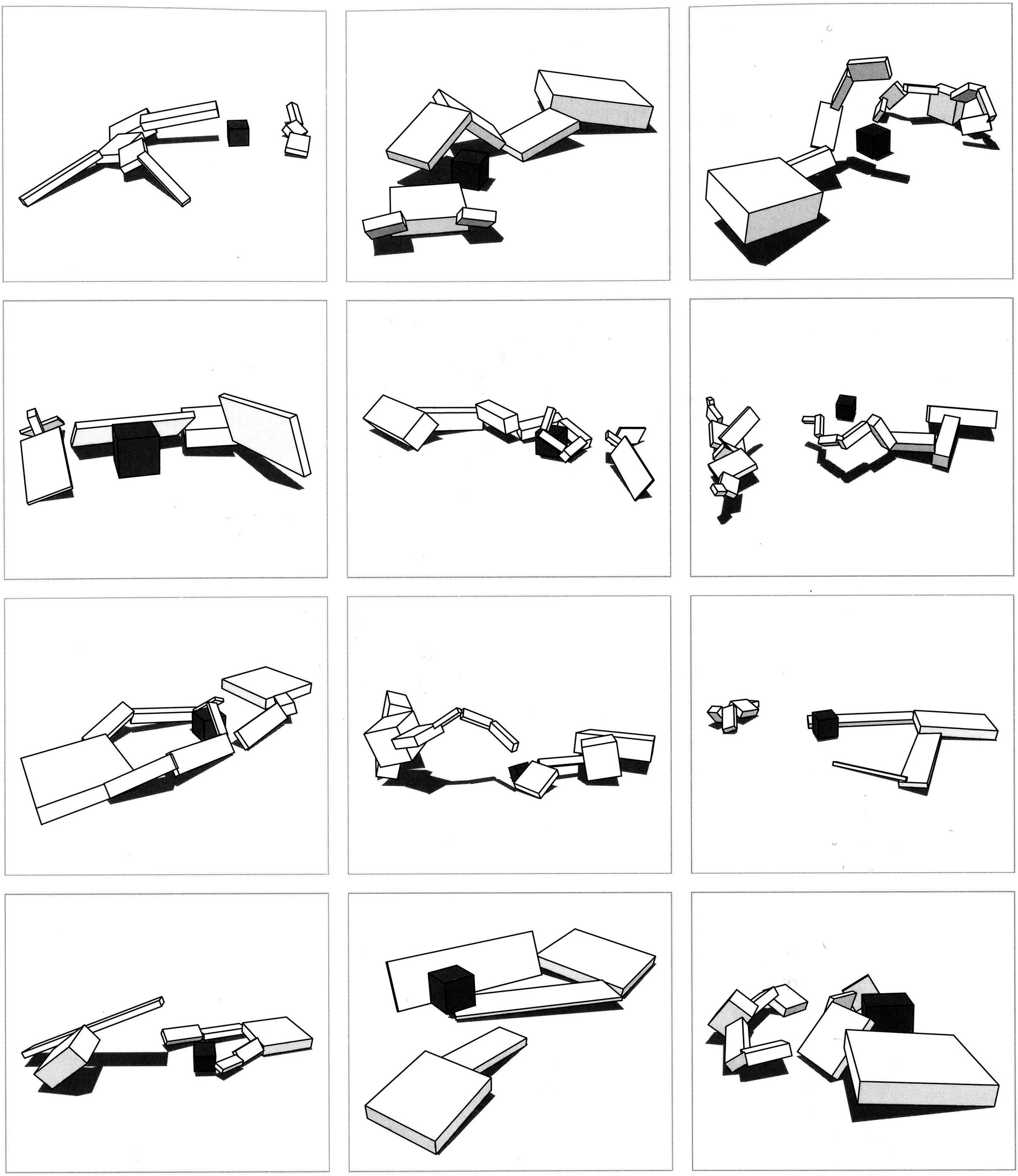


Figure 8: Creatures evolved for jumping.



Evolved Virtual Creatures, by Karl Sims, 1994
Evolved virtual creatures compete for the possession of a cube within this simulated world. The winner of each round of the competition receives a higher score, giving it the ability to survive and reproduce.