



## *The built environment*

**FIT3094** AI, A-Life and Virtual Environments  
Alan Dorin

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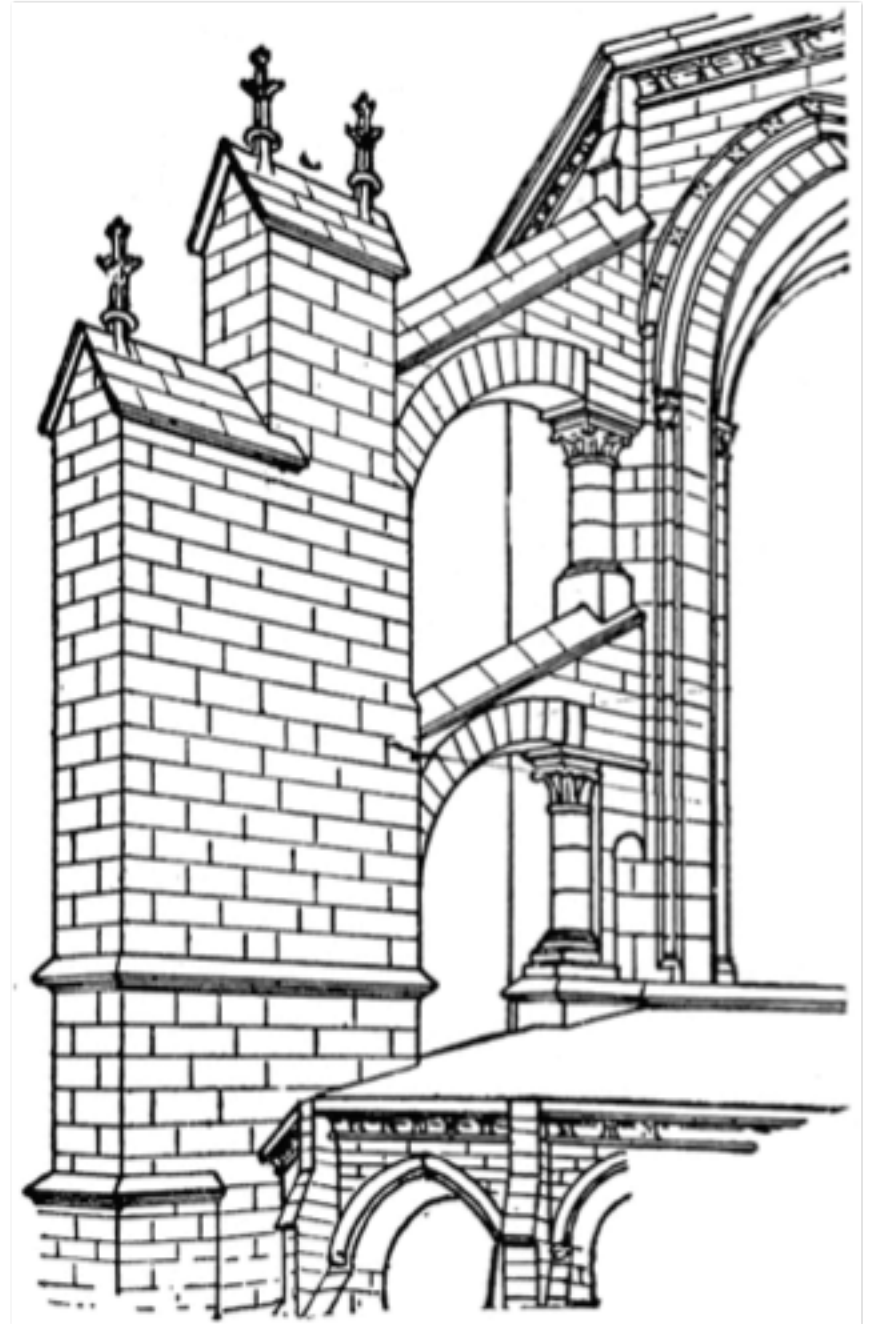
## **Learning Objectives**

To understand how and why non-human and human architectural diversity has developed, and why it is important.

To be conscious of the links between biological or natural structures and the human built environment.

To explain algorithms for generating (using emergent phenomena) architecture including heaps, nests and paths.

What is  
*architecture*?



The art or practice of designing and constructing buildings and urban areas.

The manipulation of light and shadow to generate inhabitable space.

An aesthetics of space.

# What is *architecture?*

It is what architects do.

It is the design and construction of buildings and landscapes with an *idea*.

*Are these architecture?*





## Plaster cast of a harvester ant nest



Walter R. Tschinkel, The nest architecture of the Florida harvester ant, *Pogonomyrmex badius*.  
*Journal of Insect Science* 4(21): 1-19. 2004









Butterfly cocoons, Singapore



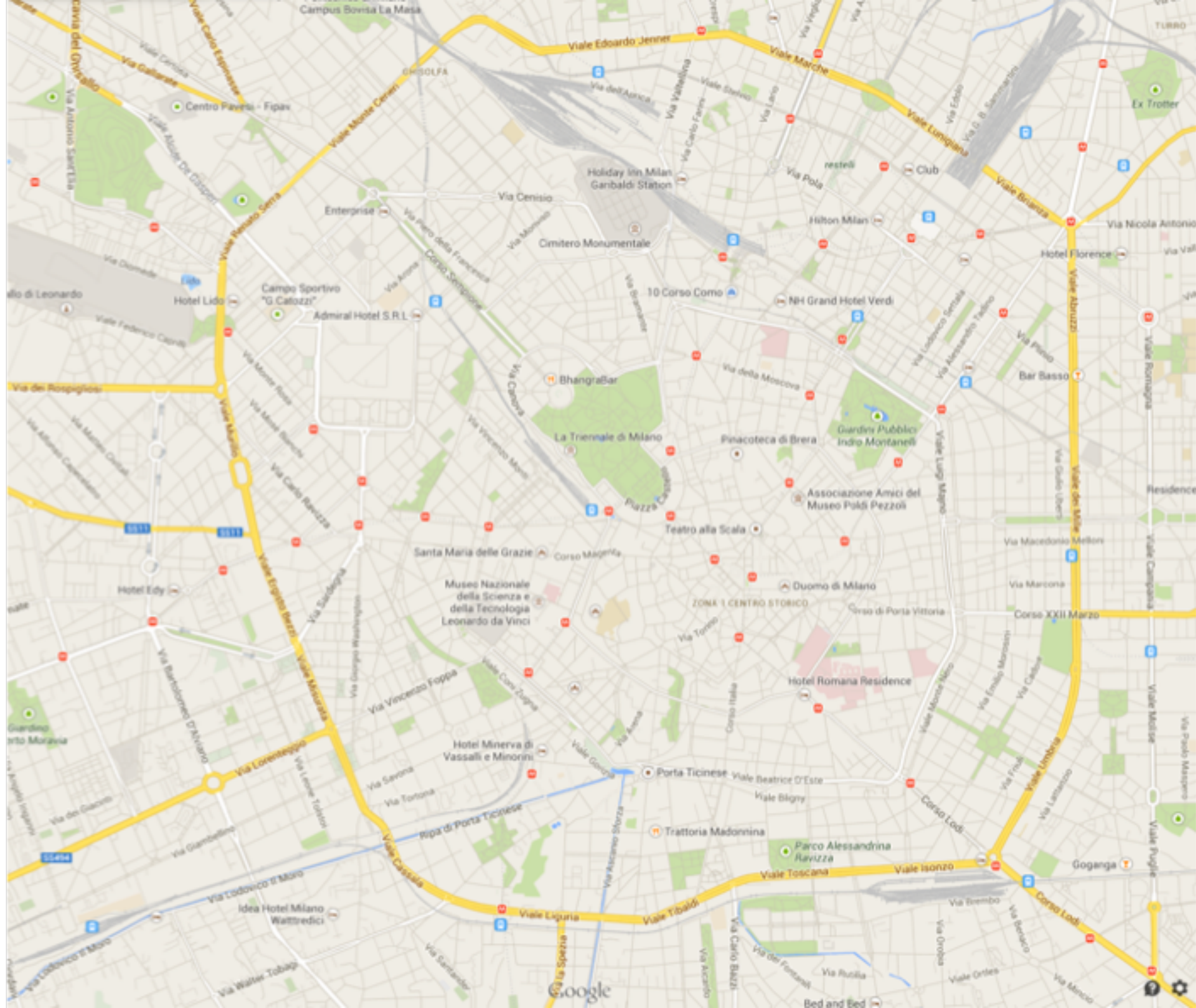
When we look at the most beautiful towns and cities of the past, we are always impressed by a feeling that they are somehow organic. This feeling of “organicness”, is not a vague feeling of relationship with biological forms. It is not an analogy. It is instead, an accurate vision of a specific structural quality which these old towns had... and have.

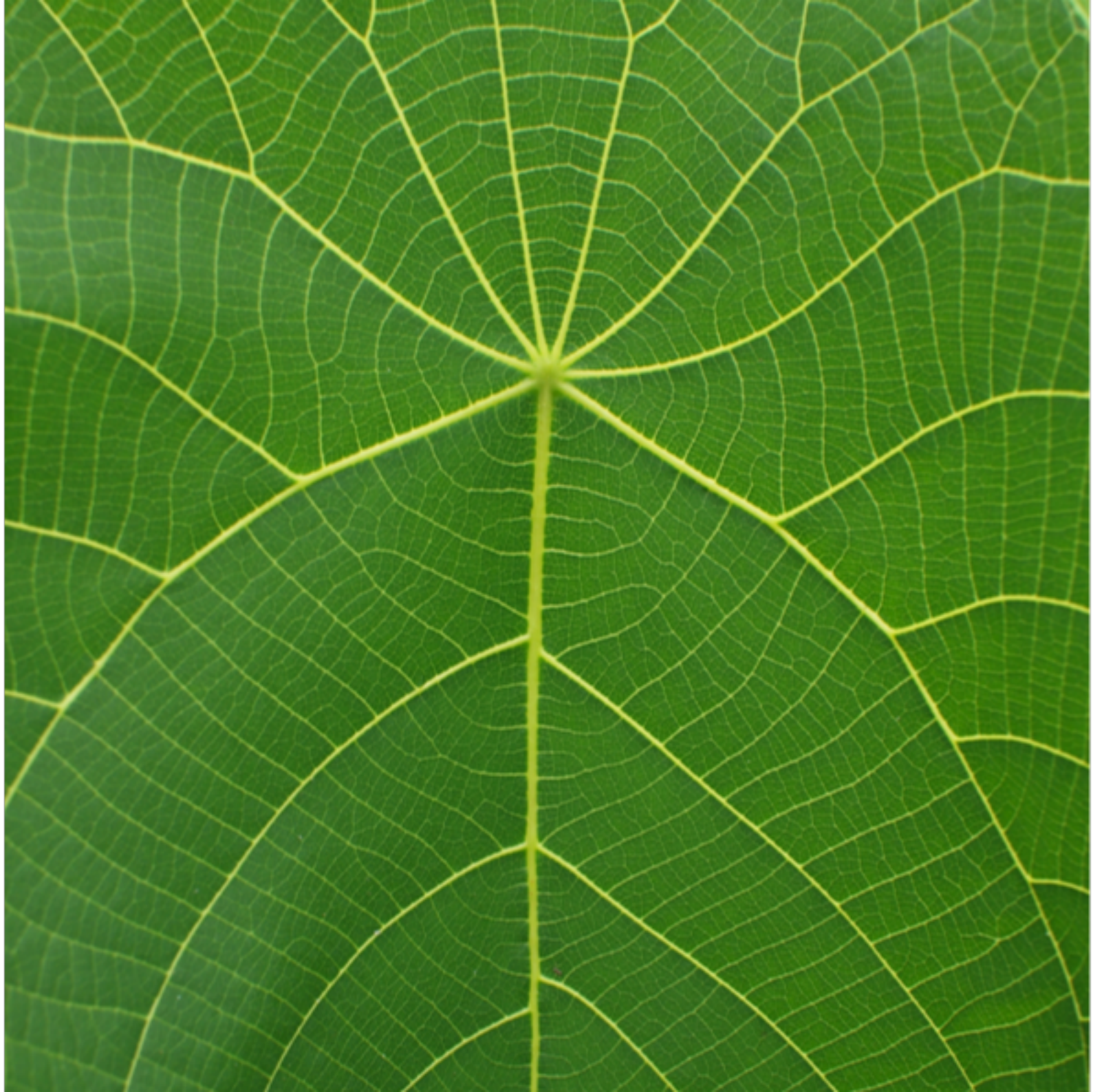
Christopher Alexander, *New Theory of Urban Design* (1987)



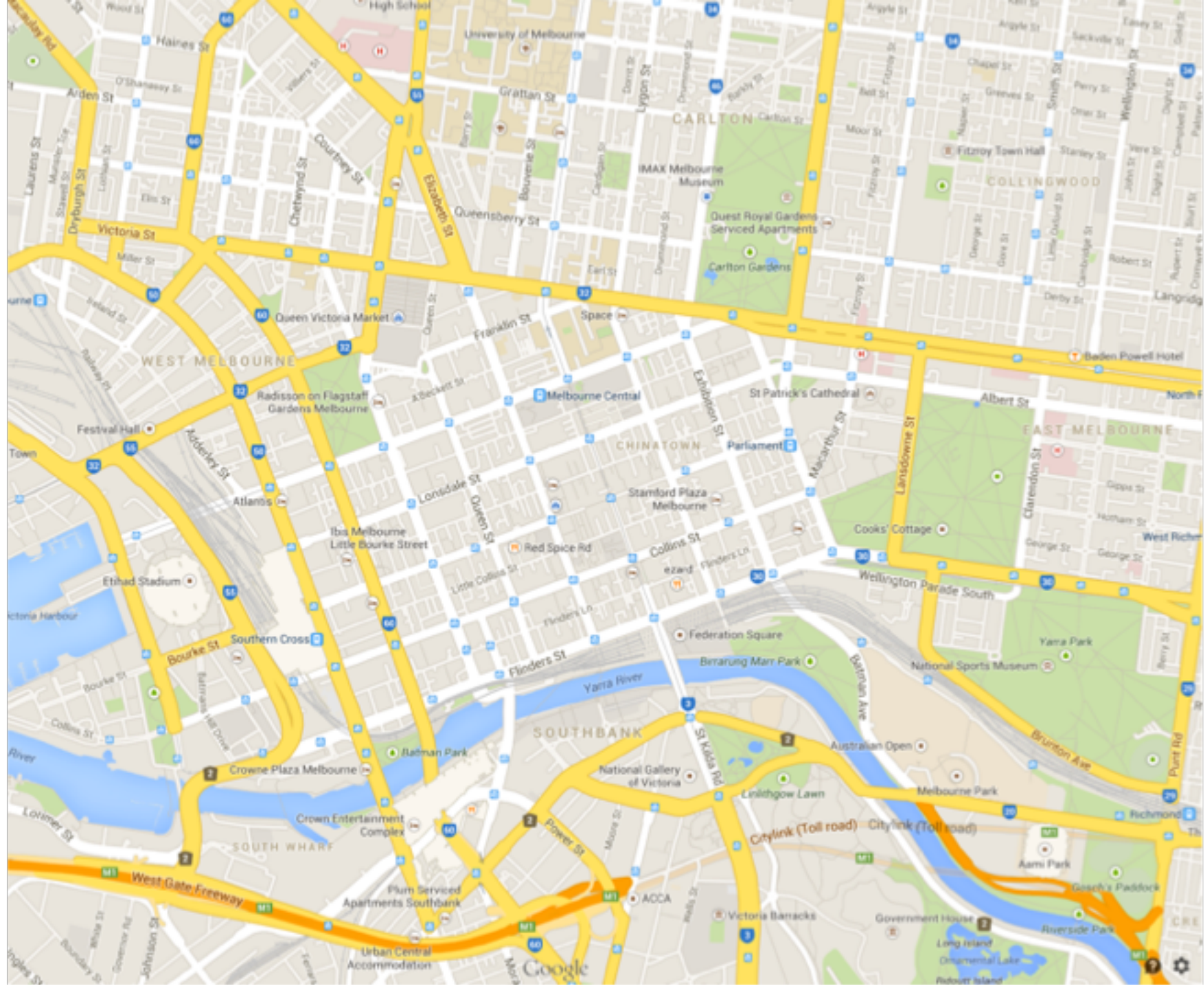
Milan (settlement ~400 BC)

Milano, 16th century. Georg Braun; Frans Hogenberg; Civitates Orbis Terrarum, 1572 (edition of 1593). Herzogin-Anna-Amalia-Bibliothek, Weimar [http://ora-web.swkk.de/digimo\\_online/digimo.entry?source=digimo.Sammelband&a\\_id=8287](http://ora-web.swkk.de/digimo_online/digimo.entry?source=digimo.Sammelband&a_id=8287)









Melbourne (colonial settlement ~1835 CE)



Via Krupp, Capri. Italy c. 1900.  
A built environment that merges with the natural landscape.

What determines dimension? shape? ornament?  
arrangement? situation and orientation? materials? ...

To answer:

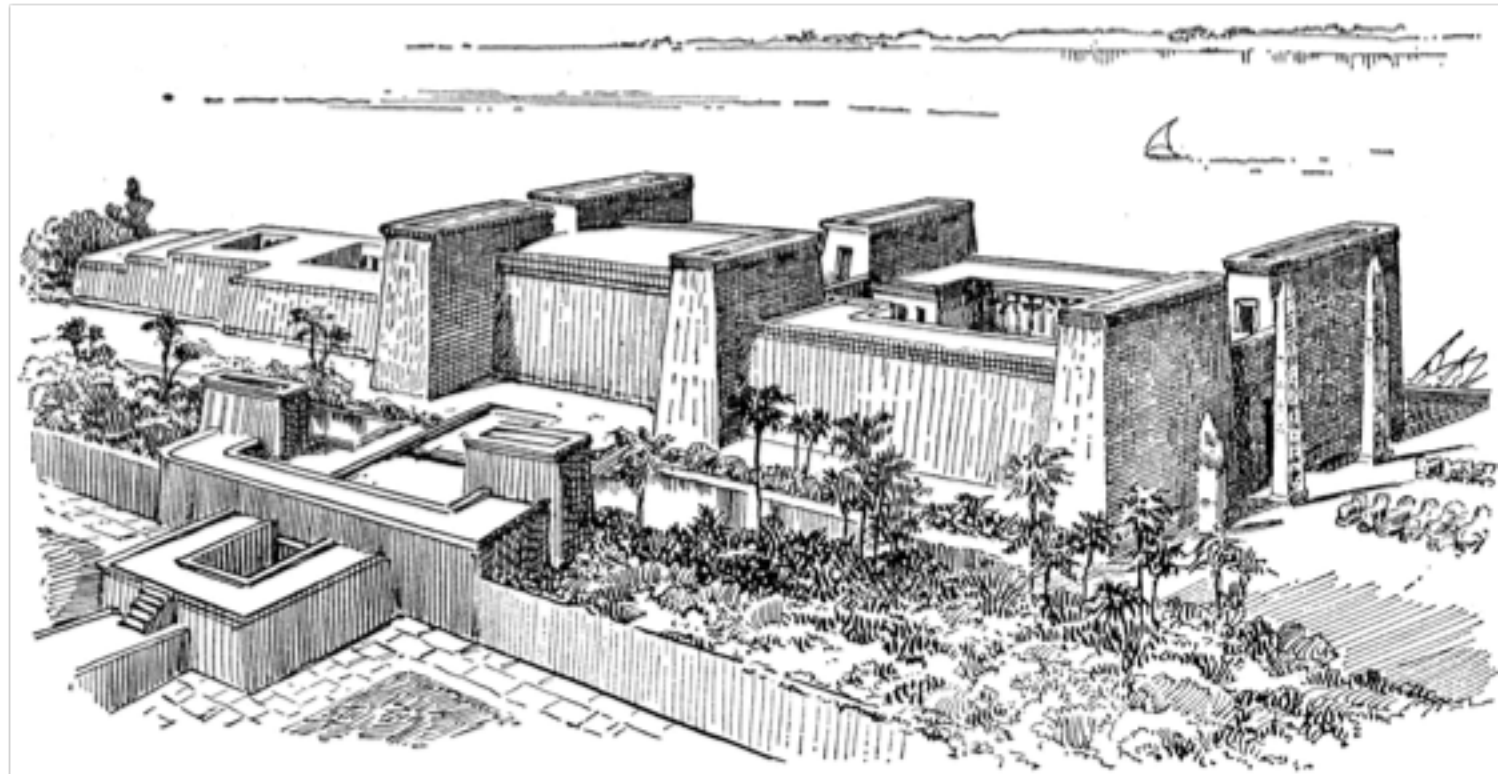
What conditions and customs dictated the  
design of these constructions and the  
building methods employed?

Here comes a selection of the world's architectural diversity...



Pyramid of Giza, Egypt (~2500 BCE).

Luxor, ancient  
Egyptian temple  
complex ~1400 B.C.E.





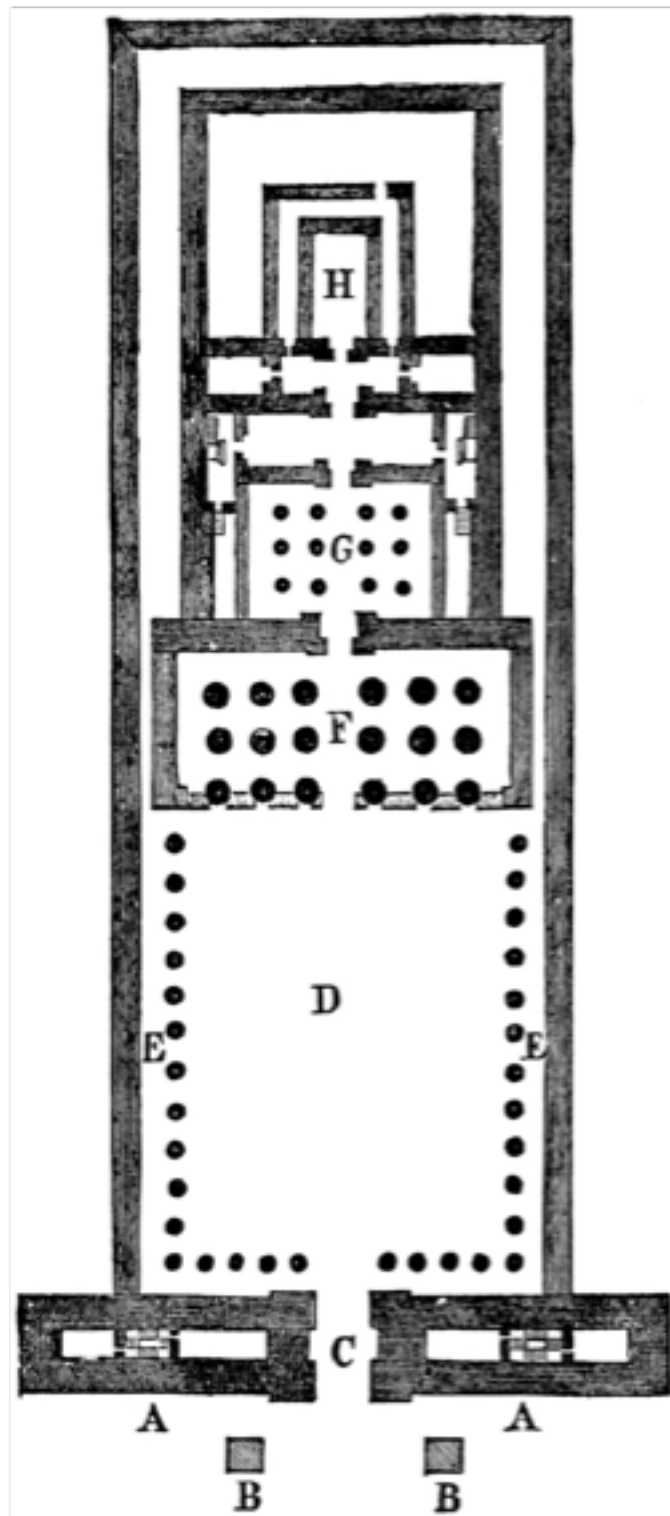
Classical Greek architecture  
Temple of Apollo, 630 BCE



Classical Greek architecture



Greek theatre at Taormina, Sicily (original 7th C. BCE, but rebuilt by the Romans)



The Temple of Edfu is an ancient Egyptian temple located on the west bank of the Nile in the city of Edfu which was known in Greco-Roman times as Apollonopolis Magna, after the chief god Horus-Apollo. It is the second largest temple in Egypt after Karnak and one of the best preserved.

The temple, dedicated to the falcon god Horus, was built in the Ptolemaic period between 237 and 57 BCE.

A, pylon; B, obelisks; C, entrance; D, temple courts; E, porticus; F, pronaos (court with colonnades); G, naos; H, sanctarium.



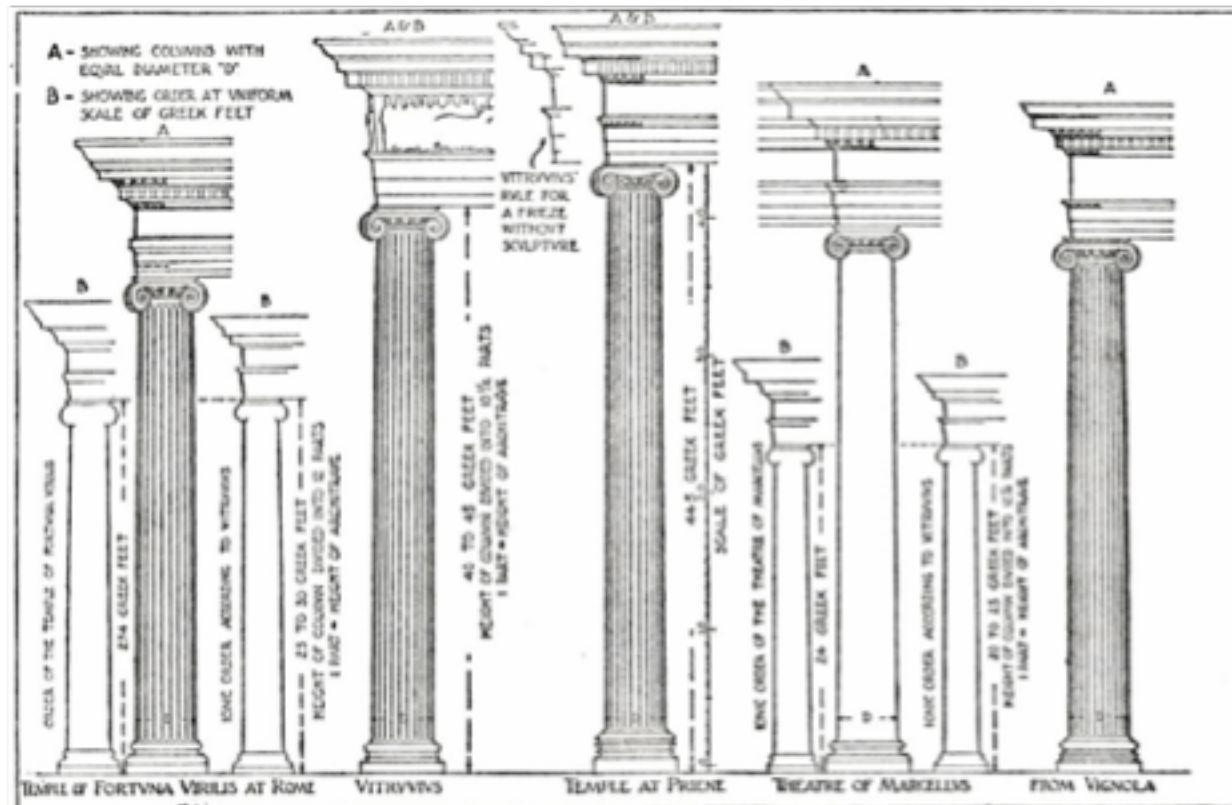
# *De architectura*, by the Roman architect Vitruvius (early 1st century CE)

A good building should satisfy the three principles of (in translation).

**Durability** – a building should be robustly and remain in good condition.

**Utility** – suitable for the purposes for which it is to be used.

**Beauty** – aesthetically pleasing through proportion and symmetry.



A comparison of the Ionic order according to Vitruvius with actual examples and with Vignola's order A: Showing the orders reduced to equal lower diameters. B: Showing the orders to a uniform scale.



The colosseum at Rome



Roman aquaduct



Roman tombs



The Pantheon, Rome 126 CE



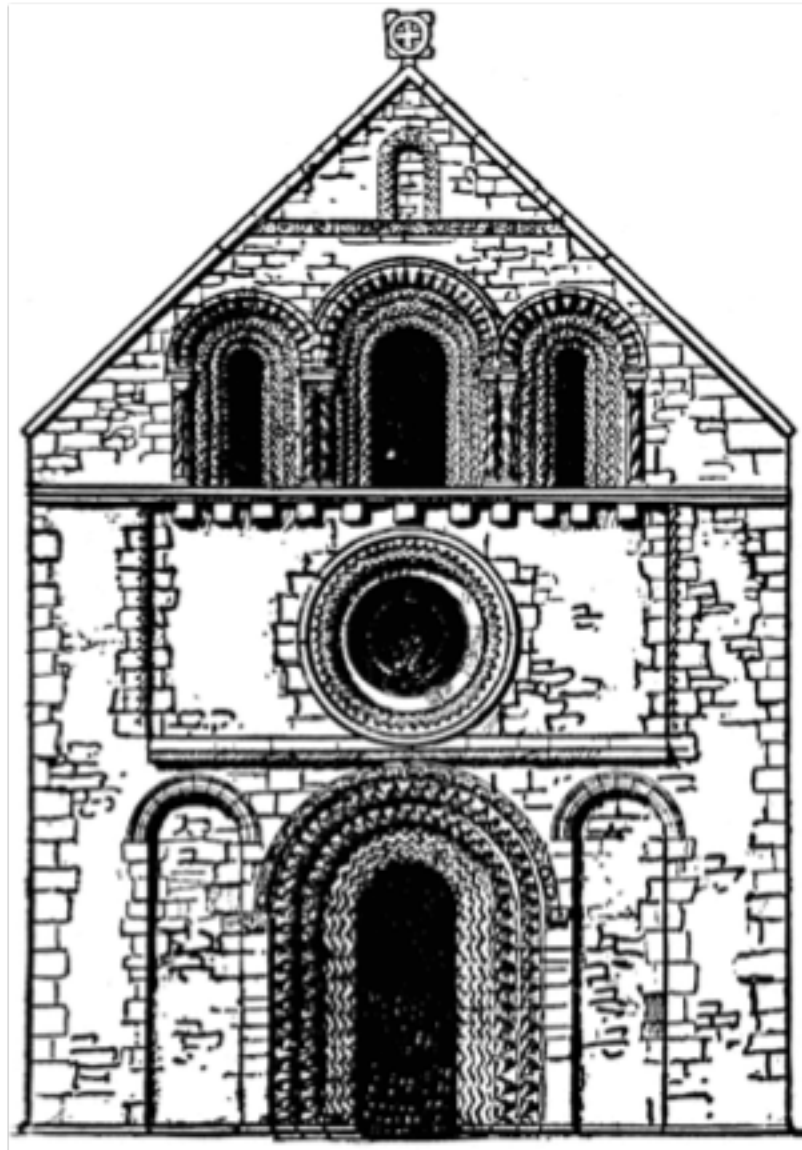
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Architecture shows signs of how time has passed...



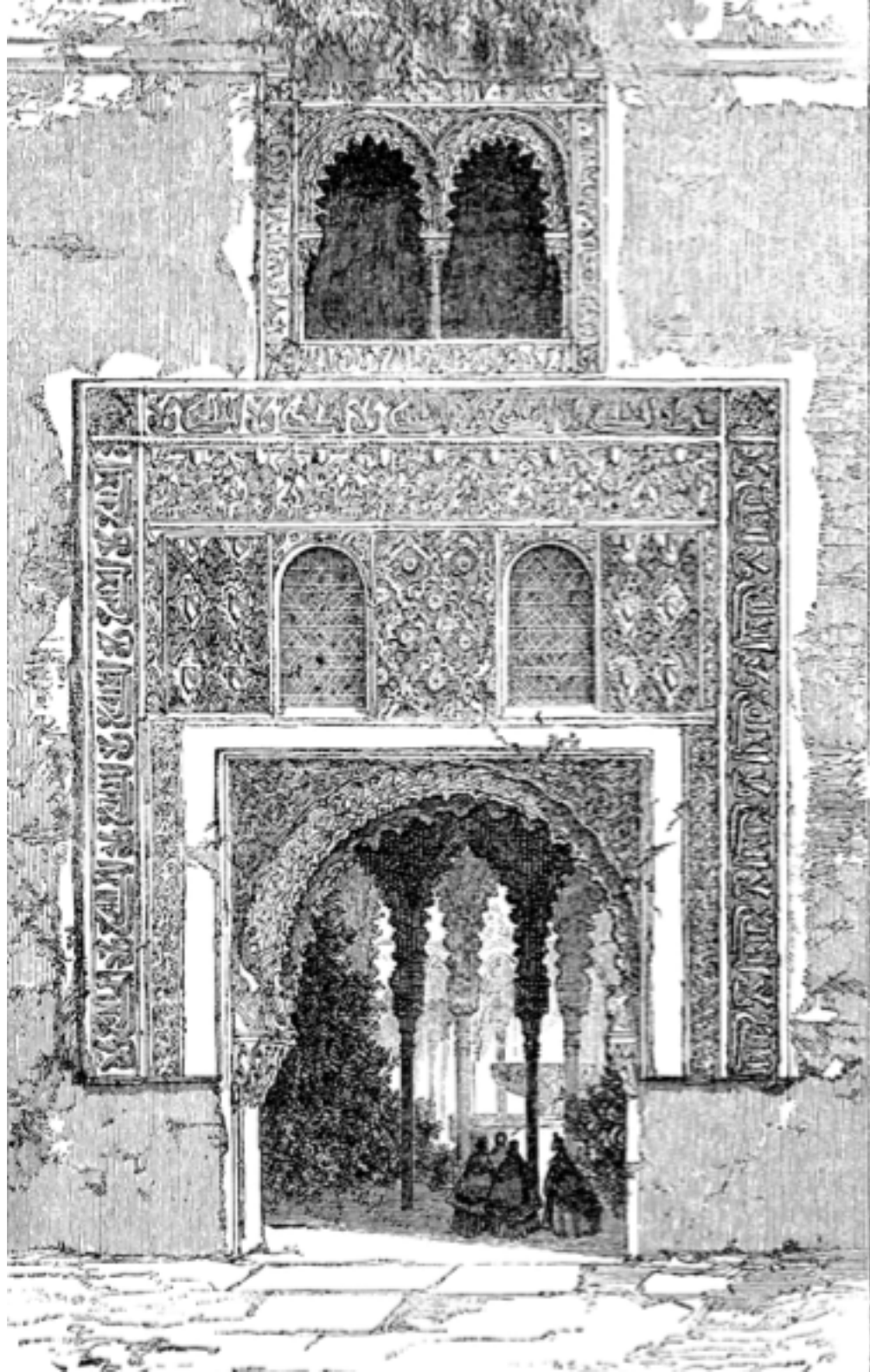


Romanesque (British Norman) church at Iffley c. 1170

Thun castle, Switzerland c.1180







The Alhambra which translates as "the red fortress". (c. mid 14th C CE)

A palace and fortress built by the Moorish rulers in Granada, Spain.



Street architecture of Tudor England, Cornwall UK c.1500.



Basilica di Santa Maria del Fiore Florence, 1296-1436

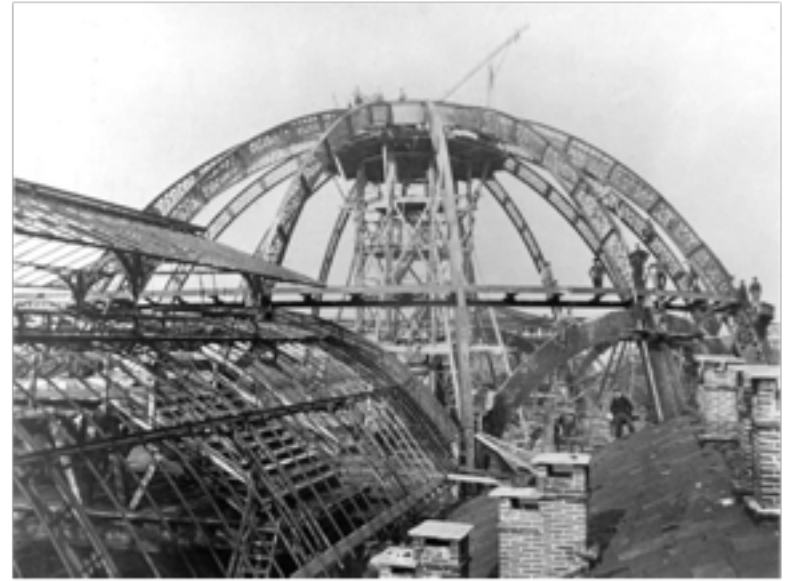


Basilica di Santa Maria del Fiore Florence, dome by Brunelleschi 1446 - ca.1461

Milan Duomo (cathedral), 1386-1935.







Milan Galleria Vittorio Emanuele II, 1865-1877



Milan central station, 1931.





Timber houses in northern Sweden.



A traditional house of the Sámi people, Finland



Royal Palace of Caserta, Italy, 1752

Royal Palace of Caserta, Italy, 1752





Natural History Museum, London 1881



Grain silos, NW Victoria, Australia.





Shanghai, China skyline (2006)

light!





Shanghai, China scaffold (2006)

temporary structures, busy streets



Shanghai, China screens and secluded garden view



Shanghai, China mass housing (2006)



Zermatt, Switzerland. Traditional timber housing.





Antoni Gaudí. Casa Batlló, Barcelona, Spain, 1904



Kinkaku-ji, Kyoto Japan (1397. current structure built 1955)



Solomon R. Guggenheim Museum, New York, USA, Frank Lloyd Wright, 1959





Sydney Opera house, Jørn Utzon, 1959-1973



Eden Project *biomes* by Nicholas Grimshaw (Cornwall UK, 2000)

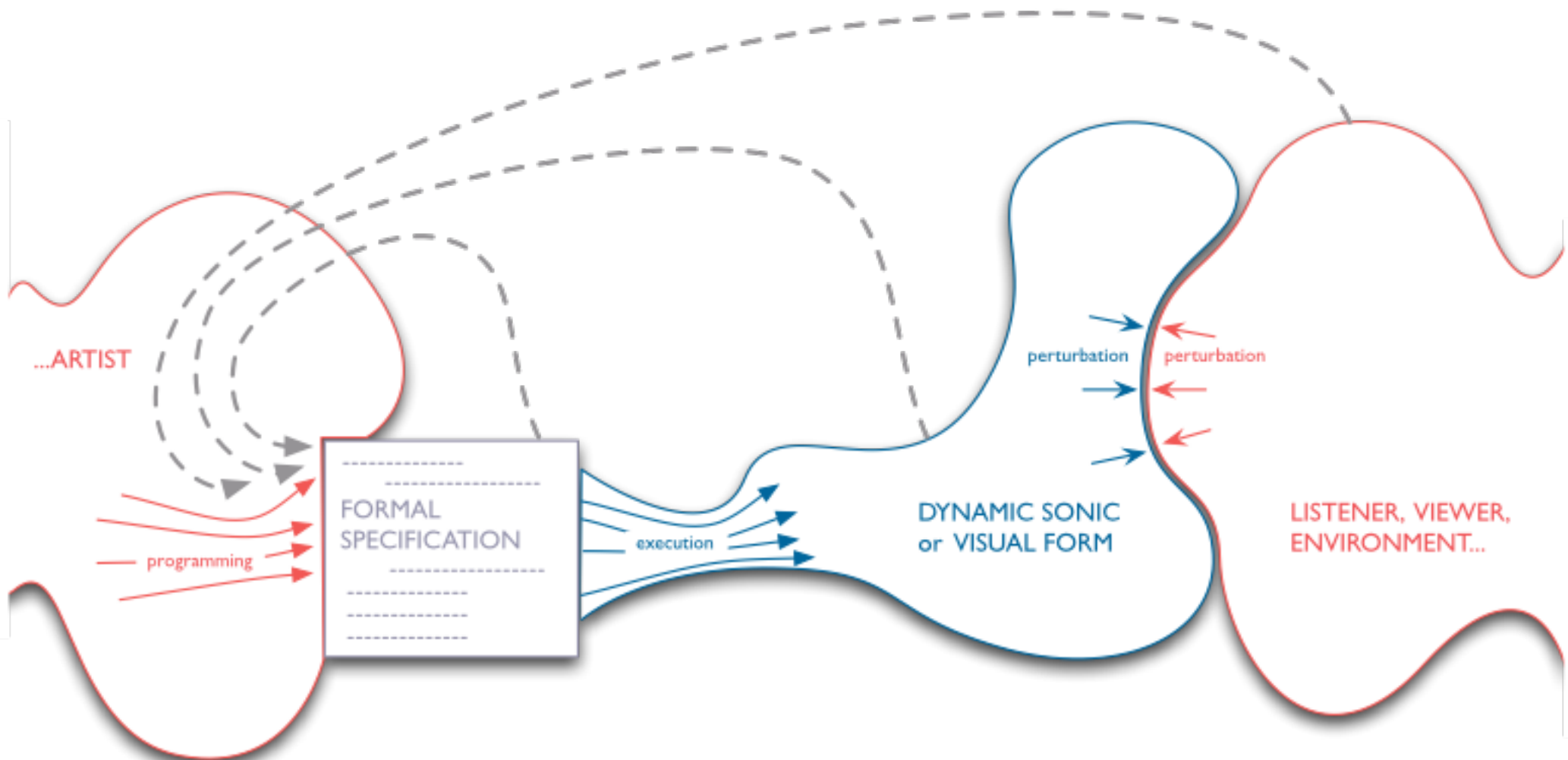


MSR Fury mountain tent (c. 2000)



Kengo Kuma, Oribe tea pavilion (2005)

# What is Generative Art, Design and Architecture?



In design based on generative specifications, the artist chooses structural and material relationships and then determines algorithmically the resulting art objects

Stiny and Gips, 1971

"La Città Ideale", Generative Codes Design Identity



generative project of **Italian medieval towns Identity**



Celstino Soddu, Variations  
of the typical medieval city

There is potential for generative techniques to be applied to:

Zoning

Urban design

Building design

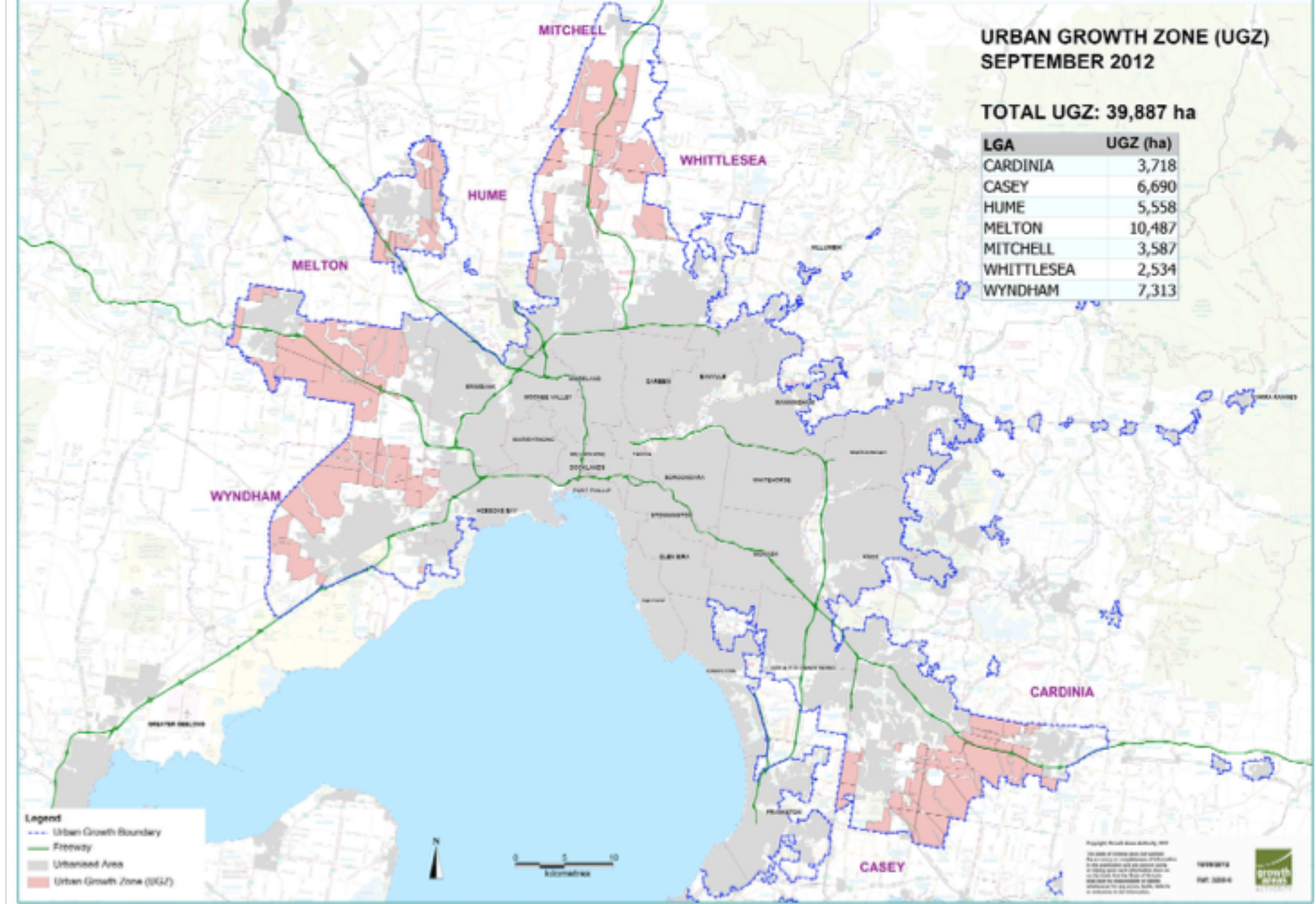
Building component design



**URBAN GROWTH ZONE (UGZ)  
SEPTEMBER 2012**

**TOTAL UGZ: 39,887 ha**

LGA	UGZ (ha)
CARDINIA	3,718
CASEY	6,690
HUME	5,558
MELTON	10,487
MITCHELL	3,587
WHITTLESEA	2,534
WYNDHAM	7,313



Zoning - how is space allocated to the different needs of a city or town?  
E.g. industrial areas, housing, agriculture, mixed use, natural environments



Melbourne sports precinct <http://populous.com>

Urban design - how are specific zones arranged for their intended purposes?

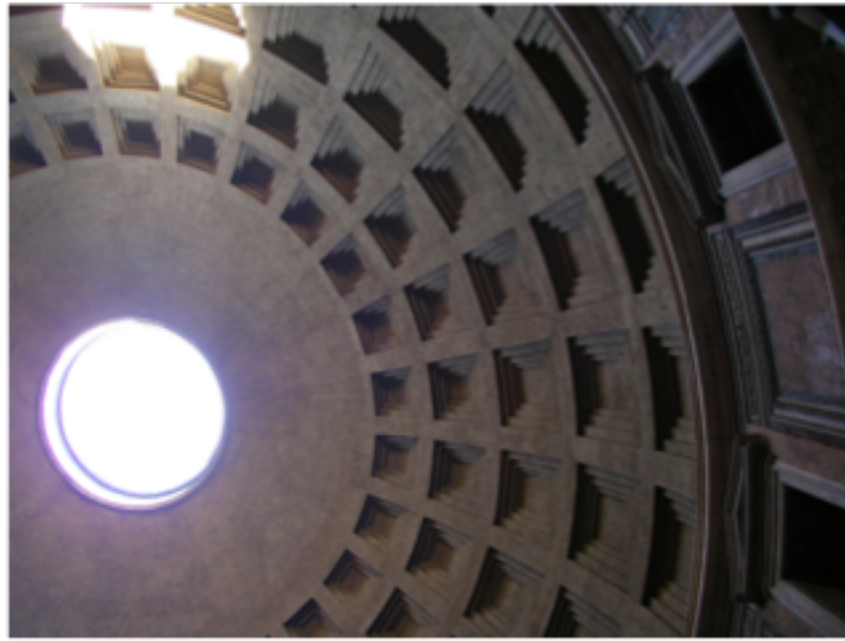
How will built spaces and open landscapes be organised? What transit networks, resource distribution channels and building footprints will occupy a designated area? How will they function?

## Building design

How will individual buildings be structured?



## Building component design



How will each detail element of a building be constructed and arranged?

Generative Parametric Design of Gothic Window Tracery  
Sven Havemann, Dieter W. Fellner





Tiling patterns, Dome of the Rock, Jerusalem, 16th C.

How can order and structure be generated through emergent interactions?

Can you give some examples from nature?

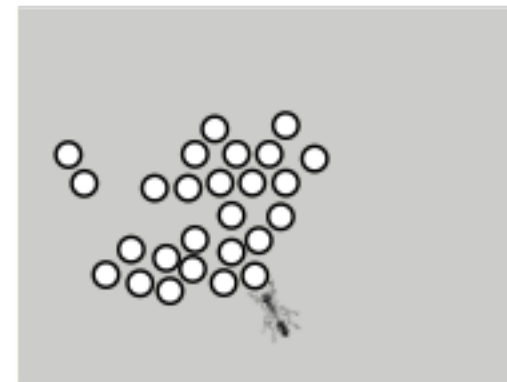
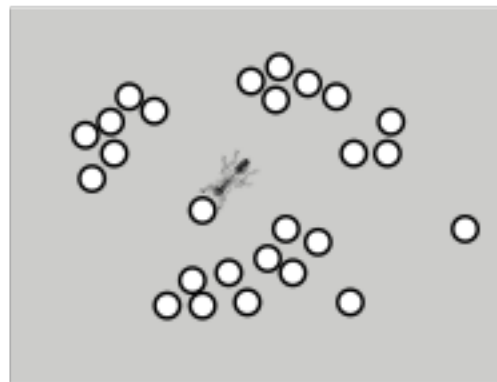
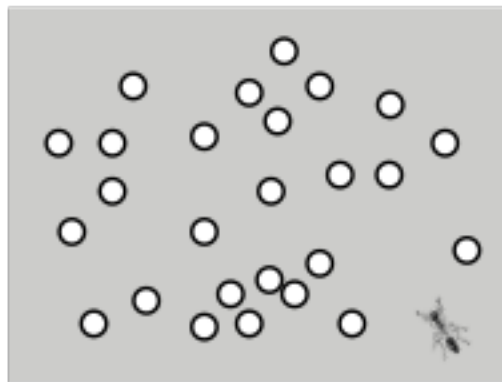
# Generative technique: a simple swarm architecture, the heap

Heap-building rules for ants:

If you find a grain and your jaws are empty, grasp the grain and move or turn randomly a little;

If you find a grain and your jaws are full, drop your grain and move or turn randomly a little;

Otherwise, move or turn randomly a little.



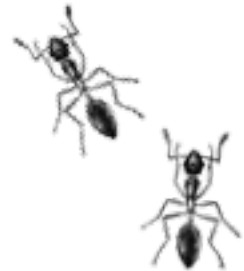


## Sequential algorithms

Regulation of an agent's (building) activity is dependent on the current state of the agent.

Information is not transferred directly between agents.

The agent does *not* respond automatically to local configurations unless internal state criteria are met.



## Stigmergic algorithms

Regulation of an agent's (building) activity is dependent on the current state of the (building) environment.

Information is not transferred directly between agents.

The agent responds automatically to any local configuration.



## Swarm architecture: nest-building algorithm

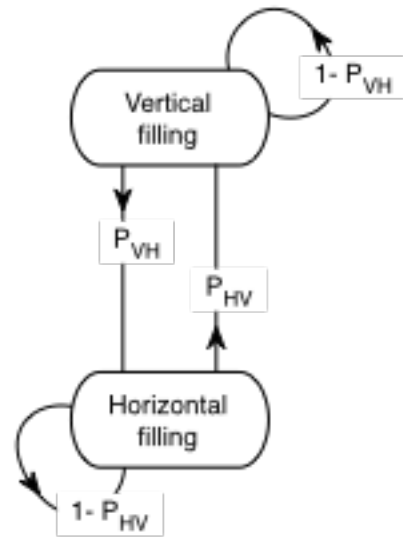
A wasp may act to fill (or not fill) an empty location in a grid.

Only three possible configurations of filled cells surrounding a wasp (in this model) stimulate the filling of the cell the wasp is currently on.

The probability a wasp will fill a cell given some surrounding configuration is given by a probability:  $P_{h1}$ ,  $P_{h2}$ ,  $P_v$ .



## The Sequential Algorithm



The past activities/current state of the wasp determine its building activity. (The local environment only 'authorises' the wasp to fill a cell.)

At a time  $t$ , a wasp may be in state horiz-fill or state vert-fill.

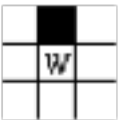

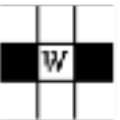
After each filling action of the wasp there is a probability  $P_{vh}$  that it will swap from vert- to horiz-fill (or  $P_{hv}$  that it will swap from horiz to vert-fill).

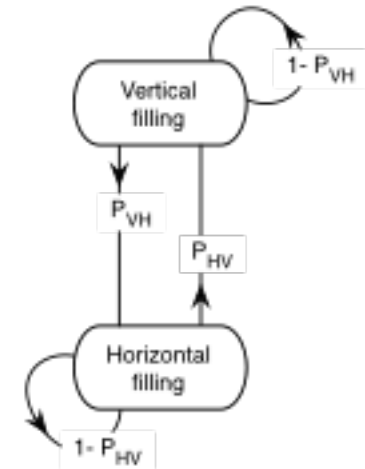
## The Stigmergic Algorithm

The local environmental configuration determines the wasp's building activity.

At a time  $t$ , a wasp may execute a horiz1-fill, horiz2-fill or vert-fill each of which may occur depending on a probability  $P_{h1}$ ,  $P_{h2}$  or  $P_v$  depending on environmental conditions.

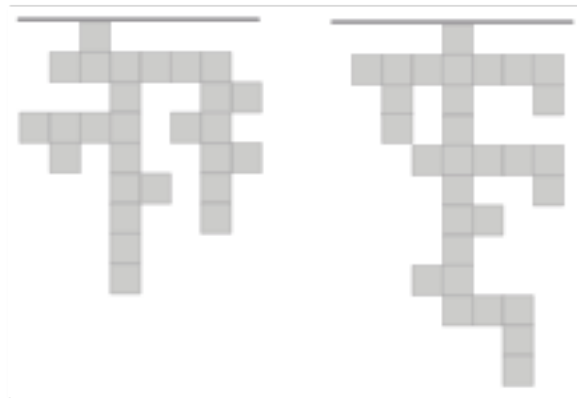
# Sequential and stigmergic algorithm parameters

Local config.				—
Sequential algorithm	0 if S=Horiz	0 if S=Horiz	0 if S=Horiz	0
	1 if S=Vert	1 if S=Vert	1 if S=Vert	0
Stigmergic algorithm	$P_v$	$P_{h1}$	$P_{h2}$	0

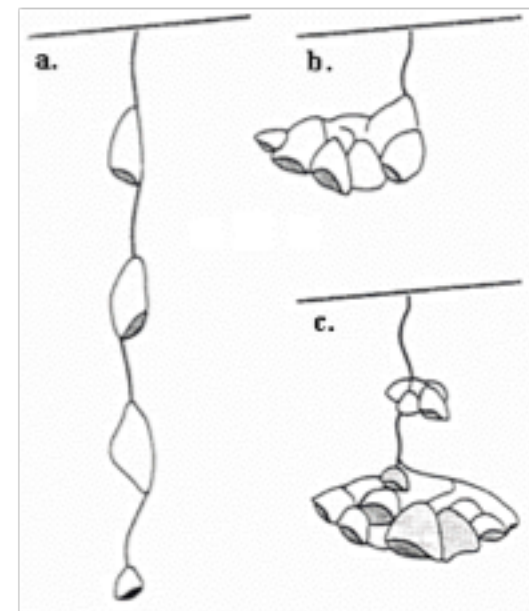
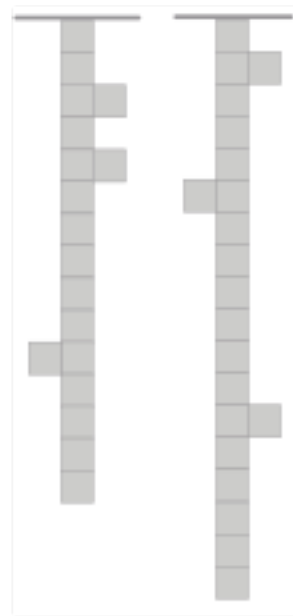


# Swarm nest architecture results

Two sample nest structures generated by simulated wasps employing a *stigmergic* algorithm in a group of size 10.



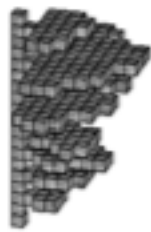
Two sample nests constructed when 10 wasps followed the *sequential* algorithm.



Some real wasps' nests of different species.



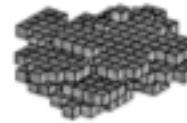
(a)



(b)



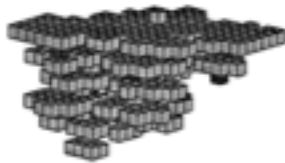
(e)



(f)



(c)



(d)



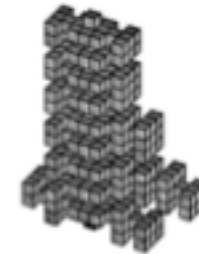
(g)



## Swarm nest architecture results



(i)



(j)



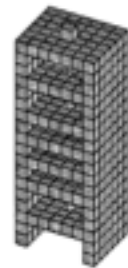
(k)



(l)



(m)



(n)

Simulations of collective building with a 2D lattice swarm. Simulations were made on a 20x20x20 Lattice with 10 wasps.

## Generative technique: ant path construction.



For discussion:

How do ants communicate?

How do ants build paths?

What properties do ant paths have?

What might human urban planners learn from ants?