

ARK-E3020 Sustainable Design Principles

Computational Cycle: Found Form

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Sustainable Design Thinking

BODY

ΔH = M - E ± C ± R

HUMAN REACTOR

SURROUNDING

Regionality local conditions

MANY CLIMATIC ELEMENTS

material & form for micro climatic modulation

active system

passive system

configuration

stable

Science of Energy

ENG

ARCH

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The diagram illustrates the equilibrium between the human body and its surrounding environment. At the top, the 'BODY' is shown with various physiological processes labeled: 'EXHAUSTION', 'METABOLISM', 'HEAT LOSS', 'HEAT GAIN', and 'RESPIRATION'. A central equation reads $\Delta H = M - E + C + R$. Below this, a red box labeled 'equilibrium' contains a complex mathematical formula: $T_b - T_a = \frac{M - E + C + R}{k} = \frac{h_c (T_b - T_a) + h_r (T_b - T_a) + h_{cl} (T_b - T_{cl}) + h_{cl} (T_b - T_{cl})}{k} = \frac{h_c (T_b - T_a) + h_r (T_b - T_a) + h_{cl} (T_b - T_{cl})}{k}$. To the right of this box, text reads 'material & form for microclimatic modulation' and '(PROCESSES OF COMFORT CONSTRUCTION)'. Below the 'BODY' section, the 'SURROUNDING' environment is depicted with labels for 'AIR TEMPERATURE', 'RADIATION', 'AIR MOISTURE', and 'AIR VELOCITY'. A bracket on the right side of the 'SURROUNDING' section is labeled 'MAIN CLIMATIC ELEMENTS'. A quote on the right side of the diagram reads: "Our need for protection is not any different from that of other species. Animals have always had enemies, in particular the climate, and other species seeking to prey upon them." attributed to Mike Hansell, 'Build by Animals: The Natural History of Animal Architecture', Oxford University Press, 2009.

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The image shows a Southern Masked Weaver bird, characterized by its bright yellow body and black face, perched on its cup-shaped nest. The nest is intricately woven from green grass and hangs from a branch. A text box in the upper left corner specifies 'material: grass' and 'construction: weave'. A vertical watermark on the right side of the image reads '@Chris_Easch'. A caption in the bottom right corner identifies the structure as 'nest of Southern Masked Weaver'.

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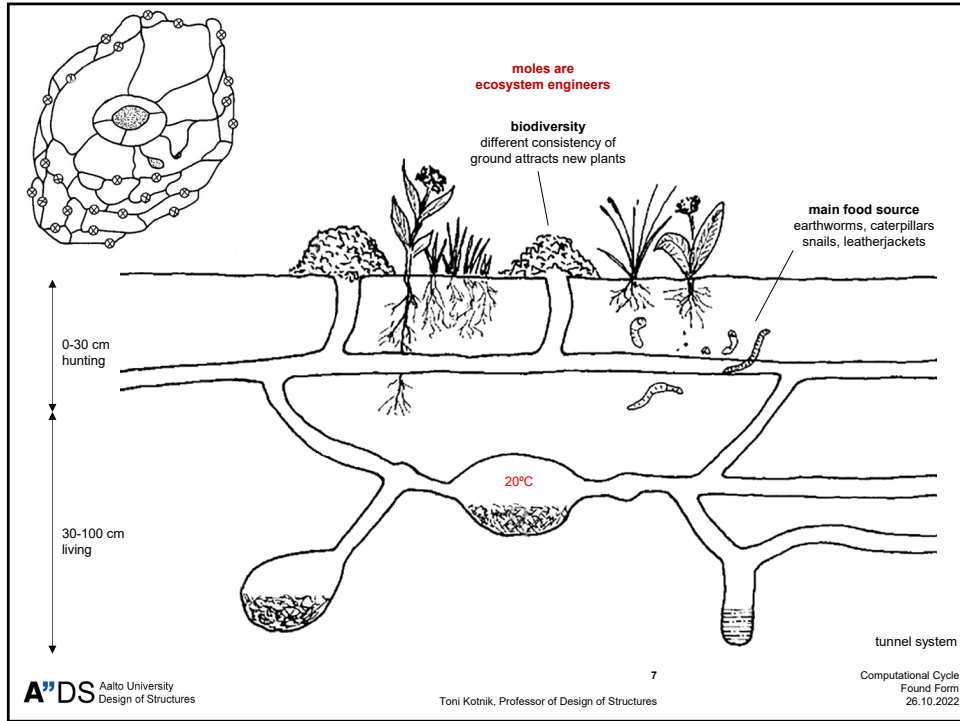
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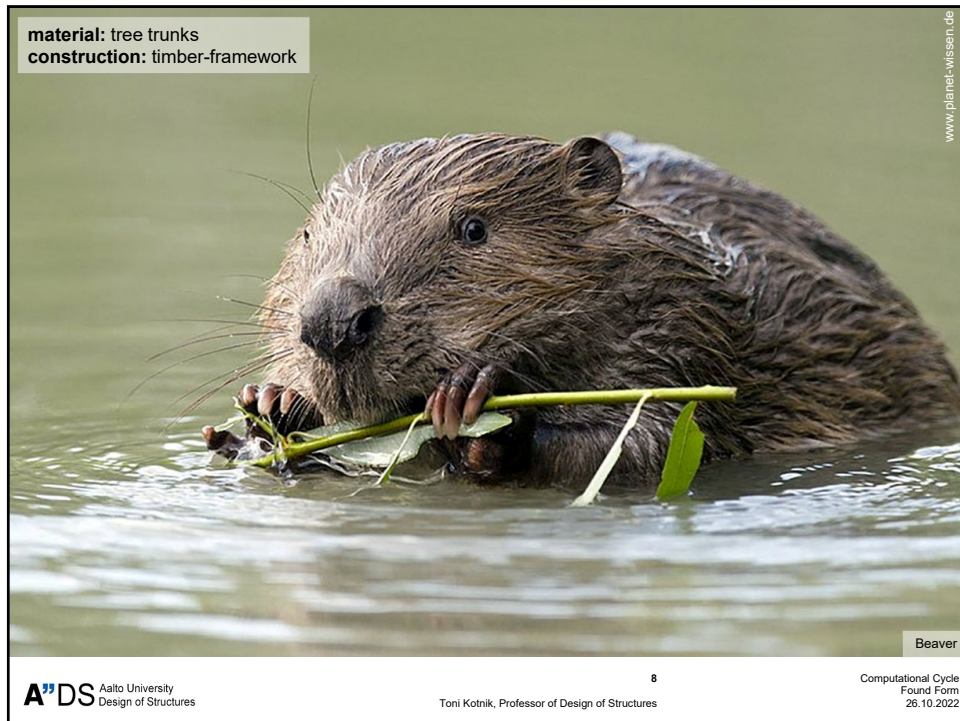
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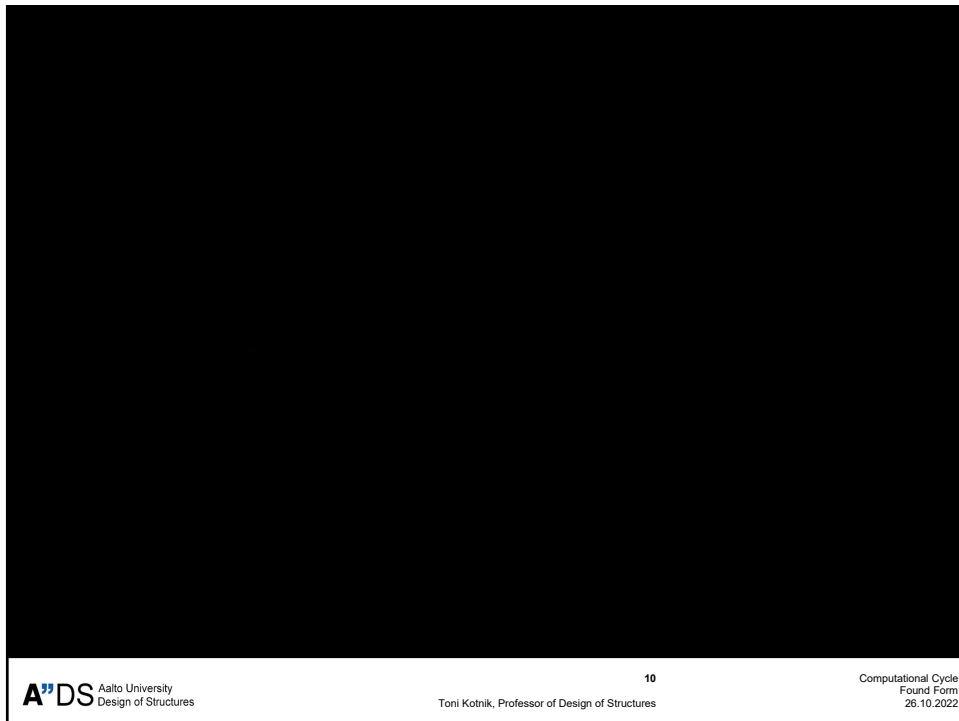
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contextual adjustment

ventilation
high level
low level
cleaning
living
bank structure
embankment
typische Biberburg
dam structure

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Animal architecture
Observation I

$\Delta H = M - E \pm C \pm R$

BODY

SURROUNDING

material & form for microclimatic modulation

"Our need for protection is not any different from that of other species. Animals have always had enemies, in particular the climate, and other species seeking to prey upon them."

Mike Hansell
Build by Animals: The Natural History of Animal Architecture
Oxford University Press, 2009

active system
passive system
configuration

human architecture
many materials
simple geometry

animal architecture
few materials
complex geometry

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Animal architecture Observation II

$\Delta H = M - E + C + R$

BODY

SURROUNDING

building

environment

material & form for microclimatic modulation

feedback loop

every interventions does not only react to its surrounding but also acts upon it!

architecture is ecosystem engineering

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A **negative feedback** loop is a reaction that causes a decrease in function. It occurs in response to some kind of stimulus. Often, it causes the output of a system to be lessened; so, the feedback tends to stabilize the system.

effector

control

sensor

stimulus

sense of discomfort

continue building ...

material & form for microclimatic modulation

... till it functions

feedback loop

Norbert Wiener: Cybernetics or Control and Communication in the Animal and the Machine, 1948

HEATING PROCESS ACTIVATED (Shivering)

COOLING PROCESS ACTIVATED (Sweating)

Body temperature decreases

Body temperature increases

Body temperature increases

Body temperature decreases

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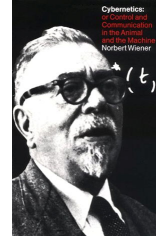
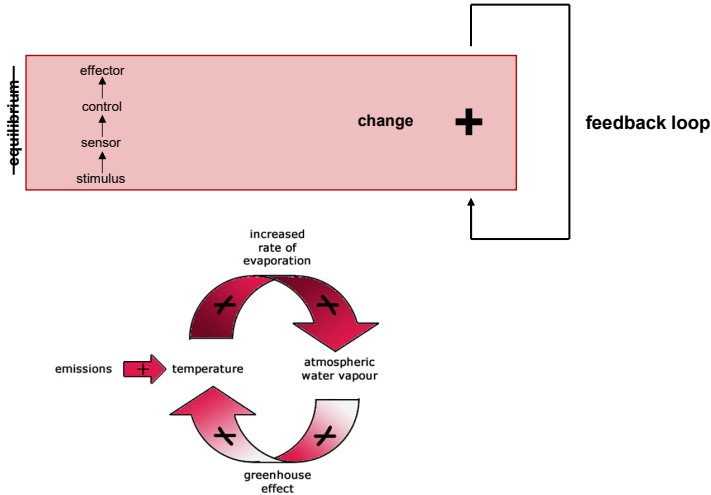
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A **positive feedback** loop is a reaction that causes an increase in function. It occurs in response to some kind of stimulus and causes the output of a system to be enhanced; so, the feedback tends to exacerbate small disturbances.



Norbert Wiener: *Cybernetics or Control and Communication in the Animal and the Machine*, 1948

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positive feedback



synchronized crowd behavior in emergency

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Feedback complex behavior

A SOURCE NEST

B SOURCE NEST

C SOURCE NEST

D SOURCE NEST

Legend:

- Red T-bar: Negative feedback
- Green arrow: Positive feedback
- Ant with yellow: Loaded ant
- Ant: Unloaded ant
- Yellow circle: Food

Labels in diagram:

- Cross-inhibition between trails
- Trail reinforcement
- P_2 , P_1
- Crowding, Food depletion, ...
- Filling of food reserve, Limited number of potential recruits, ...

Detrain, C & Deneubourg, JL: *Self-organized structures in a superorganism: do ants "behave" like molecules?*, Physics of Life Reviews, 3 (2006), 162-187

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material: sand
construction: glue

Giant Termite (*Mastotermes*)

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termite mound of *Macrotermes michaelseni*



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three challenges

- regulation of temperature
- regulation of humidity
- CO₂ concentration

outer nest wall
chewed wood
fungus comb
royal cell
supporting pillar
nursery

termite mound of *Macrotermes michaelseni*

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three challenges

- regulation of temperature
- regulation of humidity
- CO₂ concentration

CO₂ (%)

Hour of day

Legend: Nest (red circle), 1 m (green square), 2 m (blue triangle)

termite mound of *Macrotermes michaelseni*

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convection cell following oscillating thermal schedule

- temperature in nest is around $30^{\circ}\text{C} \pm 2^{\circ}\text{C}$ the whole day
- CO_2 concentration stable due to continues exchange of air

schematic airflow in termite mound

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Animal architecture
Observation III

human architecture
 isolation between out & in
 mech. control of indoor climate
 closed system

HVAC

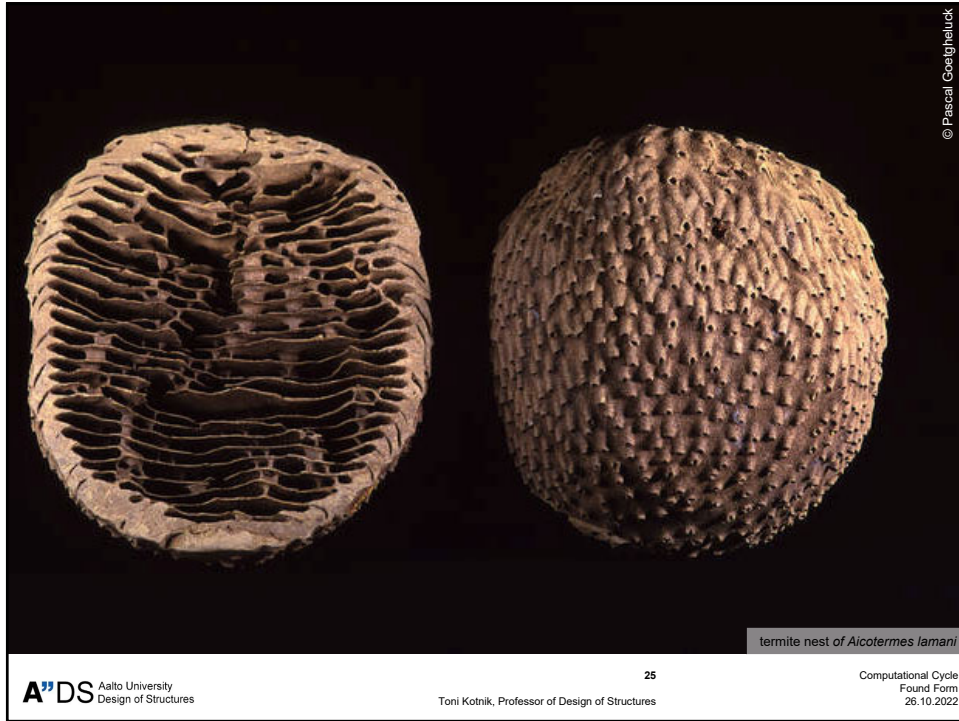
"Our need for protection is not any different from that of other species. Animals have always had enemies, in particular the climate, and other species seeking to prey upon them."
 Mike Hansell
 Build by Animals: The Natural History of Animal Architecture
 Oxford University Press, 2009

animal architecture
 porosity between out & in
 passive control of indoor climate
 open system

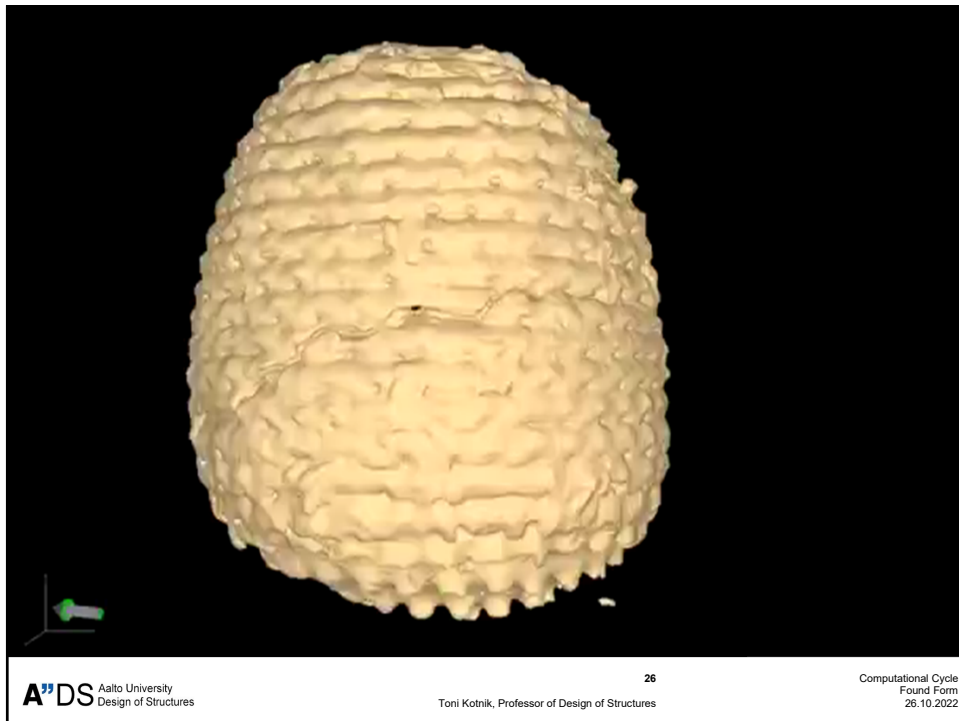
dynamic equilibrium

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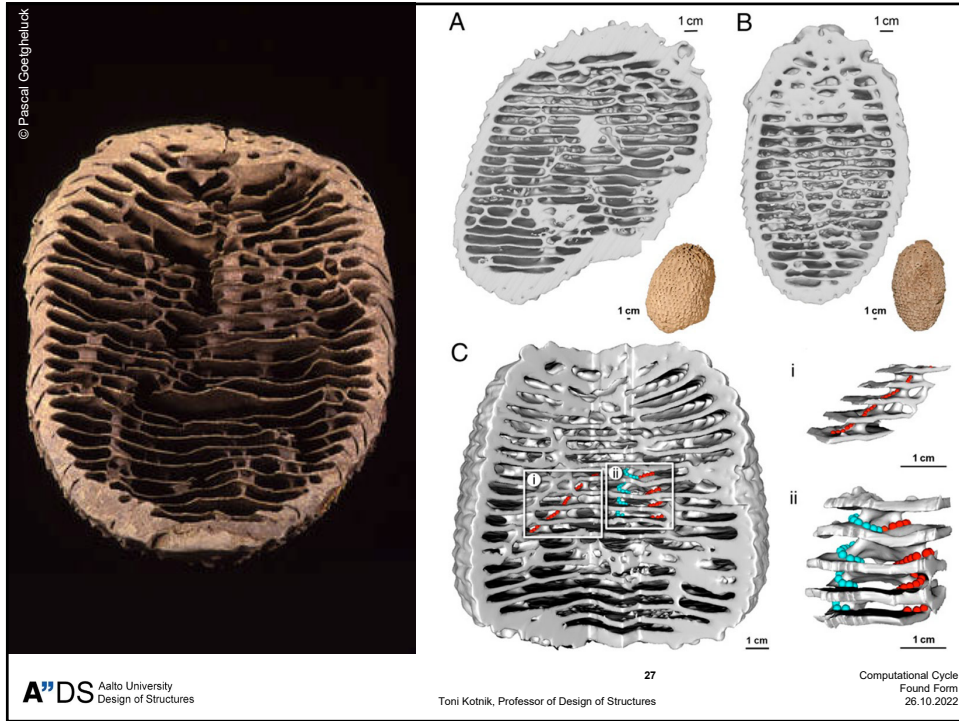
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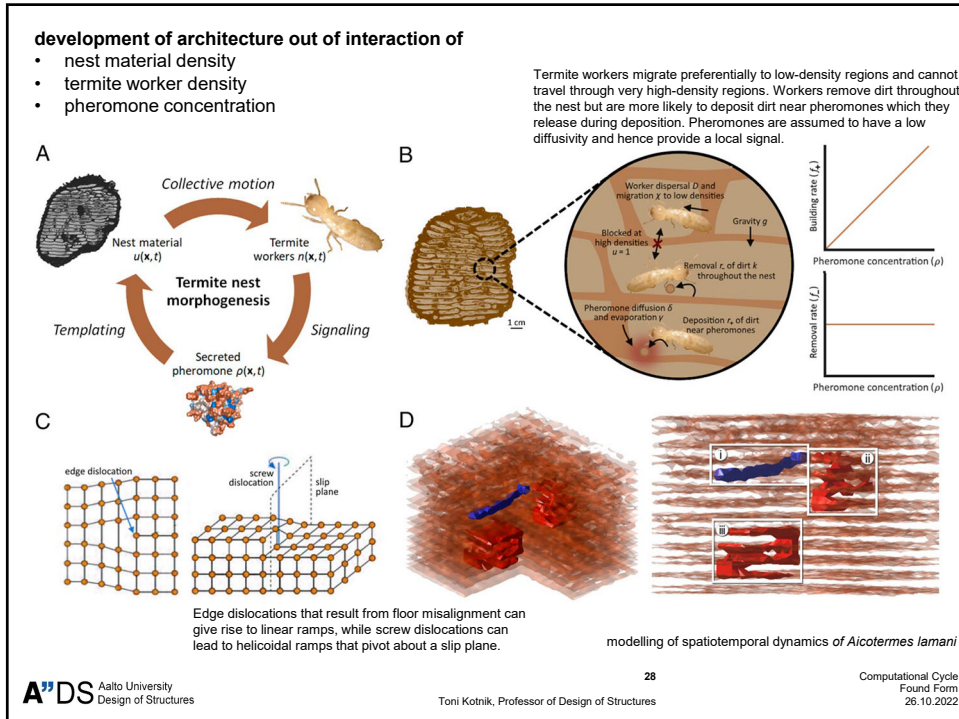
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development of architecture out of interaction of

- nest material density
- termite worker density
- pheromone concentration

A

Termite nest morphogenesis

Collective motion: Nest material $u(x,t)$ → Termite workers $n(x,t)$

Signaling: Termite workers $n(x,t)$ → Secreted pheromone $\rho(x,t)$

Templating: Secreted pheromone $\rho(x,t)$ → Nest material $u(x,t)$

feedback loop

- material property
- behavior (as simple rules)
- environmental information

modelling of spatiotemporal dynamics of *Aicotermes lamani*

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Animal architecture Observation IV

human design top-down process

define form

from global to local

Architectural Units of Analysis: 2D Building Elements Plan & Elevations, 3D Building Form

Urban Planning Units of Analysis: Cluster of Buildings (e.g., City Block), Cluster of Blocks (e.g., Neighborhood), City

Design & Planning Scales

Micro Scale, Topographical Scales (Natural and artificial topography according to micro and macro topographic scales), Macro Scale

animal design bottom-up process

find form

from local to global

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Animal architecture
view from the outside

Observation I

from material multiplicity to geometric complexity
materials are expensive, form is cheap

Observation II

architecture is ecosystem engineering
architecture is prosthetic nature

Observation III

from static isolation to dynamic porosity
architecture as an open system of fluid exchange

Observation IV

from top-down control to bottom-up process
architecture as adaptive generation to environmental conditions