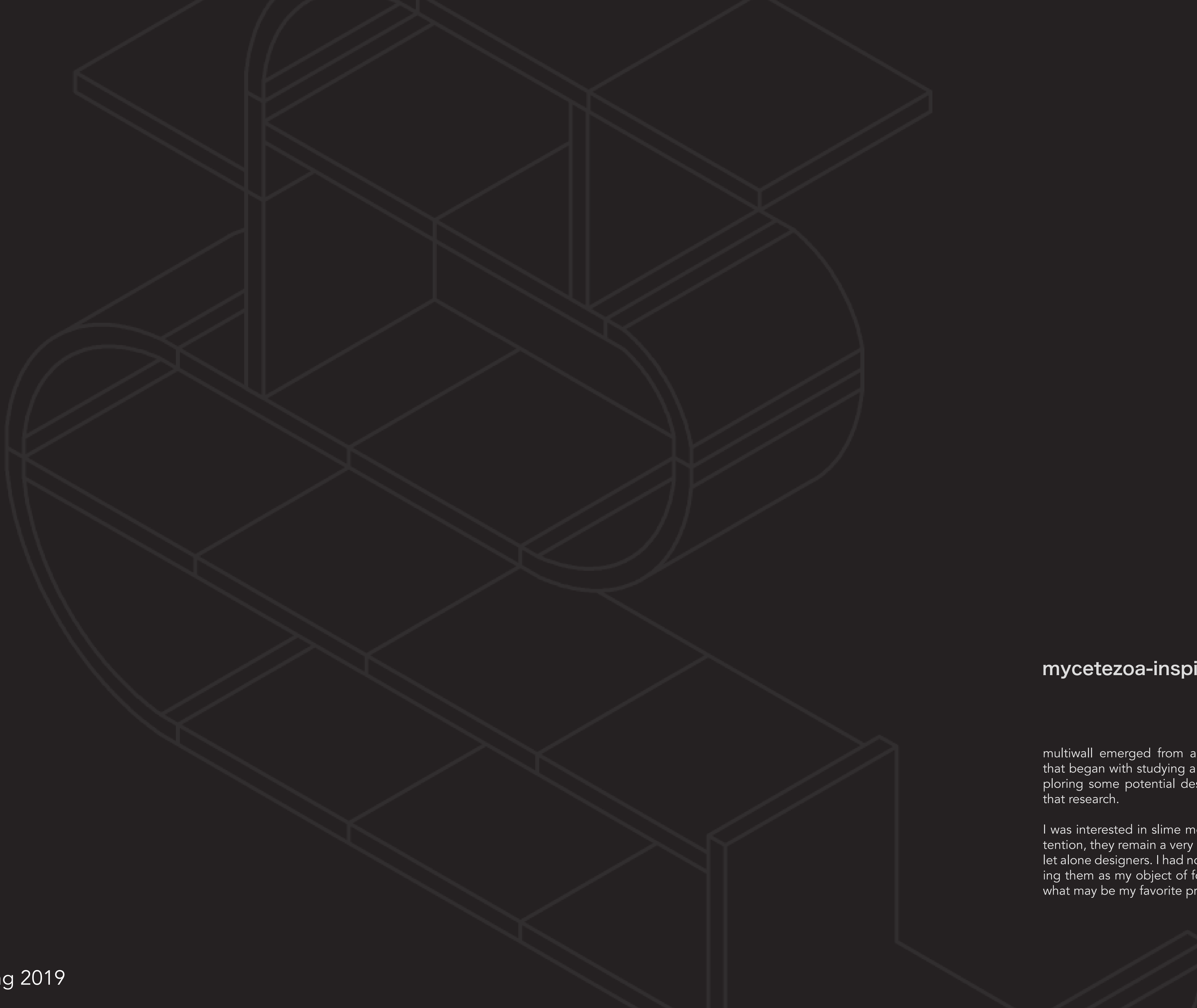


multiwall

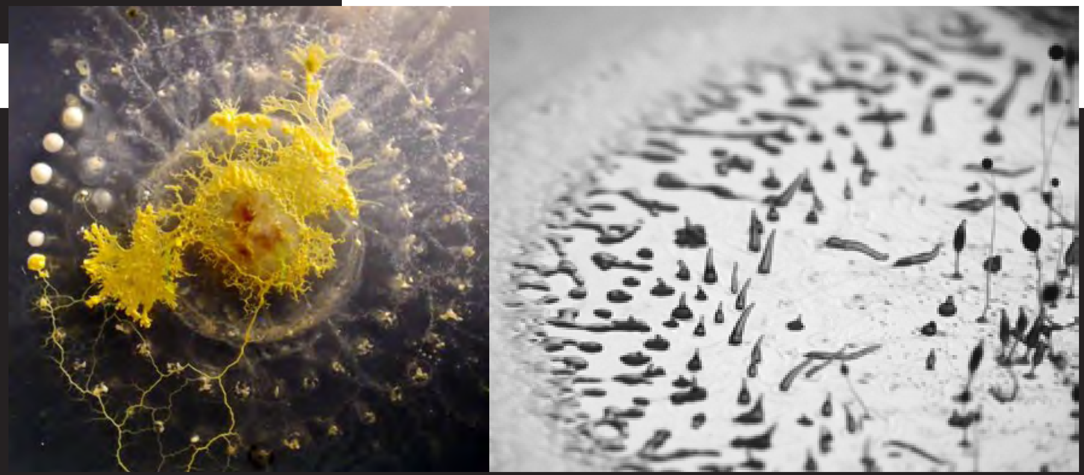
mycetezoa-inspired modular construction

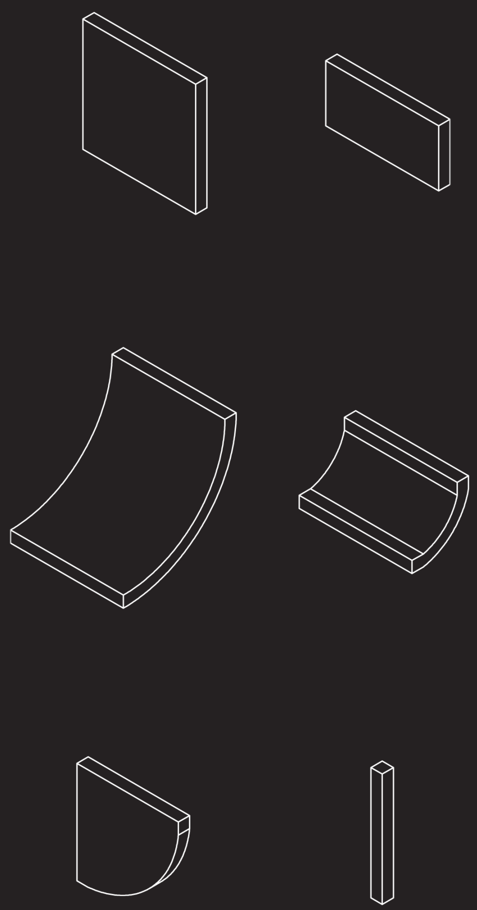
multiwall emerged from an open-ended biomimicry design process that began with studying a biological phenomenon of interest and exploring some potential design applications inspired by the results of that research.

I was interested in slime molds in part because despite some brief attention, they remain a very mysterious group of organisms to scientists, let alone designers. I had no prior design solutions in mind when selecting them as my object of focus, but the process that followed yielded what may be my favorite project in this collection.

Spring 2019

multiwall



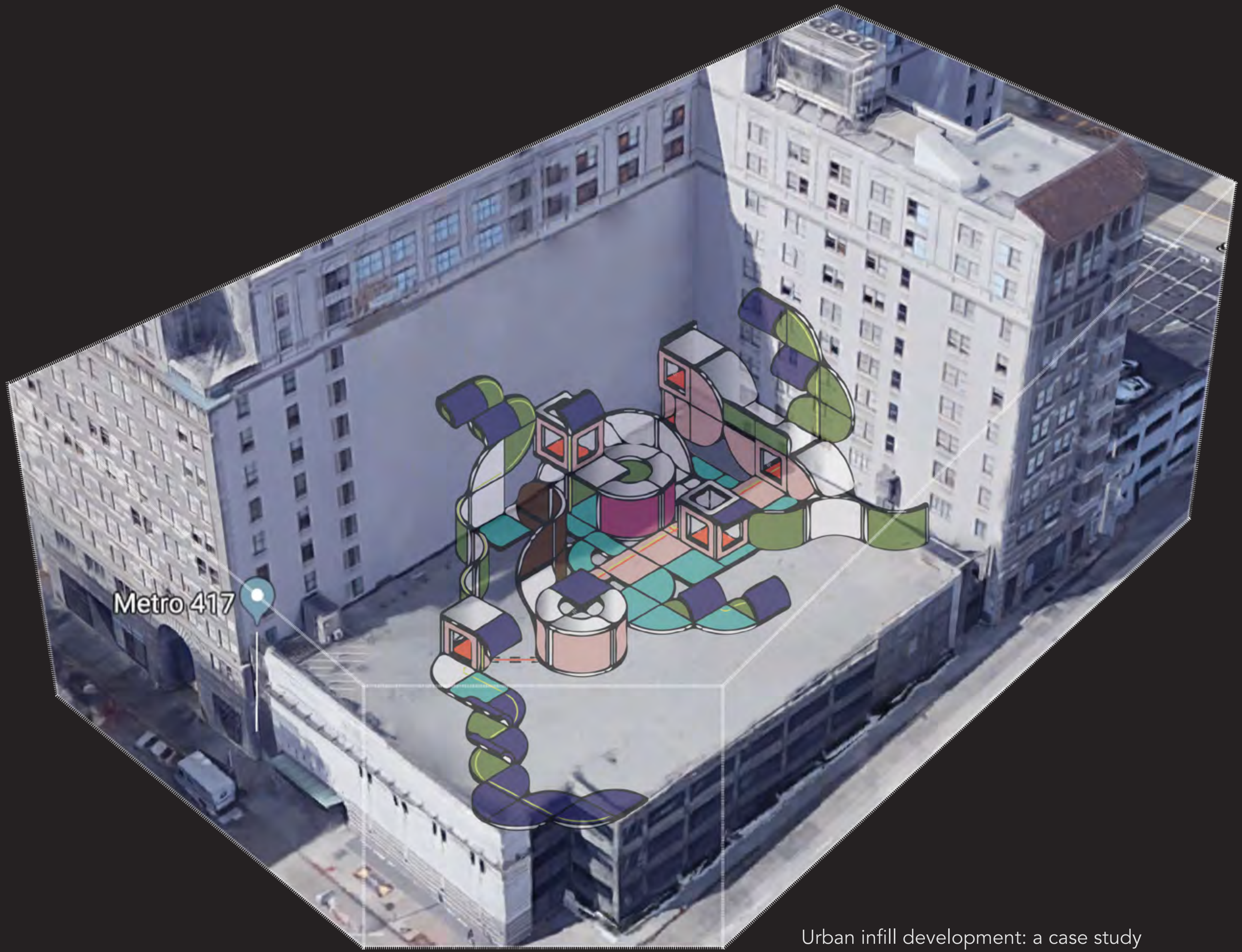


The six **multiwall** panels

MULTIWALL is an approach to modular construction informed and inspired by the Mycetozoa, aka "slime molds."

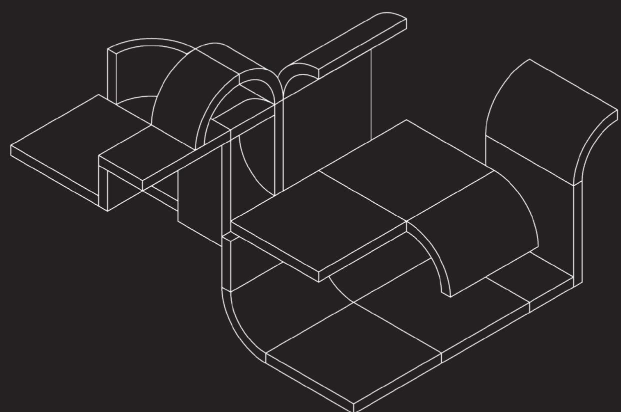
Like these molds, the panels can be combined into ambulating shapes that morph between private and public spaces, between interiors and exteriors.

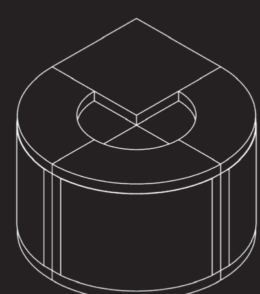
The panels do not differentiate between use as ceiling, wall, or floor. Once installed, they can be equipped with claddings, fittings, fixtures, and internal fillings and pipings to establish their role in the building - but they are always ready to become something new.

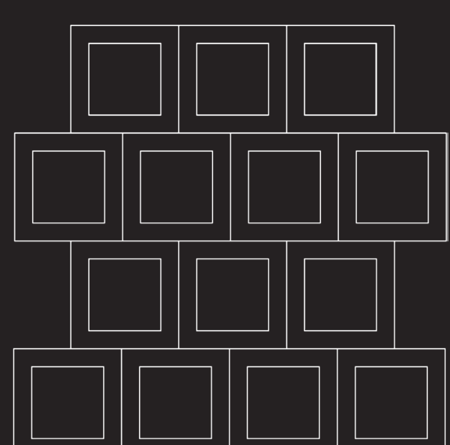


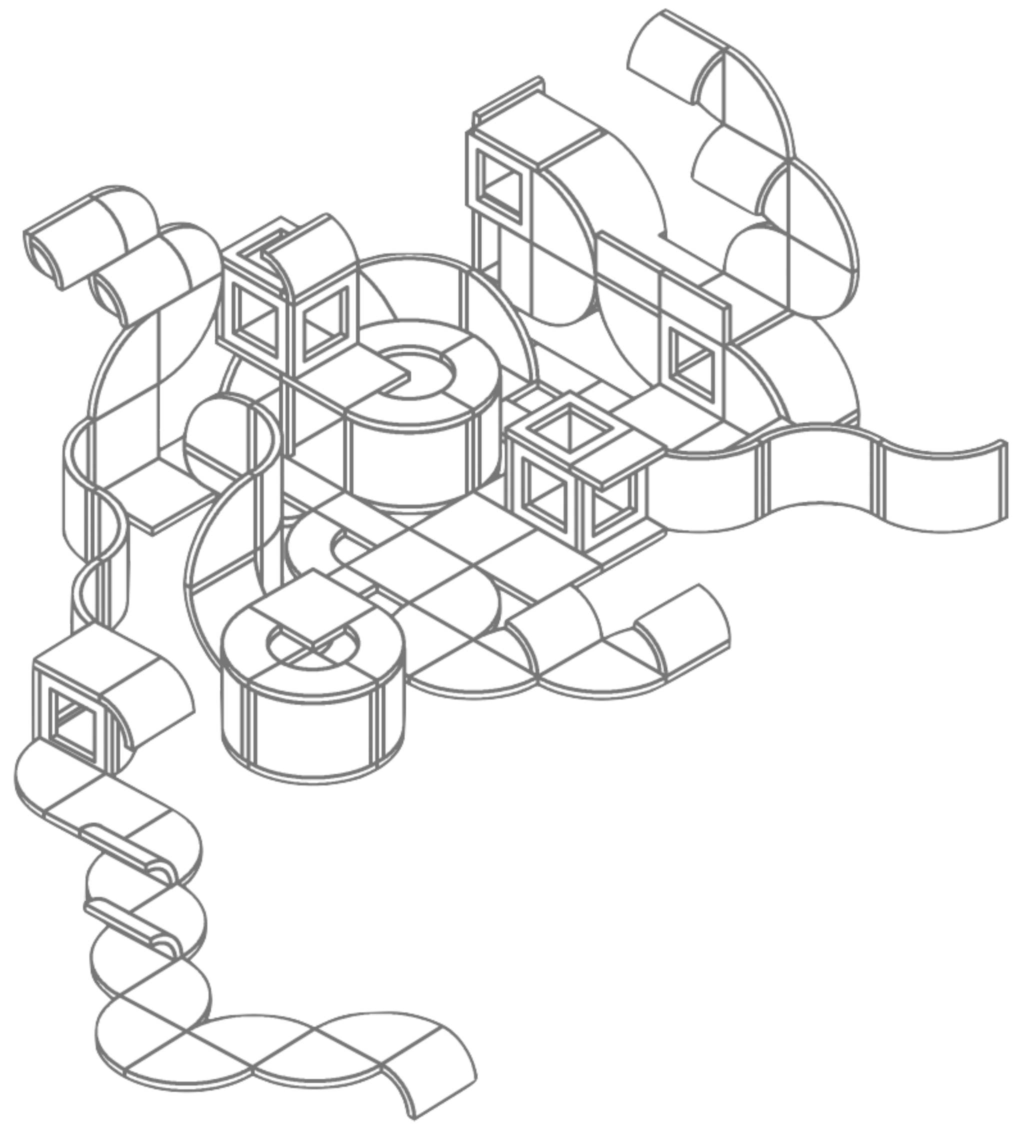
Urban infill development: a case study

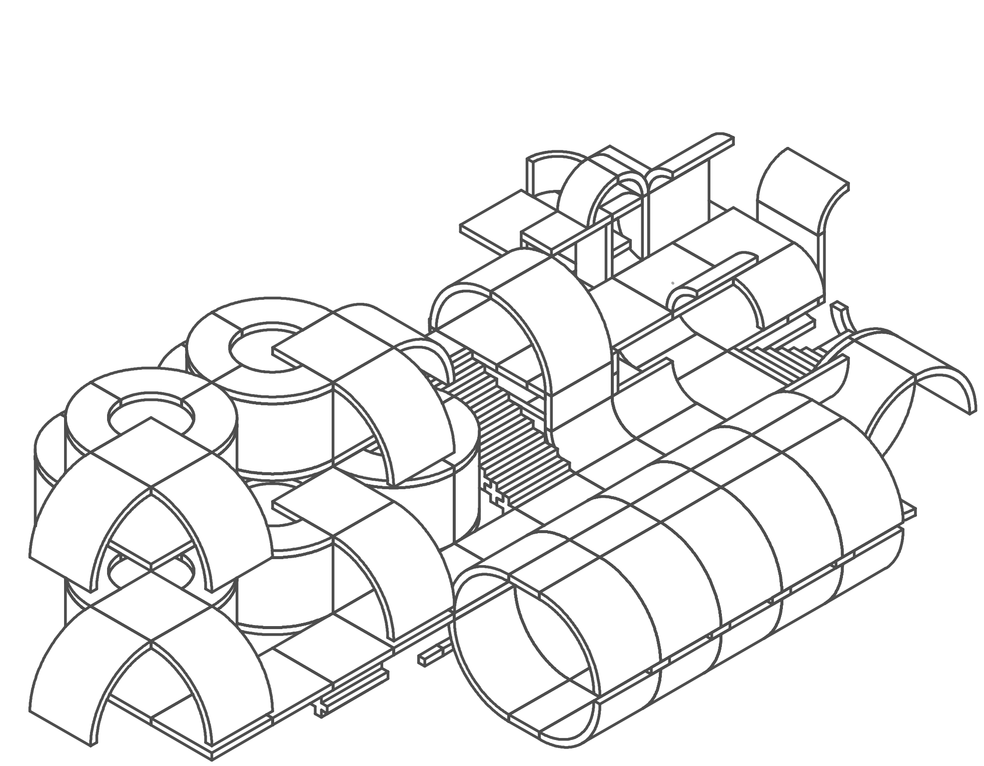
order







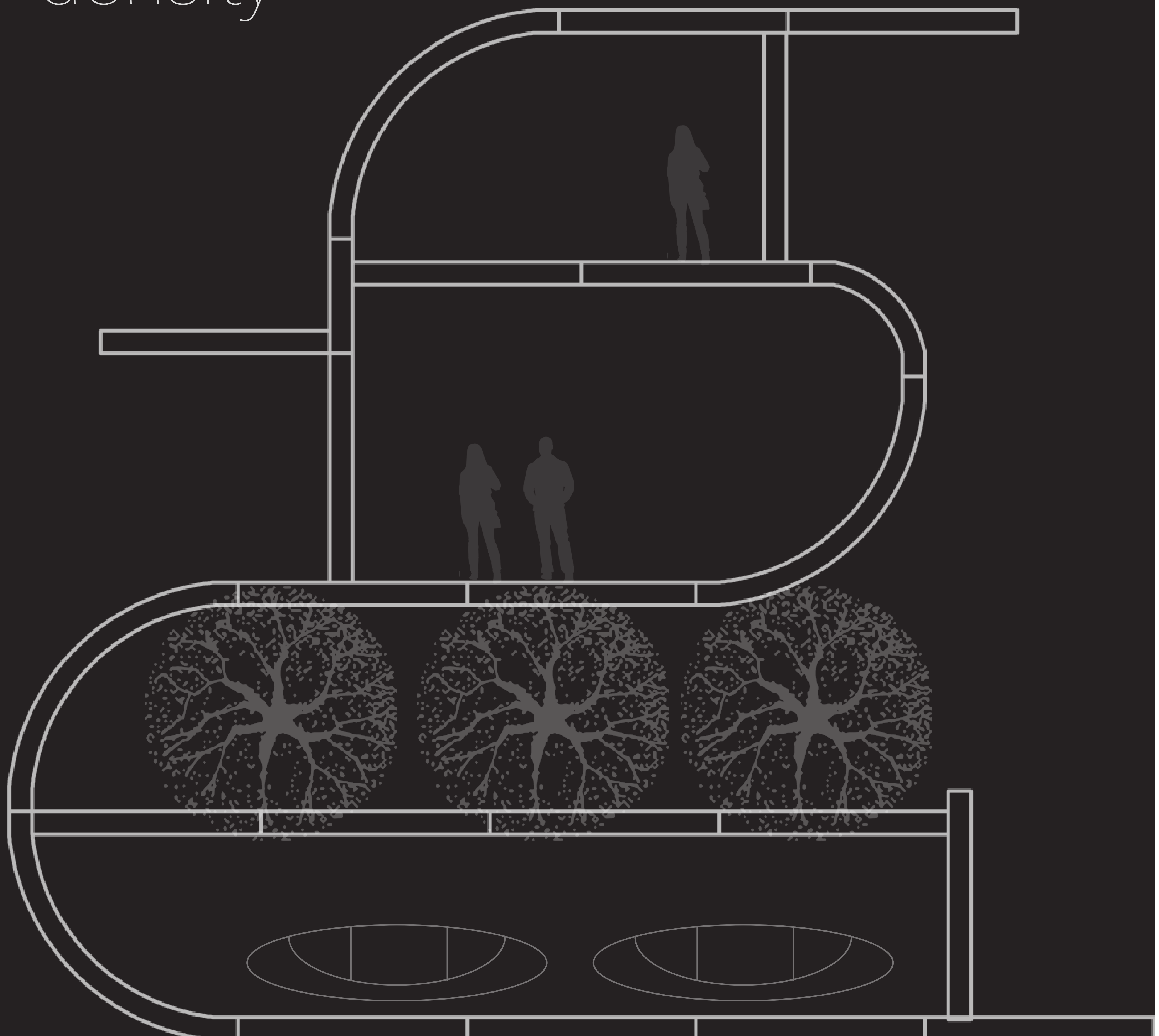


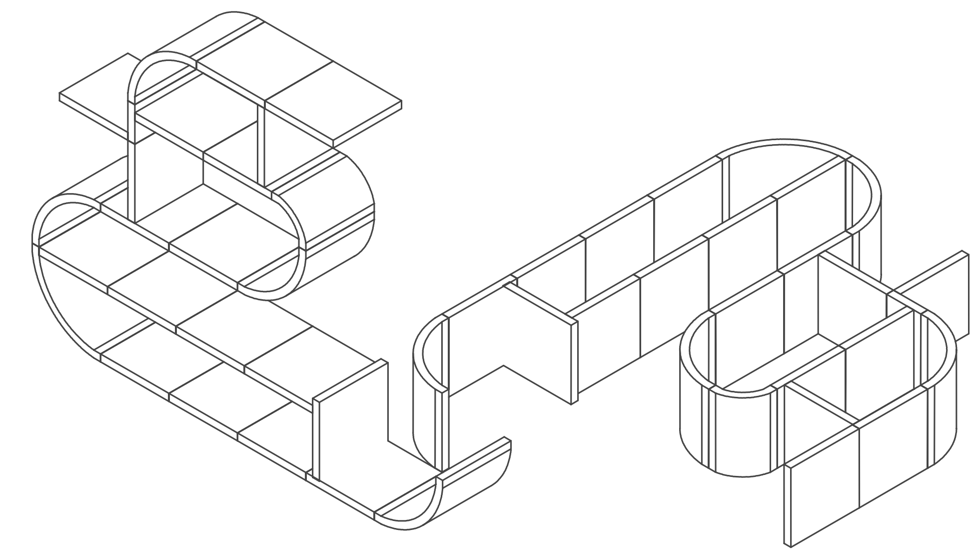


Depending on the community profile, site, and usage needs, the modules may take on a wide variety of forms. In general, the organization of these forms can be thought of as ranging from increasingly anarchic, decentralized, and opportunistic (chaotic/random) to increasingly planned, controlled, and monitored (ordered/designed).

Different formal languages that define certain usage zones may flow and transform into each other abruptly or with imperceptible gradation, but in both cases the essential rhythmic continuity of the panel geometry persists.

density



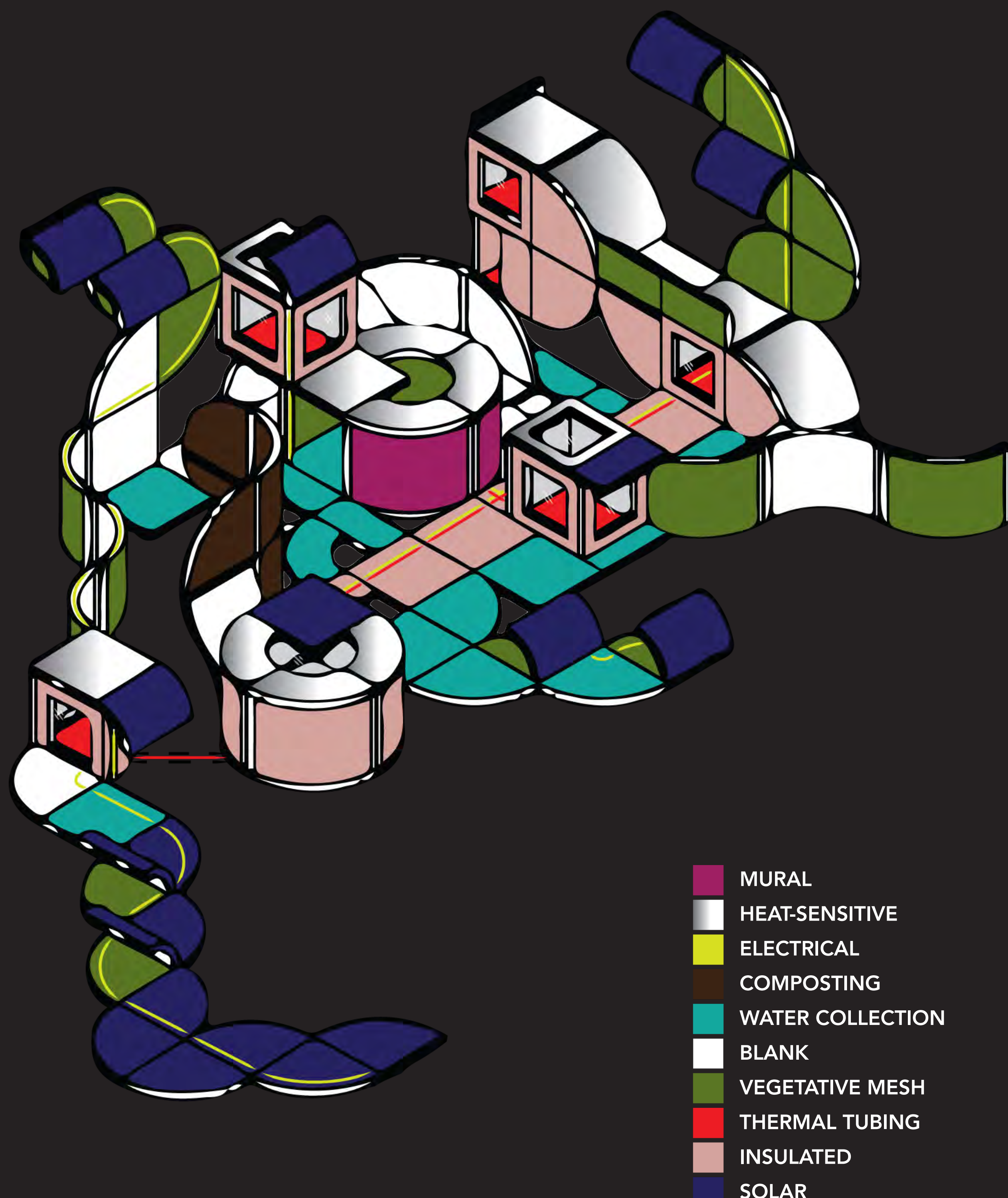


The figure to the left might be interpreted as either elevation or plan. The panels can weave back on themselves to partition off space in a visually interesting manner that may proceed along multiple axes.

For example, consider a startup that begins with a modest arrangement of panels. As they grow, their workspace grows organically with them.

Live structural sensoring might adapt with the addition of each panel, showing particularly good places to consider expansions and facilitate structurally sound vertical growth.

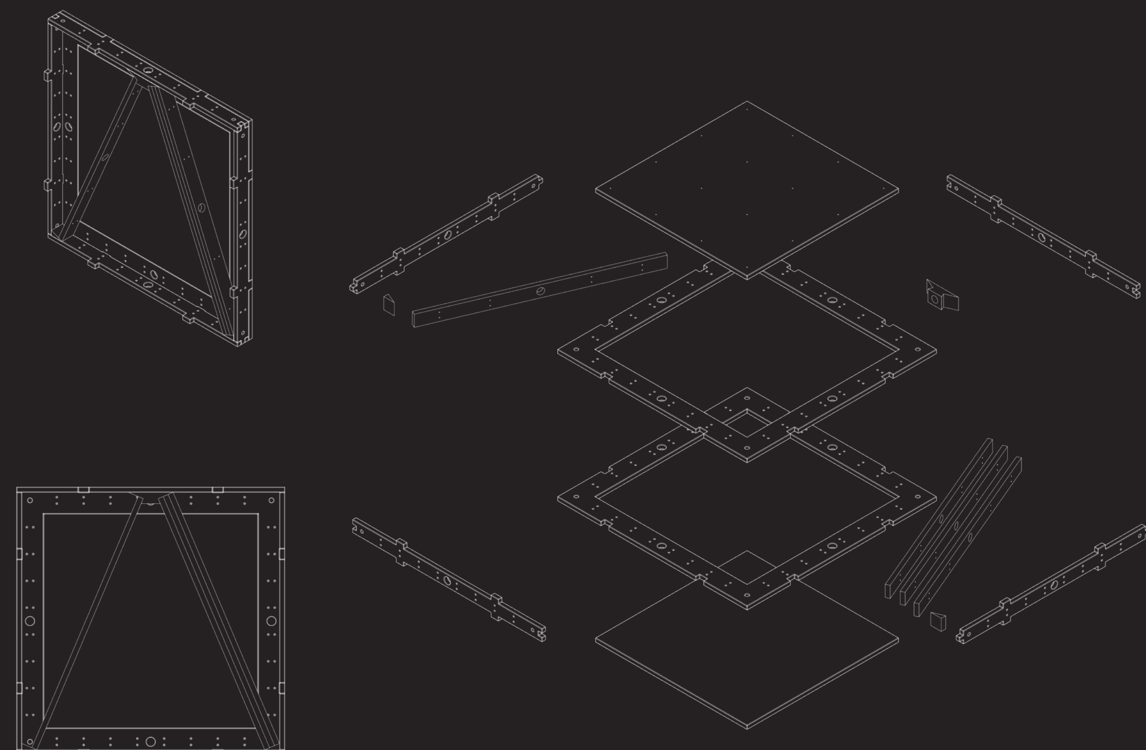
adaptability

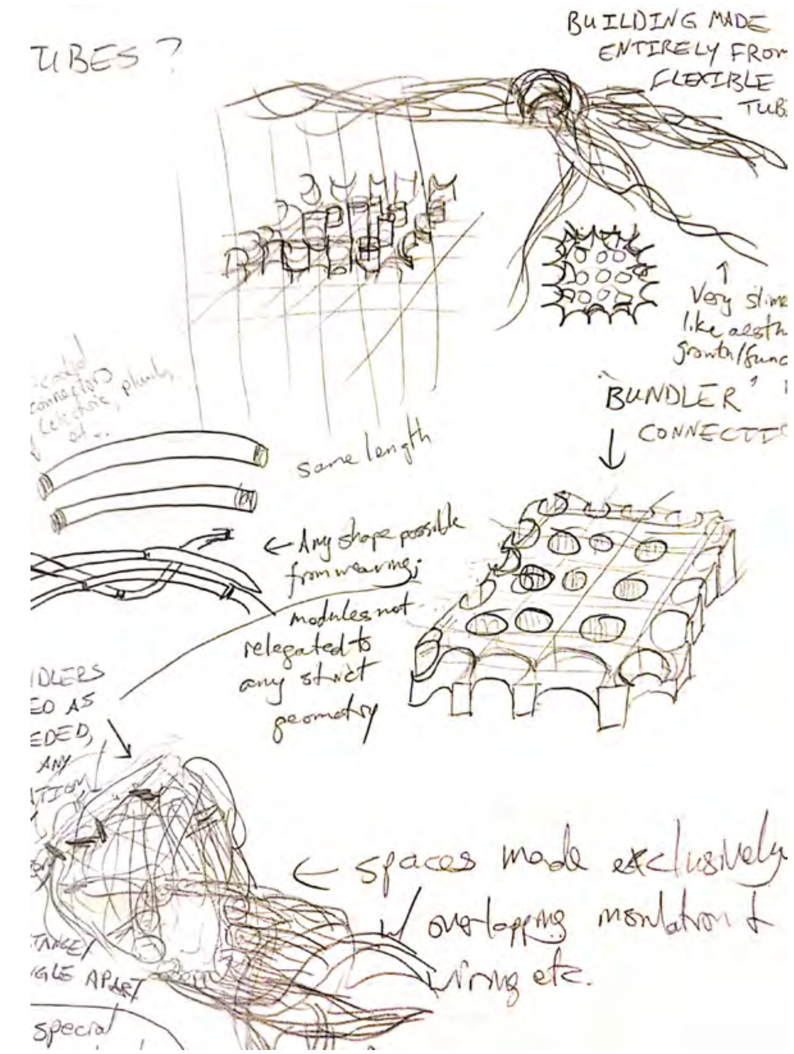


The panels can be modified with a variety of types of cladding or internal pipings and fillings. Attaching heat and pressure etc. sensors to the panels might enable real-time analysis of how efficiently certain rooms are heated, where air tends to accumulate etc.

This information could help guide adjustments to the infrastructure of the system, redirecting resources as necessary and identifying the most resource-efficient areas for expansion.

evolution





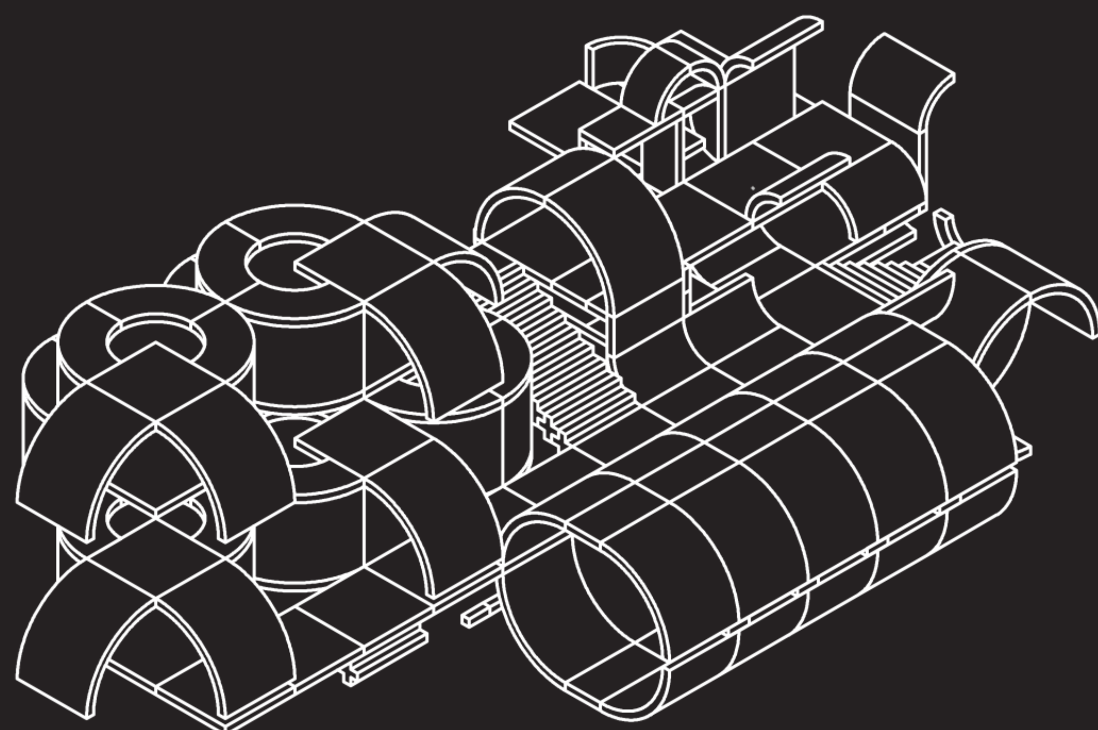
STANDARD FLAT PANEL

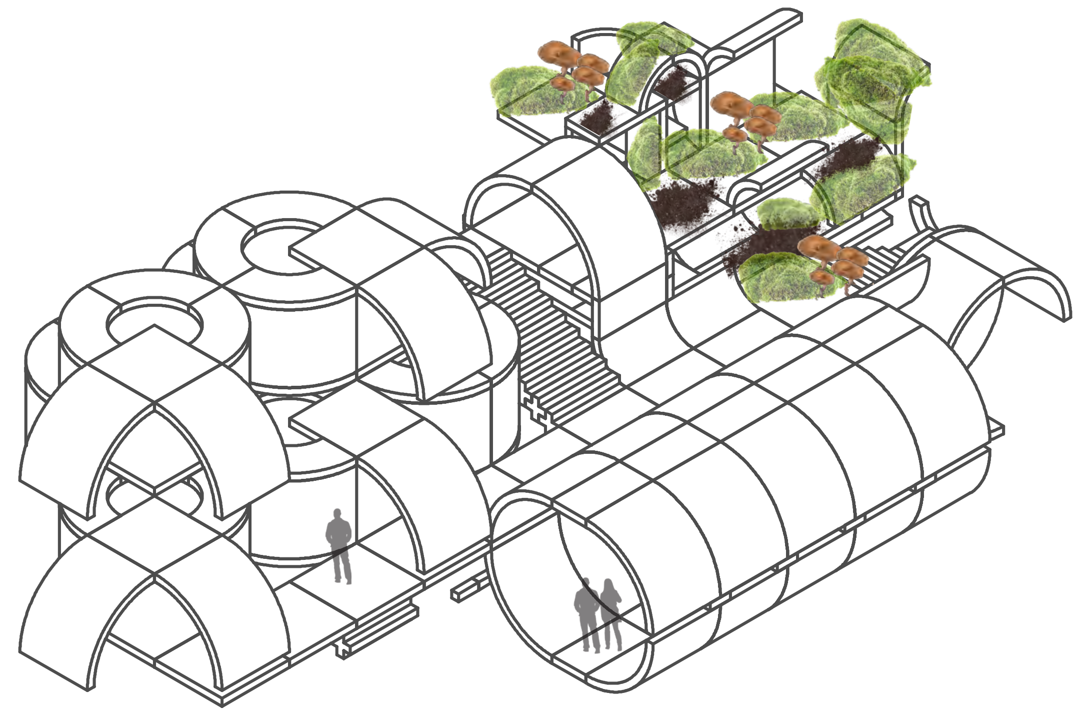
GROSS DIMENSIONS: 250cm x 250cm x 25cm
PROPOSED MATERIAL: Cross-laminated timber (prototype phase)
TOTAL PIECE COUNT: 8-17 (depending on trussing elements)
CONNECTION: Friction fit for pieces, standard hardware (bolt/nut) between panels

While this initial iteration proposes a conventional wooden frame, the system as a whole may “evolve” into increasingly organic and fluid construction methods using biological materials that “grow” into position.

As an intermediate step, perhaps the panels could be connected with a sort of structural tubing, breaking the orthogonal imperative of the current geometric logic. These tubes might then be the lattice for a growth-based construction.

decay and rebirth





With the evolution of multiwall as a system, prior iterations and heavily-used panels may become obsolete. Perhaps as the modules trend towards safe biological materials, no longer needed regions could be left to a "controlled burn" - allowing reclamation by nature in a fashion that efficiently decomposes unneeded material while providing greenery, food, or other resources.

design process documentation

RESEARCH
IDEATION
PROTOTYPING

multiwall emerged from an open-ended biomimicry design process that began with studying a biological phenomenon of interest and exploring some potential design applications inspired by the results of that research.

I was interested in slime molds in part because they remain a mysterious group of organisms to scientists. I had no prior design solutions in mind when selecting them as my object of focus.

Inspiration came partly from a building I saw in a dream after much time spent reading about slimes.

slime molds
MYCETEZOA

STRUCTURAL ADAPTABILITY
MODULAR | AMODULAR LIMINALITY
DECENTRALIZED COMMUNICATION

DOMAIN:	Eukaryota
(UNRANKED):	Unikonta
(UNRANKED):	Amoebozoa
SUBPHYLUM:	Conosa
INFRAPHYLUM:	MYCETOZOA

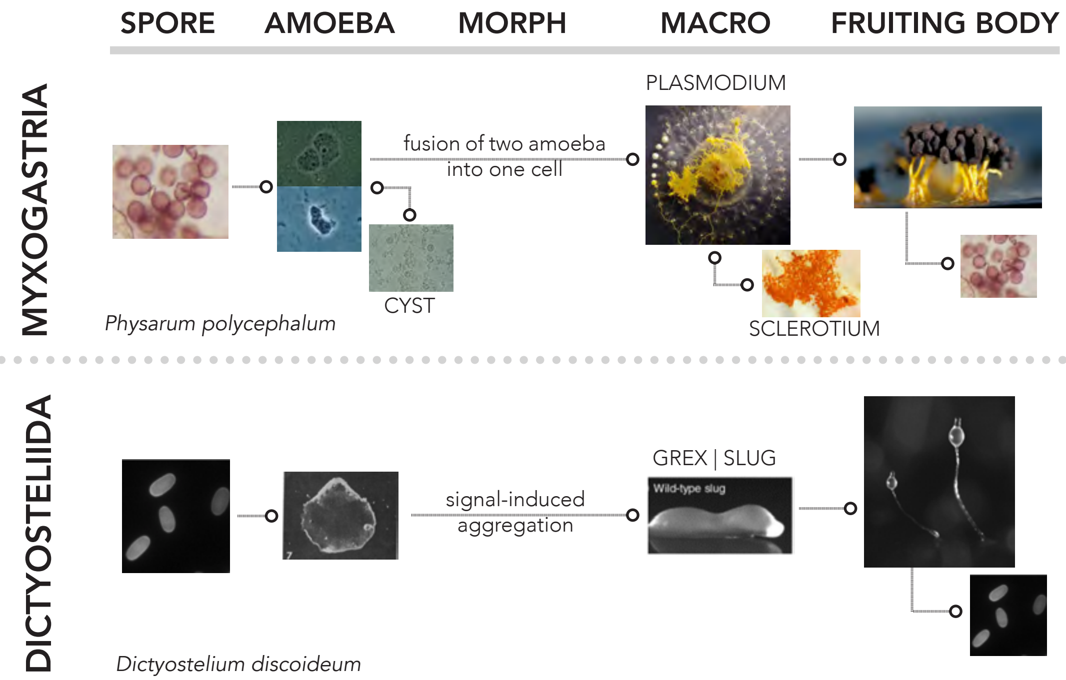
The slime molds are a collection of single-celled **eukaryotic organisms** that have repeatedly defied easy categorization. They are known for the production of fruiting bodies that release **spores** and for either **swarming** behavior (the "social amoebas") or for sprawling **symplasms** in which a single-celled individual grows to an immense size. In all cases, species have a variety of **morphologic phases** undergone in response to stimuli.

The name **mycetezoa** roughly means "fungus animals." Slime molds were originally classified under kingdom Fungi but are now part of the informal Protista kingdom, which contains a variety of hard-to-categorize eukaryotes. Research is ongoing, with some suggesting they are their own kingdom - alongside plants and animals.

Currently, "true" slime molds are found under **Amoebozoa**, where they are split into three classes: **MYXOGASTRIA**, **DICTYOSTEIIIDA**, and **PROTOSTELEA**.

LIFE CYCLE

All three classes of mycetezoa have analogous life cycles and morphological variations, but there are some critical differences, particularly between Myxogastria and Dictyosteliida.



REFERENCES

http://www.hiddenforest.co.nz/slime/what.htm
https://en.wikipedia.org/wiki/Slime_mold
https://www.pnas.org/content/94/22/12007.long
https://bio.libretexts.org/Bookshelves/Introductory_and_General_Biology/Book%3A_General_Biology_(Boundless)/23%3A_Protists/23.2%3A_Characteristics_of_Protists/23.2B%3A_Protist_Life_Cycles_and_Habitats#Plasmodial_slime_molds
https://www.wired.com/2010/01/slime-mold-grows-network-just-like-tokyo-rail-system/
https://www.autodesk.com/redshift/bionic-design/

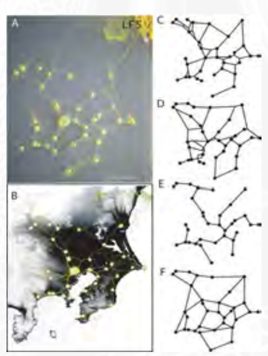
See images page for image references

GENERAL FACTS

DISTRIBUTION:	worldwide
HABITAT:	terrestrial (forest)
CLIMATE:	temperate	cool
FUNCTION:	decomposers
DIET:	fungus spores	bacteria
KNOWN SPECIES:	~900

DESIGN CASE STUDIES

TOKYO METRORAIL



In 2010, Dr. Toshiyuki Nakagaki of Hokkaido University arranged food in a pattern analogous to major population centers in Tokyo and installed Physarum polycephalum nearby. The plasmodium created a feeding network with remarkable similarity to the Tokyo metrorail networks.

AIRBUS PARTITION

In 2015, architect David Benjamin used algorithms of slime mold and bone growth patterns in generative design software to develop a lightweight, low material "bionic" airplane cabin partition for Airbus.

MYXOGASTRIA

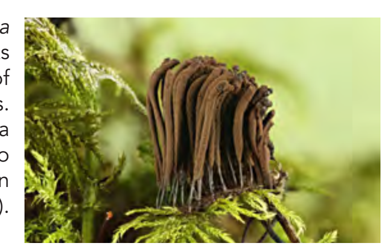
Unicellular symplasms: division without end

Myxogastria are single-celled, but exhibit a wide variety of growth behaviors in response to various stimuli. They can morph by dividing their nucleus without dividing the cell.

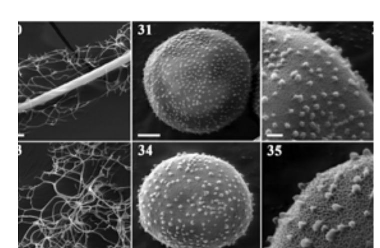
Clockwise from top left: *Hemitrichia serpula* (plasmodiocarp), *Arcyria incarnata* (sporangia), *Trichia varia* (sporangia), *Trichia varia* (capillitium and spores), *Badhamia utricularis* (sporangia).

While plasmodia tend to have a similar "veined slime" appearance, the shift into the fruiting body is highly diverse depending on the species.

Above: dense network of *Stemonitis fusca* **sporangia**.



Right: smaller *S. fusca* sporangia. The stalks contain a network of **capillitia** with spores. The stalks attach to a **hypothallus** rooted to the substrate (moss in this photo).



SEM photo of *Stemonitis axifera* capillitium branches and spores. The capillitia create a matrix which holds the spores until drying, at which point they are dispersed.

PROTOSTELEA

Lingering uncertainties

Protostelea have characteristics similar to both Myxogastria and Dictyosteliida, but may be more related to other amoebae.

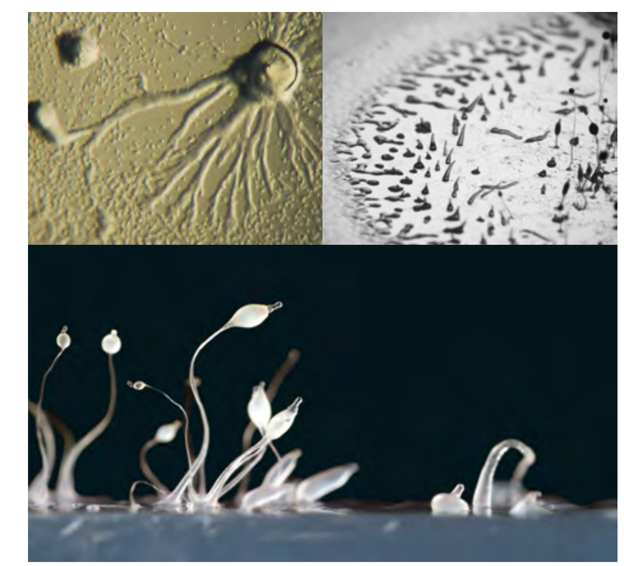
Above: *Ceratiomyxa fructiculosa*, with sporangia behavior similar to Myxogastria (porioides "net" morph shown)

Comparison of the fruiting bodies of *Protostelea mycophagy* (left) and *Dictyosteliida Polysphondylium pallidum* (right)

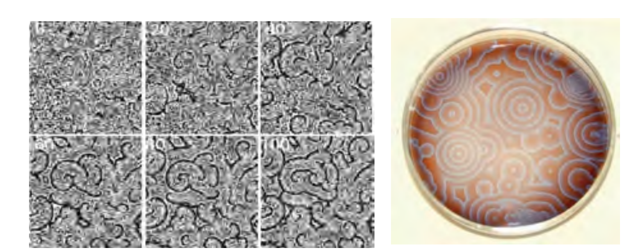
DICTYOSTELIIDA

Cellular slime molds: the "social amoebas"

Dictyosteliida swarm under stress, coming together as a pseudo-multicellular organism.



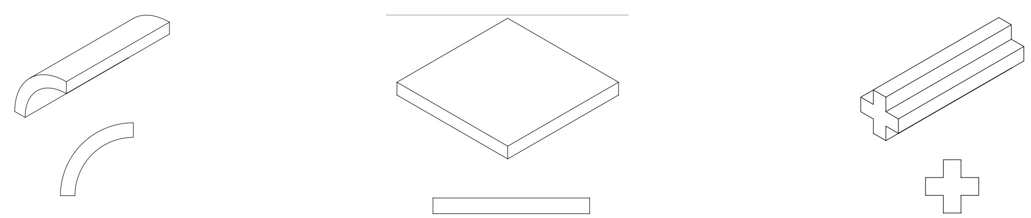
Single-celled *D. discoideum* aggregate when food is scarce, creating fruiting bodies that "stand up" to release spores.



Inter-cell communication among *Dictyostelium discoideum* (left) generating patterns similar to a Belousov-Zhabotinsky (BZ) chemical oscillator (right).

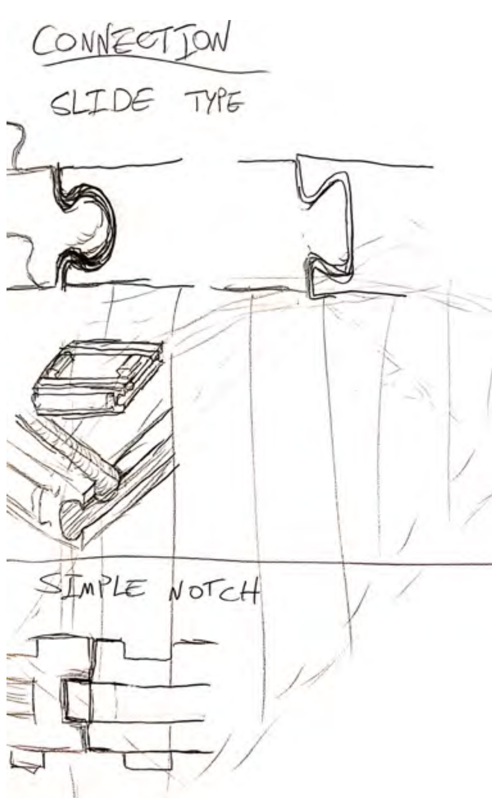
multiwall

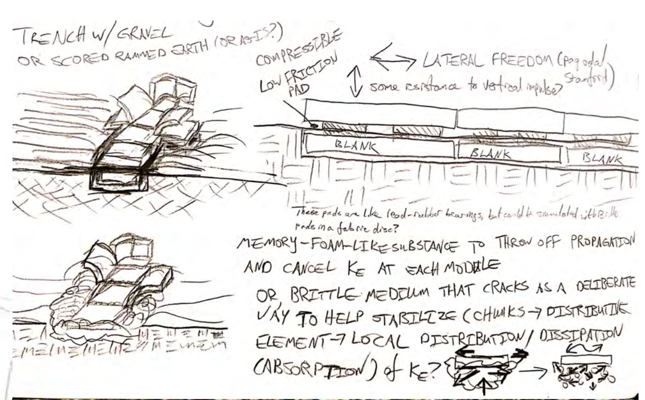
In order to get a sense of the boundaries of the space, I began by building with the basic components I had sketched in rendering software. This helped me start to get a feel for the logic of the pieces and observe inconsistencies or dead-ends in their combination.

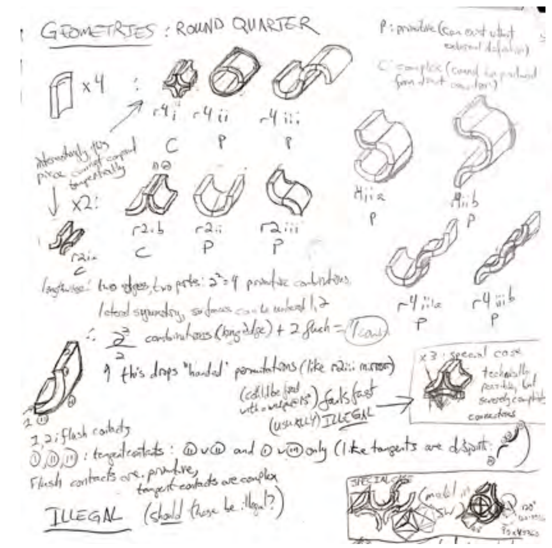


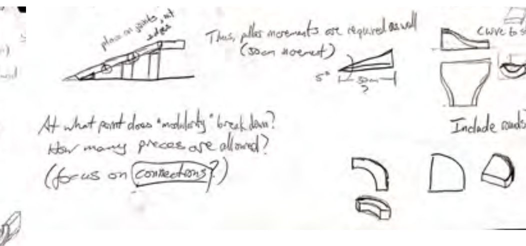
Out of a desire to establish a semblance of pragmatism, I put some thought into foundation, material, earthquake resistance, and physical connection as well.

In grappling with foundational concerns, I noticed that the sporangia phase of the slime mold has a "foundation" physiology of its own - the hypothallus. This structure connects the fruiting bodies containing the spores to the substrate (the location of attachment for the organism).





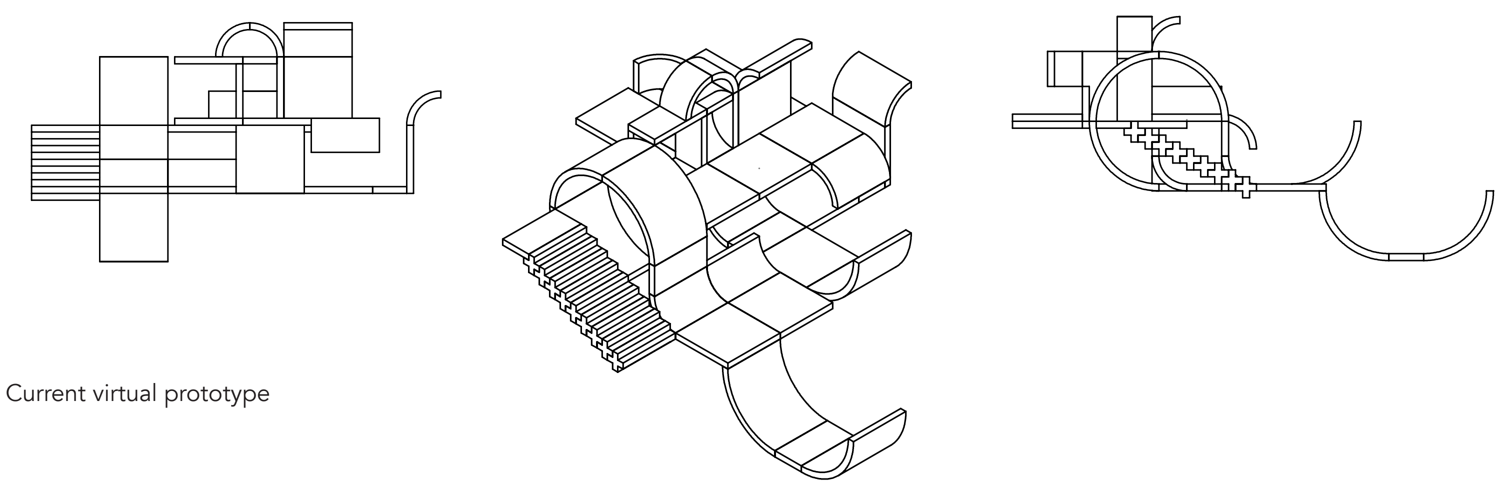




Module variety exploration

Geometry investigations

Case study site ideation



Current virtual prototype

REFLECTIONS:

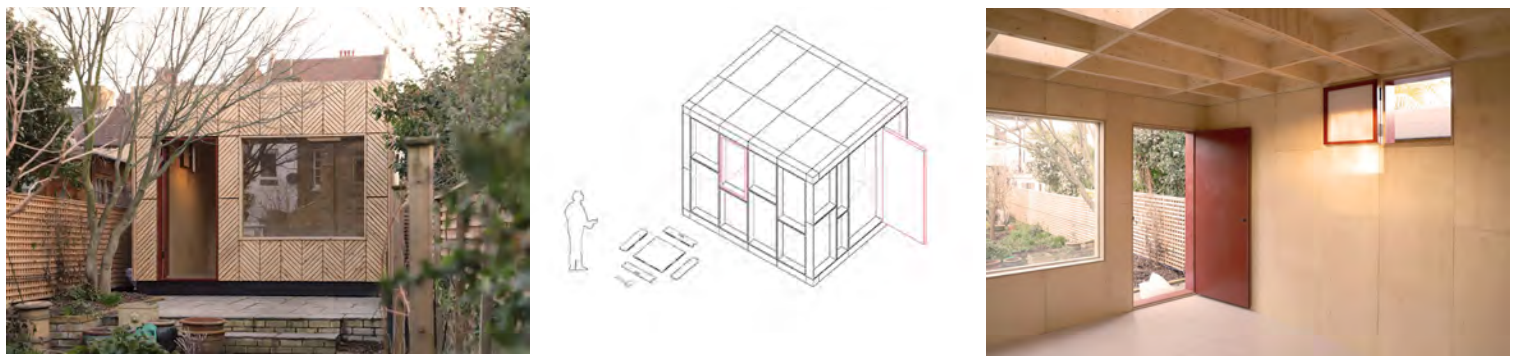
I think more groundwork needs to be done before attempting a fabrication of a large number of pieces, even at model scale. I have a good enough sense of the practical limitations for a more theoretical or experimental exploration of the concept, but I would like to compile more lists of piece combinations and select my real-world case study sites.

I expect that attempting to fill a real-world space (virtually) will answer some questions about where I would like to go with module connection and motility, which should in turn help me figure out what to fabricate and how to fabricate it.

These efforts will also better inform investigations into possible applications as well as provide something of a basis for conjecture regarding urban-scale combinatorial organization and its social implications, if I have the time for it.

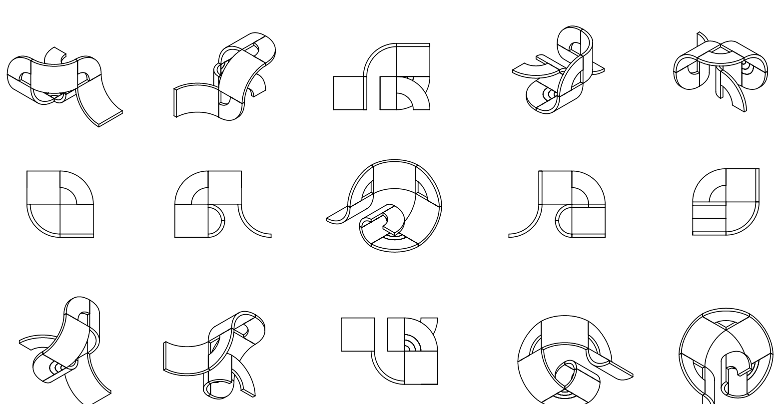
multiwall encounter with an existing project

Soon after the first prototyping round I saw an article posted on Dezeen about a modular architecture project called U-Build. U-Build has some similarities with this project, in being composed of panel modules that can be arranged by amateurs and used as floor or ceiling pieces.



U-Build

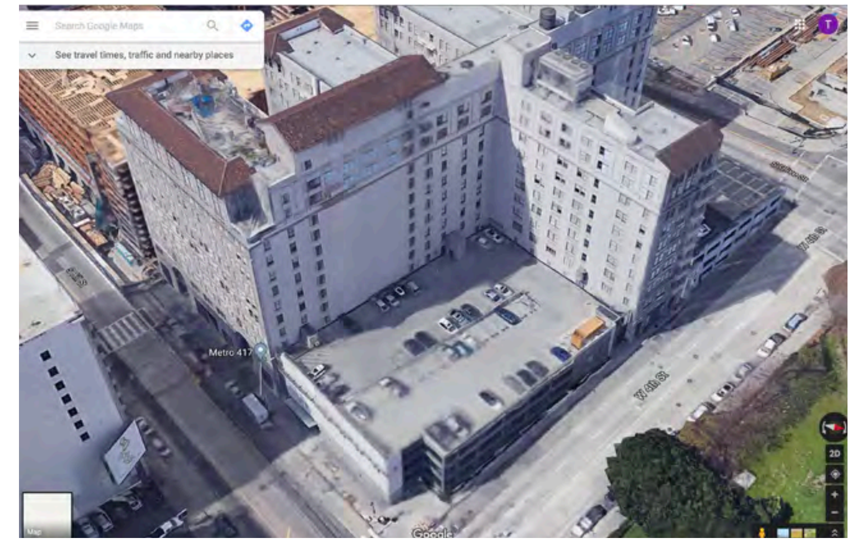
The U-Build project doesn't appear to explore disintegration of interior/exterior boundaries or infinite and location-responsive expansion. It also does not seem to position itself as a multistory/multi-unit solution or as an alternative approach to urban development in an integrated sense. However, these panels offer a basis for thinking about what a "multiwall" panel would look like and can serve as a template for a prototype design of the same.



Space possibilities resulting from rotation of a continued curve shape

COMPONENTS

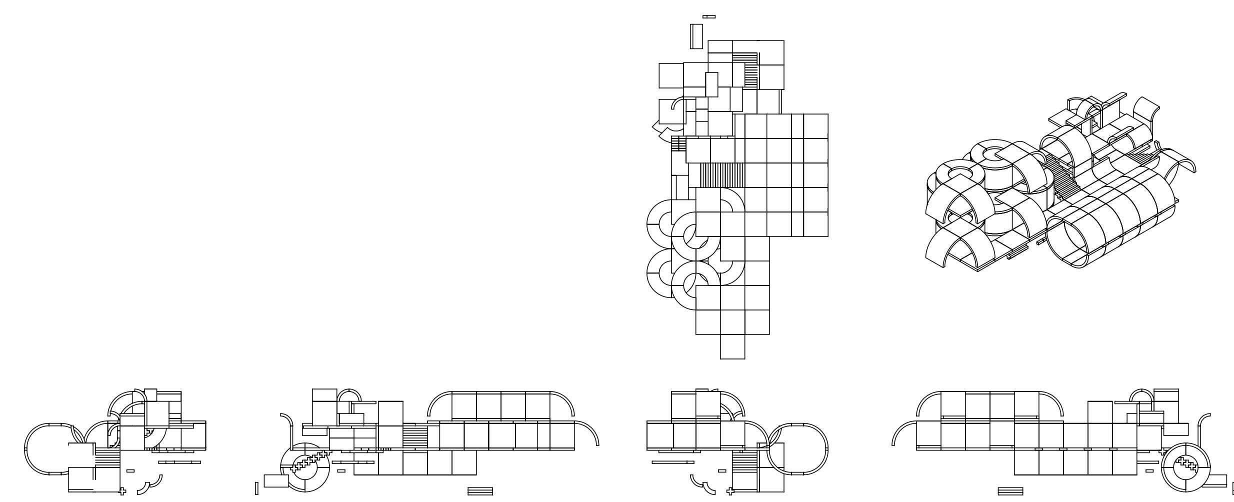
Introduction of a flat curve piece enables uninterrupted curve tangency between modules. The flows that result make for some very organic combination options, but they also highlight an issue with the curved modules: the difficulty of closing off spaces in a sealed or structural fashion. A solution may be a sort of gasket to affix between curves and flats, or leaving open spaces to finishing by users.



Proposed case study site

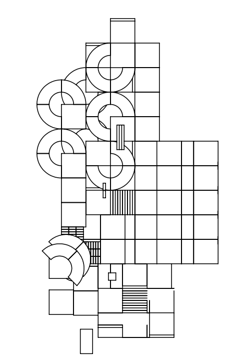
CASE

I looked into possible case study sites, and found this parking garage near Angel's Flight in Downtown Los Angeles. The visibility of the space - as well as the open stretch of wall on the building behind - makes for an appealing virtual installation site.



COMPOSITE

The current prototype incorporates a small 'development' of repeated circular module units, contrasting with the more 'bespoke' tangle of panels adjacent.



Current virtual prototype

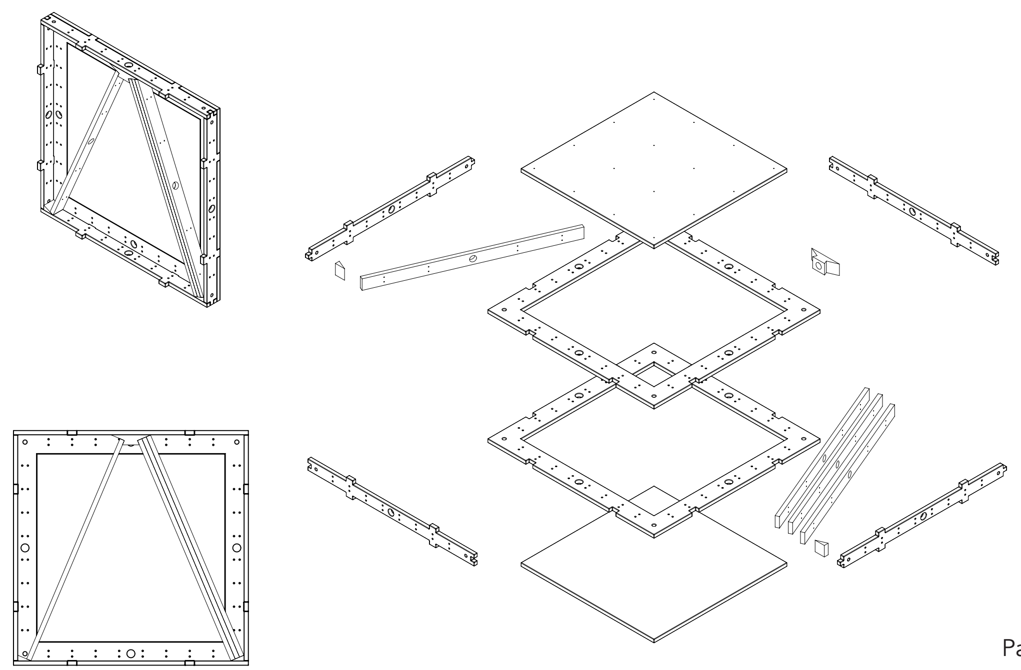
REFLECTIONS:

I now have some very clear avenues to pursue. I am going to focus on constructing units to put together, establishing the "rules" for different states based on slime molds, putting together a prototype design for the panel itself, and making some add-on elements.

multiwall making a model

DESIGN

Before moving into the case study and some renders, I wanted to see if I could put together a design for the panel itself to help me think about connections and panel functionality based on its contents (insulation, soundproofing, plumbing, electrical, ventilation etc.).



Panel design

I used U-Build as a template. As I am interested in the possibilities of CLT and U-Build panels appear to be plywood, they offer an analogue for considering a larger-scale system.

The smaller holes are used with standard connectors to connect panels. Unused holes are used for electrical or radiant heating/as additional cladding or fixture fasteners - or plugged if not otherwise in use. The larger holes are for plumbing or ventilation.

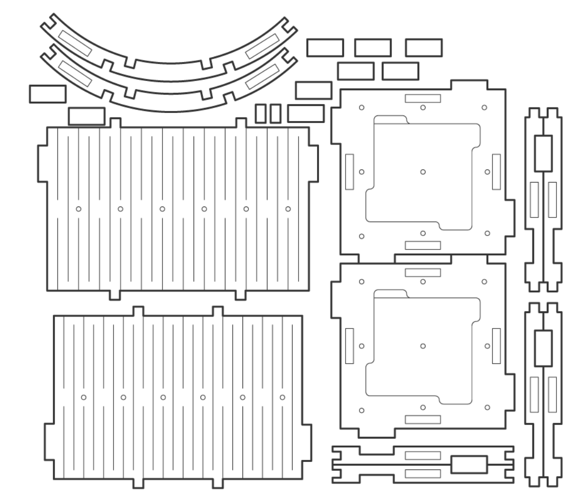
The trussing is configurable to offer increased structural support as needed. The removable central panel provides access to the interior for installation or for swapping out fillings without needing to remove the entire module, and also offers additional fenestration or other aperture configurability. This sort of interior access may also enable piecemeal deinstallation such that - with the use of a temporary support beam acting as a jack - even loadbearing panels could potentially be replaced with relative ease.

RESEARCH

I looked through some books and magazines to either confirm the viability of some of my more "ambitious" ideas or find new inspiration to help guide and shape the project and aid in better defining its nebulous goals - an issue that, while very slime mold-like and not entirely unproductive, is also very time-intensive.

While I do not go into the details here, some of these ideas include all-building sensoring and ongoing reconfiguring to best meet user needs (informed by in-operation BIM and optioneering) and use of novel biological materials (such as mycelium).

Physical model



Model design

MODEL

The model (in progress) provides some tactile sense of how the panels fit together. The design is a simplified version for general demonstration.

REFLECTIONS:

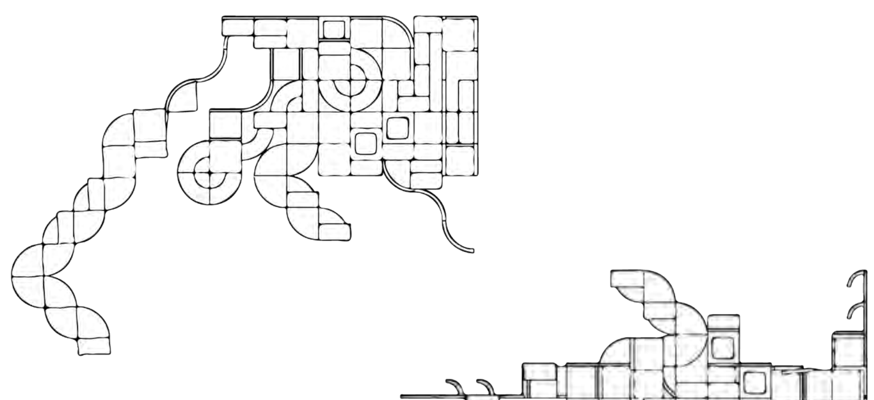
I am satisfied with the model. Additional research has provided some confidence in the "bigger picture" of the project that I am going to start sketching out. I will work towards a more site-agnostic render or the case study and develop whichever moves more quickly.

multiwall case study groundwork

GOAL

The case study will serve as the central "exhibit" for describing the functions and potential of the multiwall system, as well as its major drawbacks and possible alternatives.

The most plausible application for the panels may be mixed-use infill development, with the possibility for use as anything from shelters for the homeless or storage units to pop-up stores, installations, or student housing. The formal language of the structures assembled for any of these uses may vary - leading to distinct zones - or remain amorphous/mosaic.



"Plan" and "Elevation"

- MURAL
- HEAT-SENSITIVE
- ELECTRICAL
- COMPOSTING
- WATER COLLECTION
- BLANK
- VEGETATIVE MESH
- THERMAL TUBING
- INSULATED
- SOLAR

ANALYSIS

This configuration recapitulates previously developed elements while exploring some novel combinations. The repetition of curved panel "tendrils" is a deliberate attempt to emulate the slime mold plasmodium morphology, with the solar panel curved caps suggesting the development seeking out underutilized resources and opportunities for growth.

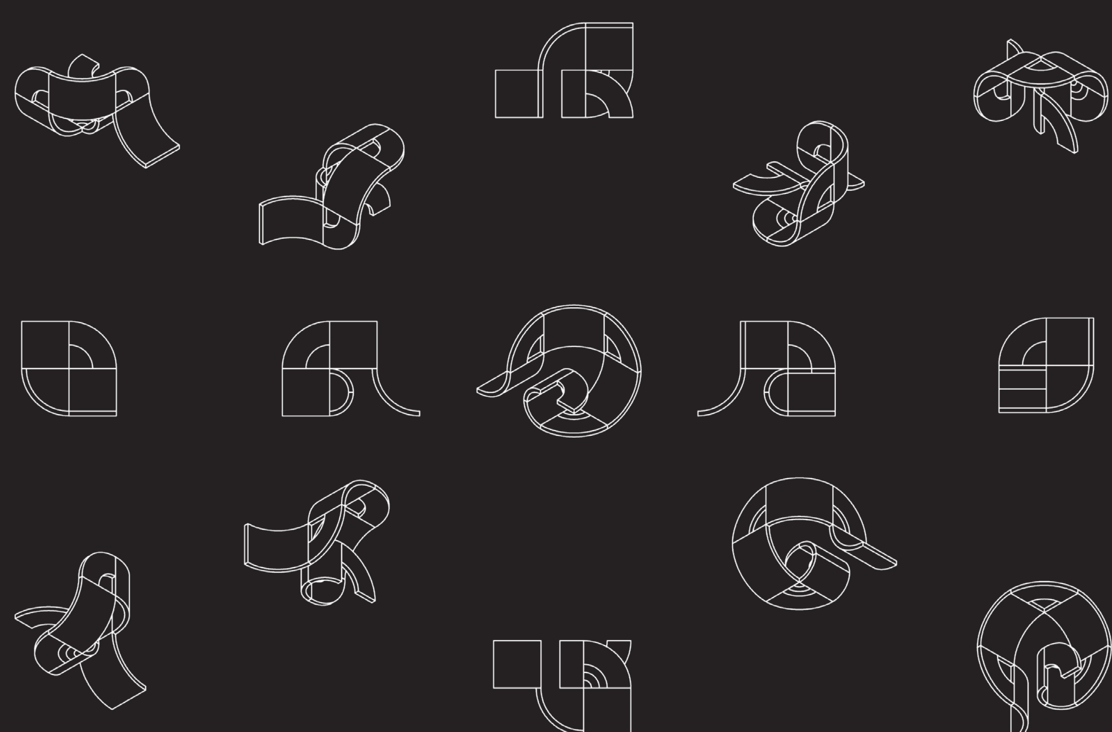
I have concerns about the possibility of this development approach to lend itself to slumming/unsafe conditions, which I hope to address in the final presentation.

REFLECTIONS:

The case study offers much-needed grounding. There remain many avenues to explore and without an "anchor" of sorts, the rush to map them out could have become very disjointed.

I'm not satisfied with the aesthetics, but it seems to communicate the needed sense of space.

analysis I



There are a few notable issues with the system worth addressing.

The first and most glaring set of issues concerns, simply, whether or not this approach would work in a practical sense. For example, would the geometric limitations result in higher infrastructure inefficiency, sensoring notwithstanding? Can the panels be structurally sound enough to be built to over 2 stories or so? How realistic is panel replacement *really*?

Efficiency can likely only be assessed with a full prototype. Testing a range of configurations with BIM software first, however, may be a good way of determining the viability of such a full-scale experiment.

Structural viability is a problem that, with changing materials, has no lasting answer. If the panels are made from CLT and a sensor-driven piecewise construction method is utilized, I would think that structures could reach a reasonable height.

It is unclear how the combination of that many free panels would react in an earthquake - the connections would take a lot of strain, but energy might be dispersed fairly evenly throughout all panels.

analysis II

While I like the idea of a decentralized approach to development, I think there would need to be oversight of some kind in order to ensure safe and equitable growth. The iterative and somewhat “sedimentary” nature of replacing and layering panels could quickly run into code problems or create cramped conditions. Furthermore, if the panel configuration requires some structural amendment, too much tenant freedom to carry it out could lead to injury or health hazards.

For example, a shelter or small dwelling at a multiwall site may have limited natural light access on the site. It may only take the adjustment of a few panels to deprive them of that access. A tenant in an “open” shelter may get too zealous about modification and attempt to drill into the panels unsupervised.

In a similar fashion, it would be difficult to ensure all tenants are familiar with their fire escape routes if the hallways/paths were constantly morphing.

Another issue is plumbing. While the panels can support plumbing fixtures and piping, installment into the local system would require a permanent connection of some kind .

To remedy these, issues, a management structure would need to impose some sort of restrictions based on a central plan for fire routes and light access etc., as well as acting as liaison with local infrastructure services. They could also supervise modification activities to ensure the result is effective and safe.