CONNECTING THE CITY
Enyi Onukwubiri

Connecting the City: 
A Vertical Farm for Baltimore's Food Desert

Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of Master of Architecture in Architecture and Urban Studies

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Nike designer Eric Agar said, “Good design is a balance between art and science -- bold expression and enough familiarity or function.” That statement is true in its own right, however I believe we should explore the boundaries of familiarities. Farming is second nature to mankind, which is why it is understandable that farming has not changed significantly in thousands of years. That lack of evolution is becoming detrimental to our rapidly growing urban population. That notion fueled the concept of this thesis.

The concept of this thesis is to use Maslow’s Hierarchy of Needs pyramid as a guide to solve human psychological needs through architecture. Maslow’s Hierarchy inspired my approach to the thesis - address the problem from the foundation. The thesis analyzes Baltimore City’s food network, and seeks a site which has the potential for several factors: site accessibility, renewable resources, solar exposure, and connecting the community. These factors serve as the basis in which to build a hybrid prototype that is able to expose people to the process of food production through a combination of traditional outdoor farming methods and indoor hydroponics in the form of a vertical farm.
LIST OF IMAGES

PG

iii  FOOD DESERT MAP (BALTIMORE)
1-2  PYRAMID DIAGRAM OF MASLOW’S HIERARCHY
3  FOOD DESERT ILLUSTRATION
4  AGRICULTURE ACTIVITY & FOOD DESERT
5-6  MASTER PLAN OF BALTIMORE
6  AERIAL VIEW OF BALTIMORE HARBOR
7-8  MODIFIED RETAIL FOOD ENVIRONMENT

FAST FOOD

FOOD AT HOME EXPENDITURES

POPULATION DENSITY

HOUSEHOLDS WITH CHILDREN LIVING IN POVERTY

HEALTHY FOOD EMPOWERMENT

MAP OF BALTIMORE [satellite]

MASTER PLAN OF THE SITE [satellite]

SITE: FIGURE GROUND

SITE: GREEN SPACE

SITE: LAND USE

SITE: TRAFFIC FLOW

INSTITUTIONAL INFRASTRUCTURE DIAGRAM

FOOD NODE NETWORK

FIND THE CONNECTIVITY DIAGRAM

CONCEPTUAL FIGURE DIAGRAM #1

THE PROGRAM

CONCEPTUAL DIAGRAM #3

CONCEPTUAL FIGURE DIAGRAM #2A

CONCEPTUAL FIGURE DIAGRAM #2B

CONCEPTUAL SITE MASS

CONCEPTUAL DESIGN A

CONCEPTUAL DESIGN B

CONCEPTUAL DESIGN C

CONCEPTUAL DESIGN D

CONCEPTUAL DESIGN E

CONCEPTUAL DESIGN F

CONCEPTUAL DESIGN G

CONCEPTUAL DESIGN PROGRAM

CONCEPTUAL MODEL DEVELOPMENT

CONCEPTUAL MODEL FORM

CONCEPTUAL MODEL CORE

CONCEPTUAL MODEL STRUCTURE

CONCEPTUAL MODEL SHELL

CENTRAL FARM: Community

SITE PLAN

SCHEMATIC DESIGN: AXIS

SCHEMATIC DESIGN: GRID

SCHEMATIC DESIGN: PGM RELATIONS

SCHEMATIC DESIGN: ACCESS & CIRC

SCHEMATIC DESIGN: TRANSITION

FARMERS’ MARKET ENTRANCE

RESIDENT FITNESS CENTER

BIOPHILIC SYMBOL

FLOOR PLANS

VERTICAL FARM - SECTION

GREENHOUSE SYSTEM COMPONENTS

CENTRAL FARM: Grow

Baltimore Seasonal Food

Benefits of Hydroponic Farming

Hydroponic Wall Diagram

Solar Life-Cycle

Central Farm - South Elevation

Vegetation Prospective Section

Living Solar Screen Diagram

Seasonal Vegetated Screen

Central Farm: Live

TABLE OF CONTENTS

PG

1  THE PARTI

2  MASLOW’S HIERARCHY OF NEEDS

3  THE PROBLEM

6  THE SITE

9  THE SOLUTION

10  THE ADVANTAGES

13  THE IDEA

15  THE APPROACH

17  THE PROGRAM

20  IDEA DEVELOPMENT

30  CENTRAL FARM: Community

31  SITE PLAN

33  SCHEMATIC DESIGN

38  CENTRAL FARM: Work

39  BIOPHILIC DESIGN

41  ARCHITECTURE

46  CENTRAL FARM: Grow

47  BALTIMORE SEASONAL FOOD

49  HYDROPONIC FARM

53  LIVING SOLAR SCREEN

55  CENTRAL FARM: Live

57  IMAGE CREDITS

58  REFERENCES

59  ACKNOWLEDGMENTS
Maslow's Hierarchy of Needs is a motivational theory in psychology comprising a five tier model of human needs, often depicted as hierarchical levels within a pyramid. Maslow stated that people are motivated to achieve certain needs and that some needs take precedence over others. Our most basic need is for physical survival, and this will be the first thing that motivates our behavior. Once that level is fulfilled the next level up is what motivates us.

McLeod, 2007) Within the Basic Needs is the Physiological Need, also known as the foundation of the pyramid. By addressing that need, I may unlock the solution to urban crisis relating to food, quality of life, educational opportunities, jobs, and greener economy.
By the year 2050, nearly 80% of the earth’s population will reside in urban centers. Applying the most conservative estimates to current demographic trends, the human population will increase by about 3 billion people during the interim. An estimated 109 hectares of new land (about 20% more land than is represented by the country of Brazil) will be needed to grow enough food, if traditional farming practices continue as they are practiced today. At present, throughout the world, over 80% of the land that is suitable for raising crops is in use (sources: FAO and NASA). Historically, some 15% of that has been laid waste by poor management practices. What can be done to avoid this impending disaster? (Despommier, 2010).
Baltimore is the largest city in the U.S. state of Maryland, and the 29th-most populous city in the country. Baltimore was established by the Constitution of Maryland and is not part of any county. With a population of 621,849 in 2015, Baltimore is the largest independent city in the United States. As of 2016, the population of the Baltimore metropolitan area was estimated to be just under 2.8 million, making it the 21st largest metropolitan area in the country. Below is an aerial view of Baltimore's Inner Harbor; an important seaport.
THE SOLUTION

COMMUNITY
Focus on local agricultural solutions to decentralize supply and increase the availability of quality food.

1 GROW FOOD LOCALLY
Build and backyard and community gardens as well as larger scale urban agriculture such as vertical farm(s).

2 DEVELOP ALTERNATIVE RETAIL OUTLETS

ACCESS
Increase the ease of obtaining quality food.

3 REPLACE "CONVENIENT" WITH QUALITY
Increase stocks of fruits and vegetables at corner stores or small grocery stores.

4 TRANSPORTATION
Improve transportation to grocery stores, farmer’s markets, public markets, and vertical farm(s).

EMPOWERMENT
Equip individuals and families with the tools to make healthier food choices.

5 NUTRITIONAL EDUCATION
To teach nutritional information involving healthier produce and lifestyle.

THE ADVANTAGES

IMAGINE:
A building that uses solar and wind energy... hydroponic methods of growing crops... Food grown, harvested, and consumed in one location.

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<tr>
<th>Vertical Farm</th>
<th>IMAGINE</th>
<th>Vertical Farm</th>
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<tbody>
<tr>
<td>20% of fossil fuels are consumed by tractors</td>
<td>The average meal travels 1000 miles</td>
<td>Additional farmland; 20% larger than Brasil needed</td>
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<tr>
<td>Three billion parasite infections worldwide</td>
<td>The urban population is growing by 80%</td>
<td>Food prices have increase by 22% from 2007 - 2017</td>
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<tr>
<td>Adds Energy back to the grid</td>
<td>Reduces dependence on fossil fuel</td>
<td>More control of safety and security</td>
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<tr>
<td>Eliminates agricultural runoff</td>
<td>Return farmland to nature</td>
<td>Uses 70% - 90% less water</td>
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<tr>
<td>Year round food production</td>
<td>No weather or pest related crop failure</td>
<td>All vertically grown food is 100% ORGANIC</td>
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</table>
The site is located adjacent to Orleans Street (high) and Central Ave (moderate).

Green Space
The map shows the green spaces surrounding the site. To the north is Dunbar football field.

Land Use
The social fabric is predominately residential, institutional, medical, and a few commercial.

Traffic Flow
The site is located adjacent to Orleans Street (high) and Central Ave (moderate).
After analyzing the social infrastructures surrounding the site, it was important that I target those institutions as my primary partners. The medical and educational institutions of John Hopkins Hospital, John Hopkins University, and the John Hopkins Children’s Center located to the east of the site. Potentially, John Hopkins could serve as an internship and/or fellowship program alongside the Central Farm to help with the research process. In addition, the Central Farm would serve as an educational infrastructure for K-12 students while also assisting parolees with the transition back into society. Growth through connection will enable a network of food node between.
The vertical farm will connect the city of Baltimore and the surrounding areas. But first, I wanted to understand the demographic of the occupants and the social fabric in which the vertical farm will serve. That approach led me to the programs suitable for the vertical farm.
The conceptual figure diagram is my first illustration of connectivity. The hatched boxes serve multiple purpose; the concept is from a macro to a micro approach. First, I understood the social infrastructures were important, therefore connecting those institutions to the functions and program of the Central Farm is ideal. Secondly, I wanted to propose a great, but yet unfamiliar idea to the community of Baltimore City. The Central Farm will serve as a haven for the community by social and educational interactions. Finally, the programs and facilities within the Central Farm are designed as a network: live, work, grow, and community.

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<th>Quantity</th>
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<th>Total Sq Ft</th>
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<td>Offices/Meetings</td>
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<td>120</td>
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<td>Lecture Halls/Seminars</td>
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<td>Restroom (M/W)</td>
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<td>Agric &amp; Farming School</td>
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<td>Env. Learning Lab</td>
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<td>Organic Grocery Stores</td>
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<td>Holistic Medical Therapy</td>
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<tr>
<td>Amphitheater</td>
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<td>2,500</td>
<td>2,500</td>
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<tr>
<td>Green Space - Art Installations</td>
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<td>Parking Space</td>
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TOTAL 324,175

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<td>1 Bedroom</td>
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<td>2 Bedroom</td>
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<td>Fitness Center/Gym/Pool</td>
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<td>Eco Spa/Yoga Studio</td>
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<td>Nursery Daycare</td>
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<tr>
<td>Service Core</td>
<td>10 Flrs</td>
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TOTAL 116,950

NET TOTAL 400,000
The diagrams below illustrate the motto of the Central Farm, “growth through connection” is an idea predicated on live, work, grow, and community. A concept that depends on each entity to be effective. The live section supports residents, which are predominantly researchers, fellows, and their immediate family members. The work, mostly regarded as the infrastructure, keeps the building functioning and is designed for the processing, laboratory, and administrative sectors. The grow, also referred to as the jewel, is solely intended for the greenhouse and poultry facilities. Finally, the community is the foundation of the vertical farm. The Farmers’ Market and all the amenities within the site cater to the needs of the community.
The site is located within the Old Town neighborhood, which sits north of Orleans Street, a high volume vehicular traffic street. It is also a major street within the Baltimore City grid system. To the east of the site is Central Avenue. Central Ave is a two-way moderate vehicular traffic flow street. In addition, the name of the vertical farm stems from the street Central Ave hence “Central Farm”. The 10 Acre site consists of two churches, a 20-story residential apartment building, a civic building, and Jai Medical Center. East of the site is heavily dense with buildings and populated with predominantly institutional buildings such as Paul Laurence Dunbar High School and John Hopkins educational and medical buildings. Whereas, the west of the site has more open space with a few residential and commercial buildings (Old Town Mall) at roughly 3-5 stories tall. A notable building southwest of the site is the Baltimore City Fire Museum.
IDEA DEVELOPMENT  Conceptual Design I

1. the 323,000 sq ft total area; extrude to 150 ft

2. divide the total area into three proposed functions

| GROW | WORK | LIVE |

3. orientate for optimal solar gain (SW) and views (SE)

4. elevate for circular solar gain which creates views and interactive space below
IDEA DEVELOPMENT

Conceptual Design II

5. Split mass (functions) at a 45-degree angle to allow for natural light.

6. Extend the base & bridge the gap. CONNECTION

7. Configure connections & space to create a form that compliments the program.

8. Identify programs and establish a residential (LIVE) space.
After the form was configured from the solar orientation, environmental conditions, and access approach, it was important for me to construct a core. The core consists of the vertical and horizontal circulations. The vertical cores are 1,575 sq-ft concrete structures, while the horizontal concrete and steel structure are concrete slabs with rebars as support systems. Due to the large overhang, a three sided k-leg support structure was implemented. The k-leg structures are 24” x 24” concrete support columns, whereas the other support columns are 14” x 14”. The shell, also known as the skin is a living solar screen with vegetation and photo-voltaic panels.
CENTRAL FARM Community
The footprint of the site is slightly over 7 Acres, therefore I thought it would be important to address the landscape conditions. My approach was to design within these 3 guidelines, environmental friendly features, access, and an socially interactive spaces. It was also important for all these guidelines to coexist together without either one compromising the existing figure ground of the block plan by addressing Baltimore city grid pattern, biodiversity, and wellness amenities. First, direct access between N. Central Ave and Aisquith Street gave me an opportunity to propose a plaza space for community interaction. Second, implementing a maze farmland and a green space between the churches helped promote an environmental friendly element. Finally, adding environmental friendly and bioretention features such as wetlands, swales, permeable pavers, indigenous trees, bioretention islands, a reflective pond, bike rack, and benches would not only benefit the sustainability of the site but it will also educate the community about bioretention. The process in which contaminants and sedimentation are removed from stormwater runoff.

Legend
1. Farmers’ Market
2. Fitness Center
3. Plaza
4. Amphitheater
5. Farmland
6. Wetland
7. Sculpture Garden
8. Reflective Pond
9. Outdoor Booth
10. Green Space
11. Parking Lot
12. Loading Dock
The schematic design process started with the axis. The motto, growth through connection was also prevalent in this design process. By replicating the axis of the streets within the buildings, that approach psychologically invites the pedestrians to explore Central Farm. The benefits of engaging all four streets meant I can also engage the community. In addition to the adjacent buildings, such as the churches, Dunbar High School, Orleans Library, etc.

The concept behind the grid was to develop a concise plan. By replicating a similar grid format system used in Baltimore City planning, it assured me that I am aligning my access points and programs accordingly. Also, it illustrates a symmetrical design that responds cohesively to the sizes and footprints of each program. According to the grid, the columns are 100 feet apart and the rows are 50 feet apart.
The concept behind the program relations design is similar to the levels of needs within the Maslow’s Hierarchy. Each level of needs requires complete fulfillment from the previous level. This program relation fulfillment can be found between masses, functions, and contrasting spaces. For example, the Fitness Center compliments the Farmland.

Access and circulation were just as important as program relations. The plaza is designed to function as the primary access. However, complimenting the building access to the pedestrian pathway helped facilitate the circulation. In addition, there are multiple egress doors and stairwells that led to an open space in case of an emergency exit.
Transitional spaces are where an individual will experience all that the Central Farm has to offer. The ambiance, though is created from the features within the space, such as a living green wall for a biophilic essence, an open atrium for natural light; even the exposed structures display repetition. The idea of transition is also associated with the functions of the space; the journey from the Fitness Center to the Farmers’ Market.
BIOPHILIC DESIGN
This conceptual and structural design in the Farmers’ Market food court symbolizes biophilic architecture: bringing nature indoors. The presence of nature in the food court promotes the awareness for healthy food and a healthy lifestyle.
The Farmers’ Market is the quintessential focus and attraction for the community. The market was intentionally designed for multiple entrances, with the primary entrance is towards the plaza. The east side of the floor plan is designed for a semi-public use, whereas the food court is intended for public consumption. This 36,000 sq-ft market hosts 14 larger size vendor units, 12 middle size vendor units, 13 small size vendor units, 5 kiosks, a food court, and multiple lounge areas inside and outside of the market.

Legend
A. Vestibule
B. Atrium
C. Resident Lobby
D. Fitness Gym
E. Cardio Equipments
F. Free Weights Area
G. Holistic Spa
H. Children Playroom
I. Men Locker Room
J. Women Locker Room
K. Gymnasium
L. Storage
M. Dressing Room
N. Rehearsal Room
O. Auditorium
P. Walk Track
Q. PT Office
R. Massage Room
S. Warm-Up/Stretch
T. Sound/Light Ctrl Rm
U. Electrical Room
V. Break Room
W. Manager's Office
X. P-Trainer Studio
Y. Multipurpose Studio
Z. Cycling Studio
The greenhouse is the jewel of the Central Farm design, peaking at a towering 300 feet high. Imagine a 2.5 acres, 13 story greenhouse that grows and produces fresh fruits and vegetables all year round through hydroponic methods. According to Farmland LP, 1 acre of indoor greenhouse produces the same crops as 4-6 acres farmland. Also, 3 acres of an outdoor farmland could feed 10,000 residents all year round, therefore Central Farm’s 2.5 acre indoor greenhouses could feed 40,000-50,000 Baltimore City residents. That is over 8% of the city population.
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Benefits of Hydroponic Farming

Hydroponic is a soilless farming method that enables the farmer to grow plants and crops using mineral nutrient solutions in water. However, Terrestrial plants can be grown with their roots in the mineral nutrient solution while perlite or gravel is present. Within the building, there will be two main hydroponic systems: the Nutrient Film Technique (NFT) channel system and the Bato Bucket System. The NFT system is ideal for growing leaf crops (lettuce, spinach, swiss chard, etc.) and herbs, while the bato bucket system is ideal for growing vine crops (tomatoes, cucumbers, peppers, etc.).
CENTRAL FARM

South Elevation
VERTICAL FARM Living Solar Screen

The Living Solar Screen is a perforated skin made from 5mm sheet aluminum. The environmentally friendly exterior skin helps control solar radiation and illumination while giving the Vertical farm a living green facade. The pattern of the diamond-shaped cutouts varies in density according to the building’s lighting, climate control needs, and atmospheric conditions.

Equipped with photo-voltaic panels, the screen will also support the growth of vines and plants on the south and west facades. The living screen infuses the interior with lots of light without causing overheating, and it also has the added benefit of quieting the interior spaces from exterior noise pollution and interior mechanical noise.
RESIDENT BUILDING
The residential building is designated for Researchers, Scientists, Farmers, and their immediate family members. The 10-stories condo accommodates 80 units with 3 apartment styles: Studio, 1 Bedroom, and 2 Bedrooms.
ACKNOWLEDGMENTS

Hard days made me, hard nights shaped me; I don’t know, it somehow saved me; I don’t take this education for granted. My journey thus far from Calabar Street is certainly worth a New York Times Best Seller. Trials and tribulations, ups and downs, sorrows and joyous moments; but those are the experiences that build character. I am forever grateful for my family, friends, fraternity, & my experience at Virginia Tech.

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For my sibling (Ugonma, Uzoma, & Okezie) and friends, thank you for your emotional and financial support, “those Cash App transfers were clutch” lol. And a special shout out to Ashley and Jr for your advice and loyalty.

Finally, thank you to the Virginia Tech School of Architecture for the opportunity and to the Hokie family for a tremendous two years that I hope to never forget. I learned a lot, matured as a man, and evolved outside my comfort zone. My memories of 2015-2017 will serve as my beacon of navigation back to Blacksburg, VA for many years to come.