

**Revolutionizing Martian Construction by Determining the
Melanin Concentrations and Growth Patterns of
Extremophilic, Filamentous Fungi in Nahal Shaharut (Negev
Desert)**

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Abstract

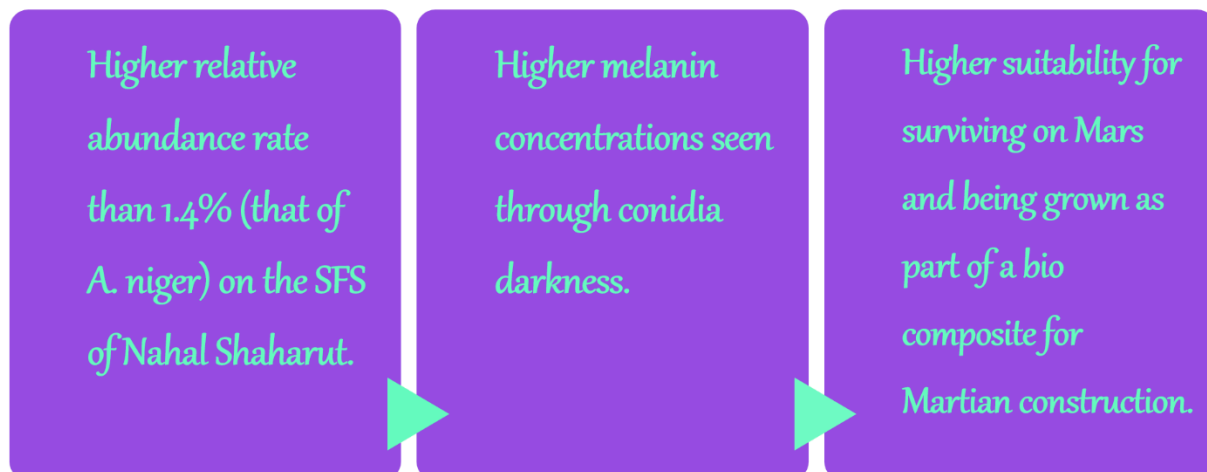
The objective of this theoretical paper is to identify extremophilic Negev Desert fungi that may be suitable for being a part of a bio composite used for Martian construction. Melanin possessing fungi are known to grow in extreme environments and exhibit enhanced growth upon exposure to ionizing radiation (Tesei, 2022), and there is experimental evidence showing that melanin possessing fungi exposed to radiation grow faster than both non melanin and melanin possessing fungi not exposed to radiation (Casadevall et al., 2017). Fungi from the Negev desert in Israel grow under especially stressful climatic and edaphic conditions and are exposed to high amounts of solar radiation (Grishkan & Nevo, 2010), making them the ideal candidates to be used as a part of a bio composite for Martian construction. The data collected from this experiment would help us understand the survival capabilities of extremophilic Negev fungi in space by analyzing their melanin levels and growth patterns. The topic of Martian construction is significant because it would increase long term mission sustainability and solve the problem of relying on Earth derived materials for construction on Mars. This paper is intended to be the first in a series, connecting the Negev Desert's environment to Mars's with the eventual goal of the Negev Desert becoming an area for Martian simulation and experimentation in preparation for future missions.

1. Introduction

Aspergillus niger is a filamentous fungus that is dominant in both the Negev Desert and on spacecrafts, as well as other extreme environments. It is protected from both the solar radiation in the Negev Desert and the cosmic radiation in space through the melanin concentrations in its conidia (Checinska et al. 2015), (Grishkan & Nevo, 2010). Melanin possessing fungi can thrive in harsh environments and can react positively to radiation through radiosynthesis (Casadevall et al., 2017). Fungi can be used for building structures on Mars by latching onto the materials around them as their mycelium grows to create a bio composite. Structures built using fungal bio composites are insulating and can have complex geometry, useful for construction on Mars (Wosten et al., 2018). I believe that the fungus most suitable for being used as a part of Martian construction will be found in the topsoil layer on the south facing slope of Nahal Shaharut (Southern Negev Desert). The location from which the fungi are collected (including *A. niger*), is critical for this experiment.

For this experiment, I'm defining fungal suitability for Martian construction as dependent on melanin concentrations (conidia) and growth rates (mycelia). I predict that fungi in the Southern Negev Desert that exhibit higher relative abundance rates than *A. niger* also possess higher melanin concentrations, reflected through conidia darkness, and that there is positive correlation between relative abundance rates of fungi on the south facing slope of Nahal Shaharut and melanin concentrations in the fungi's conidia. The research gap in this experiment is that a strain of *A. niger* collected from the ISS exhibited faster pigment spread and growth rates (Romsdahl et al., 2018), so while I predict that higher melanin levels in fungi would indicate better survival capabilities in space, the selected fungi would need to be tested in space conditions in order to definitively test my hypothesis.

My (Correlation) Predictions



2. Literature Review

2.1 *Aspergillus Niger*

Fungal melanin is a brown to black pigment with the primary function of protecting the fungus against damaging radiation. The pigmentation in fungal mycelium and spores is an adaptive response to radiation which enhances the survival capabilities of fungi in stressful environments. Melanin possessing fungi are known to survive solar radiation, high temperatures, and water deficiencies (Singaravelan et al. 2008). *Aspergillus* fungi are a type of filamentous fungi that produce small, one celled spores called conidia that are around 2-7 μm in diameter. Although *Aspergillus* is second to *Penicillium* in most common soil fungi, it is the most widely distributed in dry environments (Grishkan 2024). The relative abundance of *Aspergillus* spp. in Nahal Shaharut (Southern Negev) ranges from 1.2% in some spots of the north facing slopes to 19% in some spots of the south facing slopes. There are major seasonal variations in the mycology of the Negev Desert, except in the groups of melanin possessing fungi. Melanin possessing fungi in Nahal Shaharut absorb heat from solar radiation in the winter, leading to little seasonal variation (Grishkan et al. 2007).

Aspergillus niger is a filamentous and extremophilic fungus, and the morphological focus in this paper will be on the conidia and mycelia of *A. niger* (fig. 1) (Mokobi 2025). Due to *Aspergillus niger*'s continuous presence on space crafts (Romsdahl et al., 2018), its dominant presence in the Negev Desert (Grishkan & Nevo, 2010), and its role in several exobiological experiments, including one comparing a terrestrial strain of *Aspergillus niger* to an ISS strain (Romsdahl et al., 2018), *Aspergillus niger* will serve as a constant in this experiment, acting as a variable for comparison. Specifically, the pigment caused by melanin in *A. niger*'s spores will be act as a reference for the rest of the fungi tested.

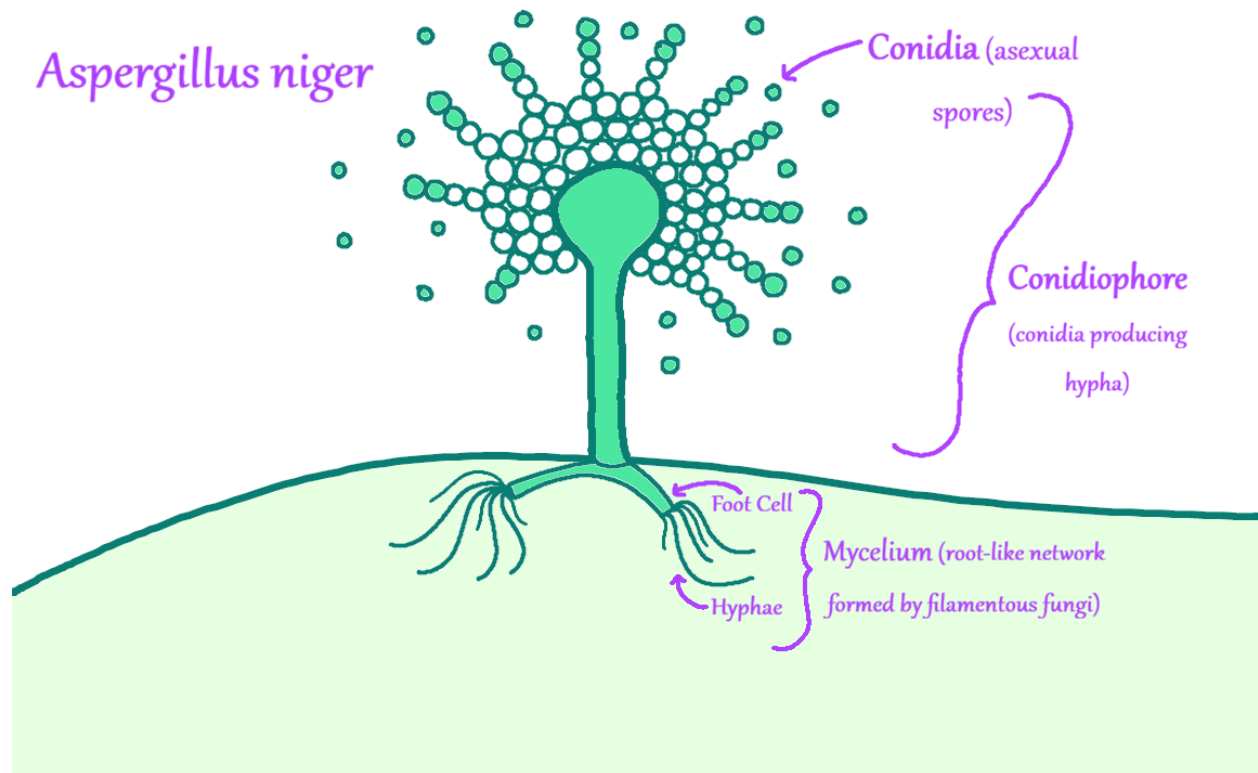


Figure 1: Simplified diagram of Aspergillus Niger.

2.2 History of Fungi in Space

Fungi containing melanin can survive in some of the most extreme and high radiation environments on Earth, such as the damaged nuclear reactor at Chernobyl and the highlands of Antarctica. Melanin is a dark pigment made by diverse fungi that can interact with electromagnetic radiation to turn it into other forms of energy through the process of radiosynthesis (named in an analogy to photosynthesis because both convert energy). Evidence that melanin possessing fungi respond positively to radiation includes attraction and growth towards radioactive sources, faster growth, and metabolic changes (Casadevall et al., 2017). *Aspergillus niger* is the dominant fungal isolate from the International Space Station (ISS), although other species of *Aspergillus* spp. are known to survive as well (Checinska et al. 2015). Filamentous fungi have consistently traveled to space with astronauts and their presence is detected on spacecrafts, with *A. niger* being frequently detected in space environments and one of the dominant fungi on the ISS (Romsdahl et al., 2018).

The Mir Space Station was in orbit for 15 years, during which a total of 136 experiments were done to test the 234 species of bacteria and fungi found aboard, including the filamentous *Aspergillus* spp. (Novikova 2004). Filamentous fungi mainly reproduce asexually by generating

prodigious amounts of asexual spores called conidia, which are the main means of dispersal for filamentous fungi and they are often melanized and highly resistant to radiation. The filamentous *A. niger* forms melanin possessing spores with thick cell walls that allow them to withstand harsh conditions and the survival of fungi in space depends on the layer of pigments in the spore cell wall (Cortese et al. 2020).

2.3 Negev Desert Mycology

Despite the high solar radiation, drought, extreme temperatures, chemical and radioactive pollution, water deficiency, and stressful desert climatic and edaphic conditions, there are more than 360 identified fungal species in the Negev Desert, with almost 200 of them containing melanin (Grishkan & Nevo, 2010). Makhtesh Ramon (Ramon crater) in the Northern Negev receives low to no UV, and fungi with one celled conidia thrive there and are dependent on rainfall for growth, while in Nahal Shahrut (Southern Negev, fig. 3), the fungi aren't dependent on soil moisture and melanin containing fungi are the dominant group, with their abundance not heavily varying spatially according to seasonal change (Grishkan & Nevo, 2010). This means that we should focus on the mycology in Nahal Shahrut in order to find the most suitable fungus for Martian construction, as that's where it's most likely to be.

While extremotolerant fungi can endure harsh conditions but grow optimally at normal conditions, we are searching for extremophilic fungi that grow optimally at harsh conditions (Tesei, 2022). Specifically, the south facing slopes (SFSs) of the Negev receive 200% to 800% more solar radiation than the north facing slopes (NFSs), and *A. niger* strains on the SFSs produce three times more melanin than strains found on NFSs (Singaravelan et al. 2008). Table 1 shows twelve fungal species with an at least 1.4% relative abundance (which is the relative abundance rate of *Aspergillus niger*) on the SFS of Nahal Shahrut, Southern Negev (highlighted). Deserts represent stressful environments that cause unique adaptive evolutionary mechanisms in fungi (Grishkan & Nevo, 2010), so I believe the fungus most suitable for Martian

construction is most likely to be found here (the geographical significance is further expanded on in section 3.2).

| Species | Along a rainfall gradient, northern and central Negev | | Makhtesh Ramon area, central Negev | | | | Nahal Shoharut, southern Negev | |
|--------------------------------|---|--------------|------------------------------------|------------|------------|-------------|--------------------------------|------|
| | BSC | under shrubs | Steppe zone | Crater SFS | Crater NFS | Desert zone | SFS | NFS |
| Zygomycota | | | | | | | | |
| <i>Mortierella alpina</i> | 4.2 | 2.5 | - | - | - | - | - | - |
| <i>M. humilis</i> | - | - | 0.6 | 0.09 | 0.15 | 0.1 | 0.2 | 0.3 |
| <i>Rhizopus stolonifer</i> | 2.4 | 0.2 | 0.3 | 0.02 | - | 0.01 | 0.06 | 0.05 |
| teleomorphic Ascomycota | | | | | | | | |
| <i>Canariomyces notabilis</i> | 0.2 | 0.1 | 0.4 | 0.05 | 2.6 | 0.8 | 1.0 | 0.25 |
| <i>Chaetomium bostrychodes</i> | 3.9 | 0.7 | 0.02 | 0.6 | 0.1 | 0.1 | 0.3 | 0.03 |
| <i>Ch. globosum</i> | 0.7 | - | 0.03 | 0.15 | 0.5 | 0.1 | 0.01 | 0.2 |
| <i>Ch. nigricolor</i> | - | - | 0.1 | - | 0.3 | 0.1 | 0.6 | 0.03 |
| <i>Ch. strumarium</i> | 0.01 | - | 0.3 | 0.1 | 0.8 | 0.3 | 0.4 | 0.25 |
| <i>Ch. succineum</i> | 0.3 | - | 0.05 | 2.4 | 0.04 | 1 | 0.2 | 0.08 |
| <i>Chaetomium (immature)</i> | 2.7 | 1.9 | 0.4 | 0.2 | 0.5 | 0.01 | 0.2 | 0.08 |
| <i>Emericella nidulans</i> | 0.1 | - | 0.01 | 0.03 | 0.06 | 0.2 | 0.07 | 0.01 |
| <i>Gymnoascus reesii</i> | 0.05 | 5.3 | 0.2 | 0.03 | - | 3.8 | - | - |
| <i>Microascus cirrosus</i> | 0.01 | 0.04 | 0.1 | 0.02 | 0.8 | 0.1 | - | 0.01 |
| <i>Sporormiella minima</i> | 3.9 | 0.1 | 4.2 | 0.5 | 1.1 | 1.2 | 0.7 | 0.1 |
| <i>Thielavia terricola</i> | 0.01 | - | 0.02 | - | 0.4 | 0.03 | 0.1 | 0.03 |
| anamorphic Ascomycota | | | | | | | | |
| <i>Alternaria alternata</i> | 2.0 | - | 8.9 | 3.2 | 15.9 | 3.0 | 7.4 | 7.3 |
| <i>A. chlamydospora</i> | 10.2 | 2.5 | 4.9 | 0.8 | 0.8 | 7.5 | 6.7 | 19.8 |
| <i>A. raphani</i> | 0.6 | 0.4 | 1.0 | 0.4 | 0.4 | 0.15 | 0.7 | 0.1 |
| <i>Aphanocladium album</i> | 1.7 | - | 0.1 | 2.8 | - | 0.05 | - | - |
| <i>Aspergillus flavus</i> | - | - | 0.5 | 0.03 | 0.1 | 0.01 | 0.1 | 0.01 |
| <i>A. fumigatus</i> | 0.9 | 2.8 | 0.1 | 61.9 | 0.7 | 2.5 | 15.5 | 2.3 |
| <i>A. microcysticus</i> | - | - | 0.01 | - | - | 15.4 | - | 0.02 |
| <i>A. niger</i> | 2.9 | 0.04 | 0.1 | 0.35 | 0.3 | 0.8 | 1.4 | 1.0 |

| Species | Along a rainfall gradient, northern and central Negev | | Makhtesh Ramon area, central Negev | | | | Nahal Shoharut, southern Negev | |
|-------------------------------------|---|--------------|------------------------------------|------------|------------|-------------|--------------------------------|------|
| | BSC | under shrubs | Steppe zone | Crater SFS | Crater NFS | Desert zone | SFS | NFS |
| <i>A. ustus</i> | - | 0.6 | 0.01 | 0.02 | 0.9 | 3.3 | 2.0 | .2 |
| <i>A. versicolor</i> | 0.05 | - | - | 0.02 | 10.2 | 0.1 | 0.05 | 0.02 |
| <i>Aureobasidium pullulans</i> | 0.7 | - | - | - | 0.15 | 0.15 | 0.1 | 0.1 |
| <i>Beauveria brongniartii</i> | - | - | 3.2 | 0.45 | 6.4 | 0.5 | 4.6 | 5.3 |
| <i>Botryotrichum pilluliferum</i> | 1.6 | 0.7 | 0.1 | - | - | 2.1 | 1.4 | 0.4 |
| <i>Camarosporium aequivocum</i> | - | - | 0.5 | - | 0.3 | - | 0.2 | 0.04 |
| <i>Cladosporium cladosporioides</i> | 0.2 | - | 33.4 | 0.6 | 3.1 | 1.5 | 3.7 | 1.6 |
| <i>Coleophoma empetri</i> | - | - | - | - | 0.1 | 9.6 | 0.1 | 0.05 |
| <i>Cylindrocarpon didymium</i> | 0.8 | 0.2 | - | - | - | - | 0.2 | 0.03 |
| <i>Curvularia clavata</i> | 0.06 | - | 0.03 | 0.03 | 0.2 | 0.01 | 0.2 | 0.05 |
| <i>Drechslera australiensis</i> | 0.6 | - | 0.02 | 0.08 | 0.3 | 0.2 | 0.06 | 0.04 |
| <i>Embellisia phragmospora</i> | 3.5 | 0.3 | - | - | - | 0.1 | - | 0.03 |
| <i>Epicoccum nigrum</i> | 0.04 | - | 0.05 | 0.08 | 0.25 | 0.25 | 0.04 | 0.25 |
| <i>Fusarium equisetii</i> | 1.6 | 0.5 | 0.3 | 1.7 | 1.7 | 1.4 | 0.4 | 0.3 |
| <i>F. oxysporum</i> | 1.7 | 1.0 | 4.3 | 3.2 | 0.6 | 0.7 | 0.6 | 0.5 |
| <i>F. solani</i> | 1.0 | 0.06 | 0.03 | 0.1 | 0.1 | 0.4 | 0.06 | 0.02 |
| <i>Geotrichum candidum</i> | 0.7 | 4.4 | 0.2 | - | - | 0.2 | 1.3 | 0.5 |
| <i>Humicola grisea</i> | 1.2 | 4.9 | - | 0.03 | 1.5 | 0.2 | 0.1 | 0.06 |
| <i>Monodictys fluctuata</i> | - | - | - | - | - | 0.07 | 0.3 | 0.4 |
| <i>Myrothecium roridum</i> | - | - | 0.1 | 0.1 | 0.07 | 0.3 | 0.8 | - |
| <i>Nigrospora oryzae</i> | 0.03 | - | 0.1 | 0.08 | - | 0.05 | 0.2 | 0.07 |
| <i>Papulaspora pannosa</i> | 0.9 | 0.01 | 0.02 | 0.02 | 0.2 | 0.25 | 0.3 | 0.7 |
| <i>Phoma betae</i> | 0.3 | - | 0.02 | - | 0.15 | 0.3 | 0.15 | 0.9 |
| <i>Ph. exigua</i> | 9.6 | 0.9 | 0.1 | 0.3 | 0.7 | 1.8 | 1.5 | 1.4 |
| <i>Ph. medicaginis</i> | - | - | - | 6.7 | 0.07 | 0.05 | 0.06 | 0.04 |
| <i>Penicillium aurantigriseum</i> | 1.2 | 26.6 | 13.5 | 3.6 | 1.3 | 8.8 | 2.6 | 2.1 |
| <i>P. chrysogenum</i> | 0.2 | 2.2 | 0.1 | - | - | - | 0.15 | 1.9 |
| <i>P. lanosum</i> | 1.4 | 16.4 | - | - | - | - | 0.3 | 1.8 |
| <i>Pleurophoma cava</i> | 0.7 | - | 0.04 | - | 0.2 | 0.15 | 0.07 | 0.7 |

| Species | Along a rainfall gradient, northern and central Negev | | Makhtesh Ramon area, central Negev | | | | Nahal Shaharut, southern Negev | |
|--|---|------|------------------------------------|------|------|------|--------------------------------|------|
| | | | | | | | | |
| <i>Scytalidium flavobrunneum</i> | 0.07 | 3.2 | - | - | - | - | - | - |
| <i>Stachybotrys chartarum</i> | 2.9 | 0.07 | 2.0 | 0.9 | 4.2 | 1.3 | 0.9 | 0.3 |
| <i>Stemphyllium state of Pleospora tarda</i> | 0.2 | - | 0.5 | 0.1 | 1.5 | 1.5 | 0.3 | 0.1 |
| <i>Trichoderma koningii</i> | - | - | 0.03 | - | 0.2 | 0.04 | - | 0.07 |
| <i>Ulocladium atrum</i> | 17.0 | 6.0 | 13.5 | 4.7 | 14.6 | 6.1 | 12.3 | 25.6 |
| <i>U. botrytis</i> | 0.4 | 0.8 | 0.3 | 0.02 | 19.1 | 14.2 | 16.2 | 11.7 |
| <i>U. chartarum</i> | 1.7 | - | - | - | - | - | 0.3 | 0.6 |
| <i>Verticillium tenerum</i> | - | - | - | - | - | - | 0.1 | 0.6 |

Table 1: “Most frequent and abundant microfungi from different sites of the Negev Desert, Israel, with their relative abundance (%)” (Grishkan & Nevo, 2010). The twelve fungi with a relative abundance rate equal to or greater than that of *Aspergillus niger* (1.4%) on the south facing side of Nahal Shaharut are highlighted, including *Aspergillus niger* (purple).

2.4 Fungal Bio Composites in the Context of Martian Construction

Structures on Mars must provide effective shielding against radiation and insulation against temperature fluctuations, which can be achieved using Martian regolith, the layer of dust and fragmented rock that coats the surface of other planets (Khah & Lopez, n.d.). Filamentous fungi have root-like structures called mycelia that bind to their surrounding materials by latching onto them as the fungi grow (fig. 2), and in a Martian context, the surrounding material would be regolith. The fungi in the structures would be able to grow to repair any damage (cracks) or for maintenance (Odell, 2024). The advantages of fungal bio composites are that the structures created are light weight, non-flammable, have good insulation properties, the materials can have a variety of textures with complex geometry depending on the fungi’s growing conditions, and they have a relatively low manufacturing cost (Wosten et al., 2018).

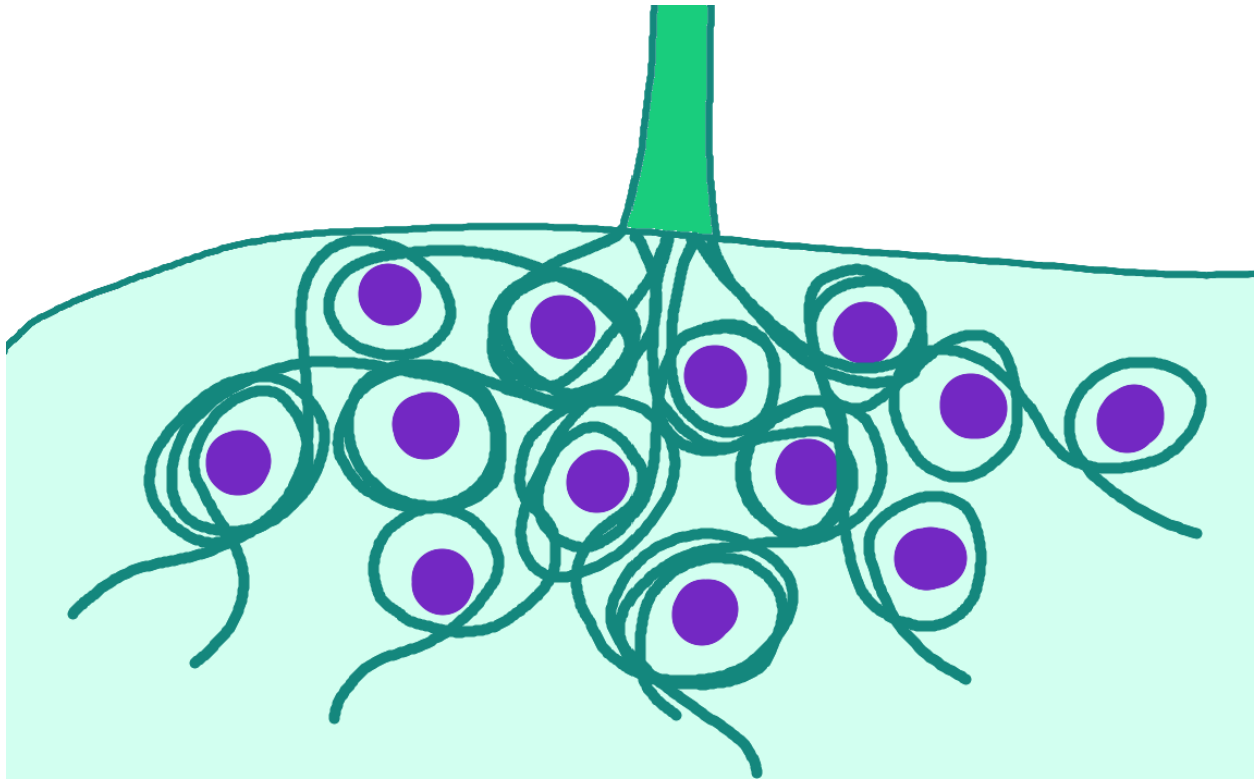


Figure 2: Diagram showing the latching and binding of fungal mycelium to its surrounding materials as it grows.

Challenges surrounding Mars's climate include its harsh environment, low air pressure, the effects of intense solar radiation and microgravity on astronauts, and limited resources such as water and energy, hence why it is critical to use the resources already found on Mars, including regolith. Structures that are designed to be partially buried or constructed with thick walls using regolith as a building material would provide natural insulation, protection against radiation, and temperature stabilization (Khah & Lopez, n.d.). Both pure mycelium and mycelium latched onto a substrate can be used as materials. Materials made from pure mycelium are made by having the mycelia completely consume the substrate that it's latching on to. The texture of these materials can be similar to paper, rubber, and leather depending on the growth conditions. The issue with production of pure mycelium materials is that it's slow and produces little product with a weaker texture, while production of fungal bio composites is fast with high yield. To stop the mycelium from consuming the substrate completely and forming a pure mycelium material, the bio composite needs to be treated at 60°C to kill the fungus. Depending on the growth conditions, bio composites can have textures similar to cardboard and brick, suitable for Martian construction (Wosten et al., 2018).

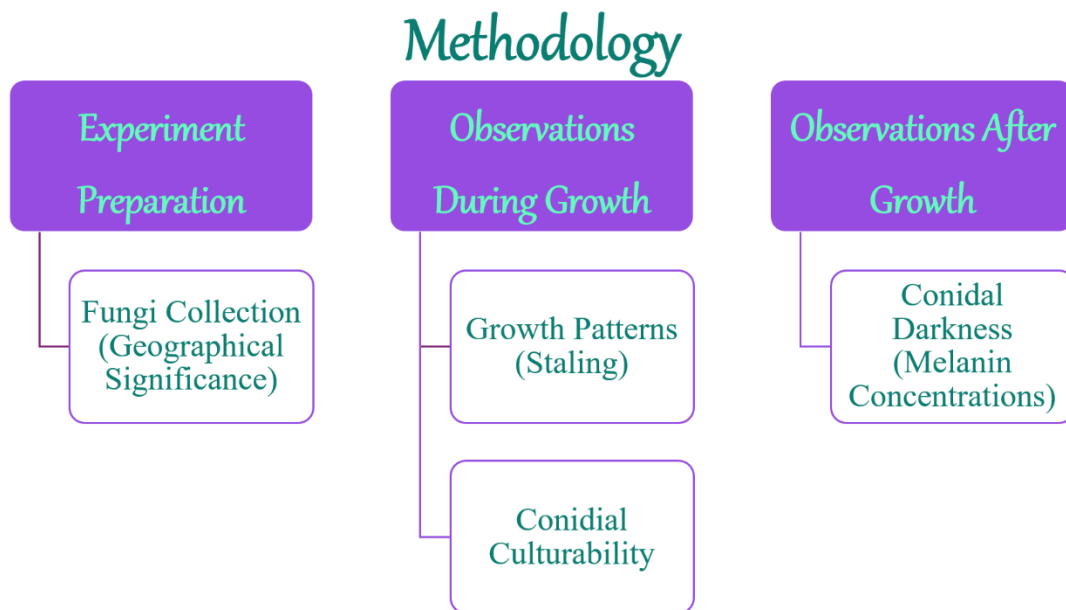
2.5 My Hypothesis

I predict that the more melanin and faster growth rates that an extremophilic filamentous fungus possesses, the more suitable it is to survive on Mars and be used as a part of a bio composite for Martian construction. The melanin levels and growth rates in this experiment should be measured in comparison to *Aspergillus niger*, since there is already evidence that it is frequently detected in spacecrafts and can survive the cosmic rays of outer space (Cairns et al. 2021). My hypothesis is that the higher of a relative abundance rate on the SFS of Nahal Shoharut that a fungus has, the more suitable it will be for being used as a part of a bio composite for Martian construction (with suitability depending on melanin concentrations and growth patterns). I predict that higher relative abundance rates indicate higher melanin levels and capabilities of surviving cosmic radiation, since we've established that *A. niger* can survive the intense solar radiation of Nahal Shoharut with a 1.4% abundance rate and the cosmic radiation in the ISS. I believe that the ranking in table 2 will also be applicable after the experiment is performed as a ranking of the conidia darkness for each fungus.

| Name of Fungi (ranked by relative abundance) | Relative Abundance (%) |
|--|------------------------|
| 1. <i>Ulocladium botrytis</i> | 16.2 |
| 2. <i>Aspergillus fumigatus</i> | 15.5 |
| 3. <i>Ulocladium atrum</i> | 12.3 |
| 4. <i>Alternaria alternata</i> | 7.4 |
| 5. <i>Alternaria chlamydospora</i> | 6.7 |
| 6. <i>Beauveria brongniartii</i> | 4.6 |
| 7. <i>Cladosporium cladosporioides</i> | 3.7 |
| 8. <i>Penicillium aurantiogriseum</i> | 2.6 |
| 9. <i>Aspergillus ustus</i> | 2.0 |
| 10. <i>Phoma exigua</i> | 1.5 |
| 11. <i>Botryotrichum pilluliferum</i> | 1.4 |
| 12. <i>Aspergillus niger</i> | 1.4 |

Table 2: All twelve tested fungi ranked by relative abundance (%) in the SFS of Nahal Shoharut in the Negev Desert. I predict that there is direct correlation between relative abundance and melanin level. Optimistically, I believe that every fungus will possess higher melanin levels than *Aspergillus niger*.

3. Methodology



3.1 Theoretical Framework (General)

Preparation:

1. Collect a strain of each type of fungus highlighted in table 1 from the SFS of Nahal Shaharut (Southern Negev Desert). The geographical significance of the location from which the fungi are collected is expanded on in section 3.2.

During Growth:

2. Observe the growth patterns of the fungi daily in order to see if the fungi exhibit staling (non-linear growth rate that falls off), expanded on in section 3.3.
3. Observe the conidial culturability, as higher culturability would indicate higher melanin concentrations (Singaravelan et al. 2008), expanded on in section 3.3.

After Growth:

4. Observe the darkness of each fungi's conidia and create a color scale. This should be done specifically in comparison to *Aspergillus niger*'s melanin concentrations, and A.

- niger should be highlighted in the color scale. This will reveal the relative melanin concentrations of the tested fungi in comparison to *Aspergillus niger*'s and determine their survival capabilities in space, since we have previously established that *A. niger* has a conidium dark enough to survive cosmic radiation (conidia darker than *A. niger* = ability to survive in space).
5. Create a table ranking each fungus by darkness of conidia (from darkest to lightest, prediction shown in table 3) and compare them to the relative abundance ranking in table 2 in order to test my hypothesis.

3.2 Geographical Significance (Fungi Collection)

The Negev Desert- The Negev Desert represents a stressful habitat with harsh climate, including limited resources, solar radiation, and high temperatures, causing the fungi in the region to adapt to the severity. Melanin possessing fungi are the dominant fungal group across almost the whole Negev Desert (more background in section 2.3) (Grishkan et al. 2023).

Nahal Shaharut (Southern Negev Desert)- Nahal Shaharut (Southern Negev) is an extremely arid region with low soil moisture content and opposite north and south facing slopes (Grishkan et al. 2007). Fungi in Nahal Shaharut can survive extreme temperatures, drought, and UV radiation both in nature and in lab settings (Grishkan and Nevo 2007). The microfungal community of Nahal Shaharut (Southern Negev) has evolved under extreme climatic and edaphic conditions, displaying adaptive strategies such as the dominance of melanin possessing fungi with large conidia, including *Aspergillus* spp. comprising a basic part of the microfungal community in the region, and little seasonal variation (Grishkan et al. 2007). The poor edaphic conditions in Nahal Shaharut select melanin possessing fungi as the dominant microfungal group, leading the mycology of Nahal Shaharut to display little seasonal variation and be considered relatively stable. Melanin possessing fungi also grow on the south facing slopes of the Northern Negev, but they display seasonal variation and grow at around half the abundance as in Nahal Shaharut (Grishkan and Nevo 2007).

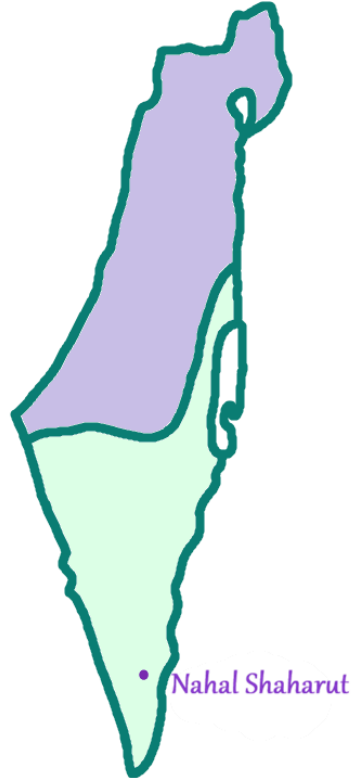


Figure 3: General location of Nahal Shaharut (Southern Negev) within the Negev Desert (with the Negev marked in light green) on a simplified map of Israel.

South facing slope (SFS)- Although the north and south facing slopes of the Negev Desert share the same geology and soil type, the mycology on the slopes differs due to the higher amounts of radiation received by the SFSs. The south facing slopes of the Negev receive 200-800% more solar radiation than the north facing slopes although they can be geographically close. Conidial melanin concentrations of fungi found on the SFS are three times higher than fungi found on the NFS and they resist irradiation better. Solar radiation is a major selection agent for what organisms survive on either slope, and melanin is an adaptive trait against UV radiation in fungi. Temperatures are higher on the SFS due to the higher amounts of direct sunlight that it receives, but humidity is higher on the NFS, leading to higher soil moisture

content which fungi on the NFS depend on, creating seasonal variation (Singaravelan et al. 2008). The SFS of Nahal Shaharut has a soil moisture content of 0.6% compared to the 1-1.4% on the NFS and relative humidity is 1-7% higher on the NFS than on the SFS (Grishkan 2017), (Singaravelan et al. 2008). There is more vegetation on the middle of north facing slopes and less on the top of south facing slopes (Singaravelan et al. 2008), meaning that the fungi should be collected from the top of a SFS, because I believe it's those are the sunniest points in the Negev Desert, and any fungus that survives there is exposed and adapted to the highest amounts of aridity and solar radiation possible within Nahal Shaharut.

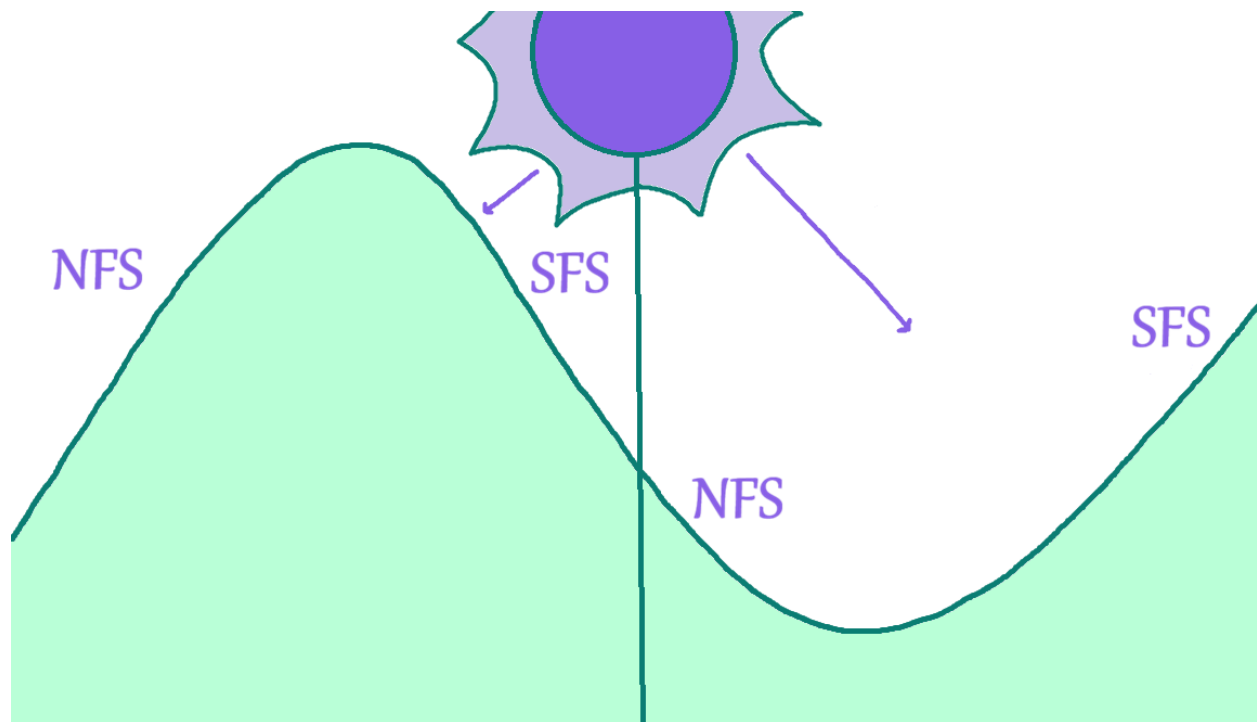


Figure 4: Diagram differentiating south facing slopes from north facing slopes by showing how the sun hits.

Topsoil layer- The majority of topsoil layers across the Negev Desert contain melanin possessing fungi with thick walls and large spores that are resistant to solar and UV radiation, high temperatures, and chemical and radioactive pollution, while light colored fungi with small conidia thrive at a depth of 1-30 cm underground (Grishkan et al. 2023). The high amount of solar radiation hitting the top soil layers in the Negev Desert leads to the dominance of dark, melanin possessing fungi across the desert (Grishkan and Kidron 2016), and *Aspergillus niger* spore samples collected from an open locality (sun exposed) top soil layer (0-2 cm depth) were able to survive and germinate under the solar radiation and high temperatures of Nahal Shaharut (Grishkan 2017). This means that the fungi for the experiment should be collected from the

topsoil layer (0-2 cm depth) on a sun exposed part of the SFS in Nahal Shaharut because they would be more exposed and adapted to solar radiation.

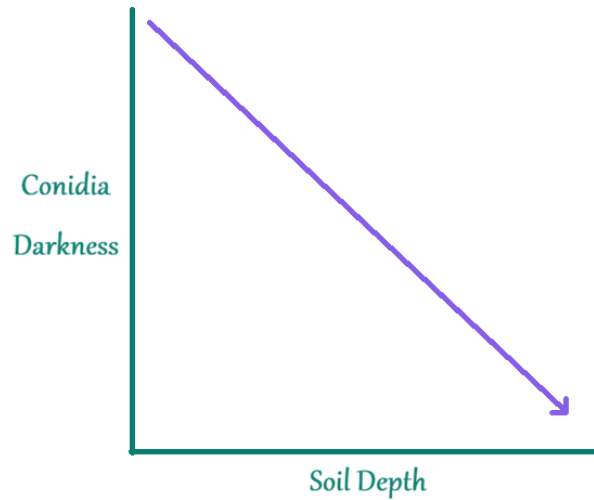
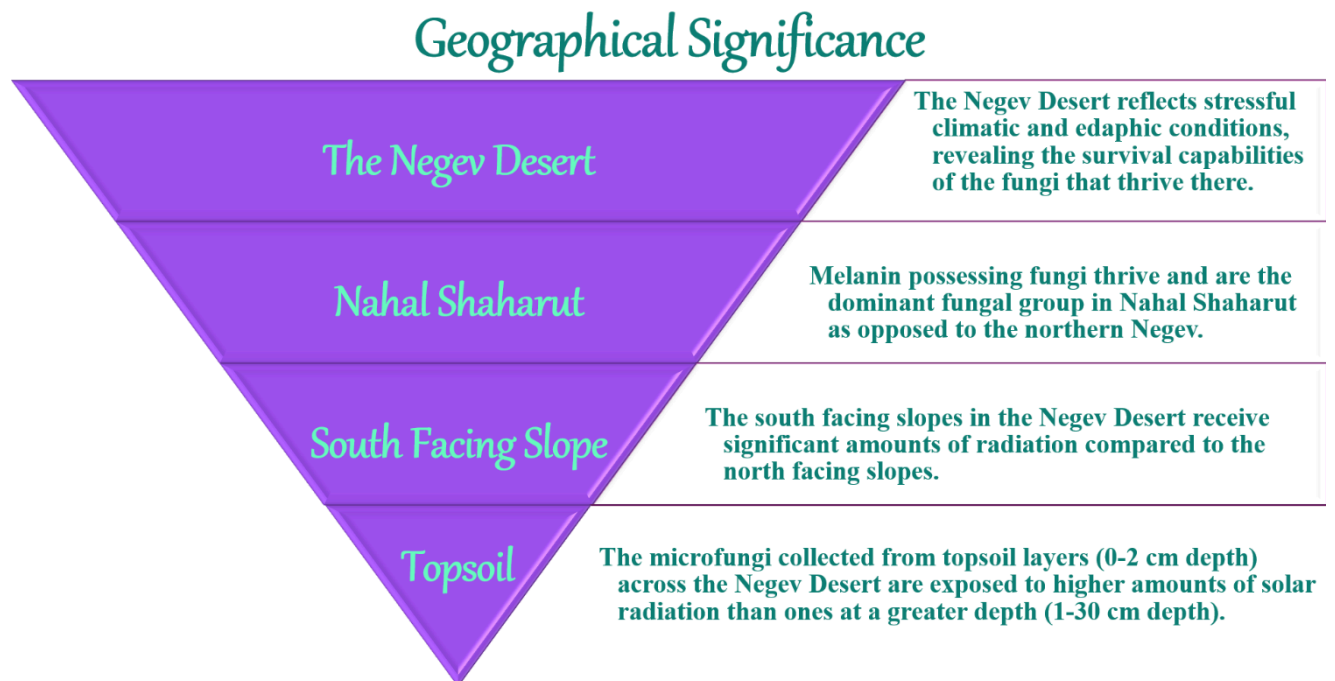


Figure 5: Diagram showing the negative correlation between soil depth and conidia darkness.



3.3 Traits to Test For (During Growth)

Fungal Growth Phases (Staling)- The growth phases of fungi include the initial phase of growth, the phase of continual growth, and the staling process (growth rates drop steeply over time) if staling occurs (Tomkins, 1932). The ideal fungal candidate for Martian construction would have a shorter initial phase of growth and longer phase of continual growth, indicating that the fungus would grow quickly in the limited time astronauts have to create materials for construction. Whether the fungi exhibit staling or not should be tested by seeing if their growth rate falls off or is continuously linear (Tomkins, 1932), as fungal staling could be a convenient growth pattern and natural indicator that the bio composite is complete and ready to be treated and used for construction.

Conidial Culturability- Conidial culturability after irradiation was higher in strains from the SFS in comparison to strains from the NFS. There is also positive correlation between higher melanin concentrations and higher conidial culturability (Singaravelan et al. 2008), meaning that the selected fungi should also be tested for conidial culturability because that would indicate higher melanin concentrations.

4. Conclusion

I predict that the fungus most suitable for Martian construction will be found in the Negev Desert high abundance. Specifically, I believe that this fungus will be *Ulocladium botrytis*, *Aspergillus fumigatus*, or *Ulocladium atrum*, and that their melanin concentrations will measure highest (respectively) amongst the tested fungi, meaning that they will be most suitable for Martian Construction (this will also be further determined by their growth patterns). As previously stated above, the location of a south facing slope in Nahal Shaharut found in the Southern Negev Desert is critical for the fungi collection portion of this experiment and this is where I believe the fungus most suitable for Martian construction will be found.

The conidia darkness of each fungus must be compared to the conidia darkness of *Aspergillus niger*, since we have already established that *A. niger* is a dominant fungus in space, as well as a dominant fungus on the SFS of Nahal Shaharut (1.4%). To reiterate my hypothesis, I believe that every fungus highlighted in table 1 will possess higher melanin concentrations than *Aspergillus niger* (proved through comparing conidia darkness) because every fungus highlighted has a relative abundance rate equal to or higher than that of *Aspergillus niger*'s (1.4%).

| Name of Fungi (ranked by predicted conidia darkness) | Conidia Darkness Predicted Ranking (darkest to lightest) |
|---|---|
| 1. <i>Ulocladium botrytis</i> | 1 |
| 2. <i>Aspergillus fumigatus</i> | 2 |
| 3. <i>Ulocladium atrum</i> | 3 |
| 4. <i>Alternaria alternata</i> | 4 |
| 5. <i>Alternaria chlamydospora</i> | 5 |
| 6. <i>Beauveria brongniartii</i> | 6 |
| 7. <i>Cladosporium cladosporioides</i> | 7 |
| 8. <i>Penicillium aurantiogriseum</i> | 8 |
| 9. <i>Aspergillus ustus</i> | 9 |
| 10. <i>Phoma exigua</i> | 10 |
| 11. <i>Botryotrichum pilluliferum</i> | 11 |
| 12. <i>Aspergillus niger</i> | 12 |

Table 3: Shows my ranking predictions for which fungus has the darkest conidia. In correlation with table 2, I believe that the higher of a relative abundance rate that a fungus has on the SFS of Nahal Shaharut (Negev Desert), the darker its conidia will be.

Benefits of Fungal Bio Composites

- Lightweight
- Non-flammable
- Insulating
- Variety of Textures
- Allows for Complex Structures
- Low Manufacturing Costs
- Self-repairing
- Utilizes Local Resources

4.1 Potential Implications

1. This experiment could lead to a generally better understanding of what fungi can survive in space in addition to *A. niger*.
2. More research can be done on the ISS testing the survival capabilities of the selected fungi highlighted in table 1, further (definitively) testing my hypothesis.
3. More research can be done testing the latching abilities of the mycelium in order to understand their full abilities in the context of Martian construction and not just general survival in space.
4. These fungal bio composite structures can also be constructed on earth, specifically in the Southern Negev Desert, acting as sustainable and affordable construction using the locally derived materials from the region (rocks / sand from the Negev + fungal mycelium from fungi Negev fungi = sustainable construction in the Negev).

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