Yeast Artistes

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ANZIAM SA Challenge
Yeast

- Single cell fungus, about 1 µm to 4 µm in diameter.
- Saccharomyces cerevisiae used in food production (bread, beer, wine, kombucha, Vegemite)
- Has been used to produce fuel.
- Causes infections (Candida albicans).
- Can grow on/in medical equipment.

Figure: Saccharomyces cerevisiae
Growth

- Yeast cells cannot move by themselves.
- The cells grow together in colonies.
- Commonly, cells reproduce by mitosis (splitting) through budding.

**Figure: Budding**
Filamentous Growth

- Mould grows in long segments each called a hypha.
- Yeast cells can stay connected to form a pseudohypha (chain of cells).
- Transition from one mode to another.

*Figure: Filamentous growth on agar*
The overall aims are to:

1. develop methods to quantify both the spacial patterns and the mechanisms that control the morphology; and

2. use the techniques developed to identify and classify strain-specific properties.
Basic Model Structure

Figure: Cells within a grid

- Model yeast as cells within a grid.
- Seed with initial pattern (line or single cell).
- Cells can reproduce into an unfilled neighbouring space.

Figure: Cells within a grid
Eden Model

- The algorithm is:
  1. Start with an initial configuration.
  2. Add a new cell to a space adjacent to an existing cell.
  3. Repeat (2) as many times as required.

(a) Single cell  |  (b) Line
Diffusion-Limited Aggregation

- Witten Jr & Sander (1981):
  - The algorithm is:
    1. Start with an initial configuration.
    2. New cell moves randomly until it touches an existing cell and stops.
    3. Repeat (2) as many times as required.
  - Can think of the moving cell as a nutrient.

(a) Single cell  
(b) Line
Classifying Growth

- Fujikawa & Matsushita (1989) classified bacteria growth using these simple models.
- Ohgiwari et al. (1992): ‘...the softer the agar plate becomes, the faster nutrient diffuses.’

Figure: Fujikawa & Matsushita (1989)

Fig. 9. A schematic phase diagram of the growth patterns of *B. subtilis* colony in relation to the concentrations of peptone and agar of an agar plate. The concentrations were shown as round numbers, because the phase boundaries of the colony morphology was not so clear.
Classifying Growth

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Figure: Ohgiwari et al. (1992)

Fig. 1. Phase diagram of pattern change in colonies of *Bacillus subtilis* (wild type).
Matsuura’s Model

- Cell proliferation, nutrient movement and nutrient consumption.
- Both the cells and nutrient are modelled as discrete particles.

1. Cells can consume and store nutrient.
2. Given enough nutrient a cell can reproduce.
3. Nutrient moves randomly.

Figure: Matsuura’s model
Proliferation Bias

- Matsuura: cells proliferate in each direction with equal probability.
- During filamentous growth cells appear to grow ‘outwards’.
- Propose that new cells grow in the same direction as the parent with probability $p_h$.
- Cells can’t proliferate ‘backwards’.
- Remaining two directions have probability $(1 - p_h)/2$.

**Figure:** Biased growth
Matsuura with equal probability

Initial nutrient → Nutrient steps →

↑

Initial nutrient

Nutrient steps →
Matsuura with $p_h = 0.5$

Initial nutrient → Nutrient steps →
Matsuura with $p_h = 0.9$
Quantifying Patterns

- The fractal dimension has been used perviously to quantify the growth patterns (Matsuyama et al. 1989, Matsushita & Fujikawa 1990).
- Expected to lie between 1 and 2.
- Measures how the complexity of the pattern changes with the measurement scale.
- Can be calculated using the box-counting method.
Fractal Dimension (No Bias)

Initial nutrient → Nutrient steps →

↑
Initial nutrient

Nutrient steps →

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Fractal Dimension (No Bias)
### Cell Count (No Bias)

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Perimeter (No Bias)
Conclusions

- Matsuura (2000) model has been modified to include directional bias.
- Further work needed to quantify the geometry (PCA?).
- Particle-based nutrient model is computationally-expensive.
- Will develop hybrid models with continuous nutrient.
References I


