# Modeling Antibiotic Resistance with ResistoMeter: An Interactive Simulation from Pakistan

Ahsan Azeemi
Department of Computer Science
Habib University, Karachi

## Introduction

Antibiotic resistance is a critical global health threat, especially in developing countries like Pakistan where unregulated use of antibiotics accelerates the emergence of resistant bacterial strains. According to Laxminarayan et al. (2013), lack of stewardship and self-medication contribute significantly to the resistance crisis. Interactive simulations are increasingly used in education and research to convey complex microbiological behaviors (Krockow et al., 2019). This study presents **ResistoMeter**, an interactive web-based **open-source** simulation that visualizes the dynamics of bacterial resistance under different antibiotic treatments. The tool aims to improve public understanding and encourage informed prescribing behaviors through real-time, data-driven models.

## Methodology

ResistoMeter uses a canvas-based rendering system to simulate bacterial growth influenced by pharmacodynamic principles. It models two phenotypes: sensitive and resistant strains. The population change is based on the following components:

### 1. Antibiotic Dose Effect

At any given time $t$, the cumulative antibiotic concentration $A(t)$ is computed using exponential decay:

$$A(t) = \sum_{t_i \in \text{schedule}} e^{-\lambda(t-t_i)} \quad \text{for } 0 \leq t - t_i < 24$$

where $\lambda$ is the decay rate and $t_i$ are dosing times.

### 2. Growth and Killing Rates

Let $P(t)$ be the current population at time $t$, and $r$ be the baseline growth rate.

- For **resistant** strains:

$$r_{\text{eff}} = 0.9r, \quad k = 0.1 \cdot \varepsilon$$

- For **sensitive** strains:

$$r_{\text{eff}} = r, \quad k = \varepsilon$$

Where $\varepsilon$ is the antibiotic efficacy, and $k$ is the kill rate.

## 3. Antibiotic Type Adjustment

If antibiotic concentration $A(t)$ exceeds the MIC (Minimum Inhibitory Concentration):

- **Bactericidal:**

$$\text{Kill Effect} = -k \cdot A(t) \cdot P(t)$$

$$r_{\text{eff}} \leftarrow r_{\text{eff}} \cdot (1 - 0.5k)$$

- **Bacteriostatic:**

$$r_{\text{eff}} \leftarrow r_{\text{eff}} \cdot (1 - k \cdot A(t))$$

## 4. Logistic Growth with Carrying Capacity

$$\text{Growth Component} = r_{\text{eff}} \cdot P(t) \cdot \left(1 - \frac{P(t)}{K}\right)$$

where $K$ is the carrying capacity.

## 5. Natural Decay

$$\text{Decay Component} = \delta \cdot P(t)$$

where $\delta$ is the natural decay rate.

## 6. Mutation Dynamics

For sensitive strains, mutation occurs with probability:

$$\text{Mutation Probability} = \mu \cdot P(t)$$

If a mutation occurs:

$$P_{\text{resistant}} \leftarrow P_{\text{resistant}} + 0.01 \cdot P(t), \quad P(t) \leftarrow P(t) - 0.01 \cdot P(t)$$

## 7. Final Population Change

$$\Delta P = \text{Growth Component} - \text{Decay Component} + \text{Kill Effect}$$

$$P(t+1) = P(t) + \max(\Delta P, -0.5 \cdot P(t))$$

# Results

Simulation results indicate that longer dosing intervals allow bacterial populations to recover, facilitating the dominance of resistant strains (Figure 1). Conversely, shorter intervals suppress overall growth more effectively (Figure 2). A key example included administering ciprofloxacin every 24 hours versus every 8 hours; the latter significantly reduced regrowth. Visual outputs such as bacterial density plots and colony representations mimic susceptibility tests and enhance user comprehension. The platform successfully demonstrates competitive exclusion dynamics and resistance evolution under pharmacological pressure.


Figure 1: Figure A: Bacterial regrowth under 24-hour antibiotic dosing interval (long interval) for 10 days.

# Conclusion

ResistoMeter offers a scientifically grounded yet user-friendly educational tool for visualizing antibiotic resistance. By highlighting the importance of dosage schedules, mutation probabilities, and drug mechanisms, it serves as a valuable resource for students, clinicians, and policymakers. Future improvements may include immune response modeling and broader environmental factors. Overall, the simulation encourages informed treatment protocols and contributes toward combatting antibiotic resistance through awareness and education.

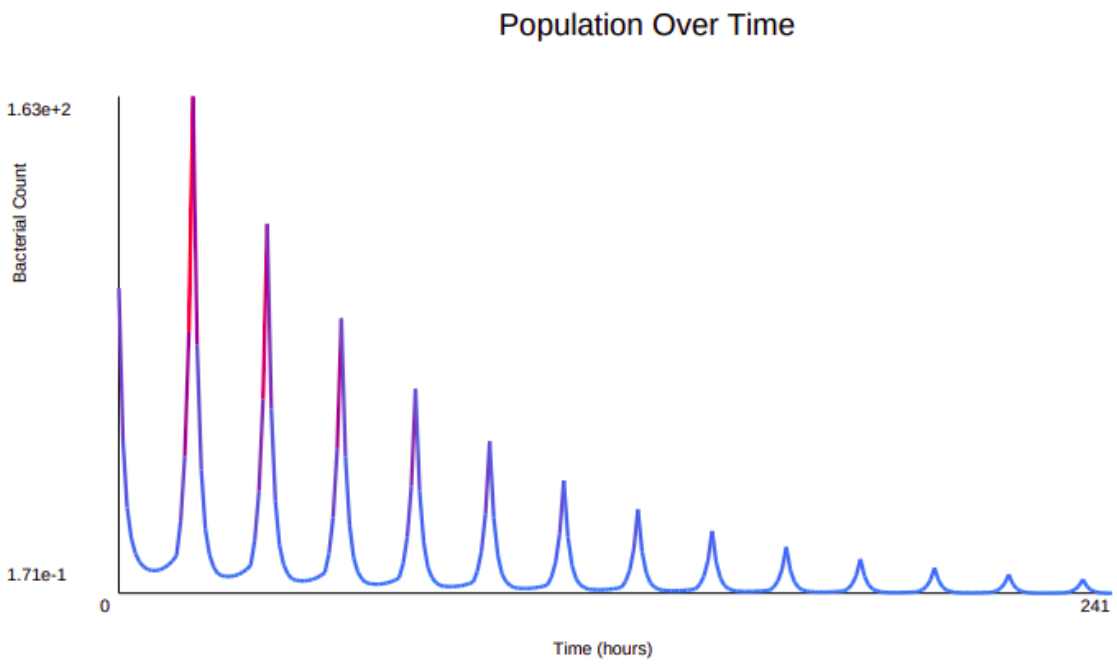


Figure 2: Figure B: Bacterial suppression under 8-hour dosing interval (short interval) for 10 days.

# References

Laxminarayan, R., Duse, A., Wattal, C., Zaidi, A. K. M., Wertheim, H. F. L., Sumpradit, N., ... & Cars, O. (2013). Antibiotic resistance—the need for global solutions. *The Lancet Infectious Diseases, 13*(12), 1057–1098. `https://pubmed.ncbi.nlm.nih.gov/24252483/`

Krockow, E. M., Colman, A. M., & Chattoe-Brown, E. (2019). Balancing the risks to individual and society: A systematic review of antibiotic prescribing decisions in primary care. *British Journal of General Practice, 69*(684), e331–e339. `https://www.sciencedirect.com/science/article/pii/S0195670118304183`

ResistoMeter Interactive Simulation. (2025). Retrieved from https://m4lf0rm3d.github.io/ResistoMeter/

ResistoMeter Source Code. (2025). Retrieved from https://github.com/m4lf0rm3d/ResistoMeter