Physics of Social Systems:

Modelling the Emergence of Social Divisions

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This is America.. in 1960s

- MLK slain in the fight against segregationist regimes

This is America.. in 2010s

- Civil Rights Act (1964) and Fair Housing Act (1968) promised equality.

- Yet, U.S. cities remained starkly segregated.
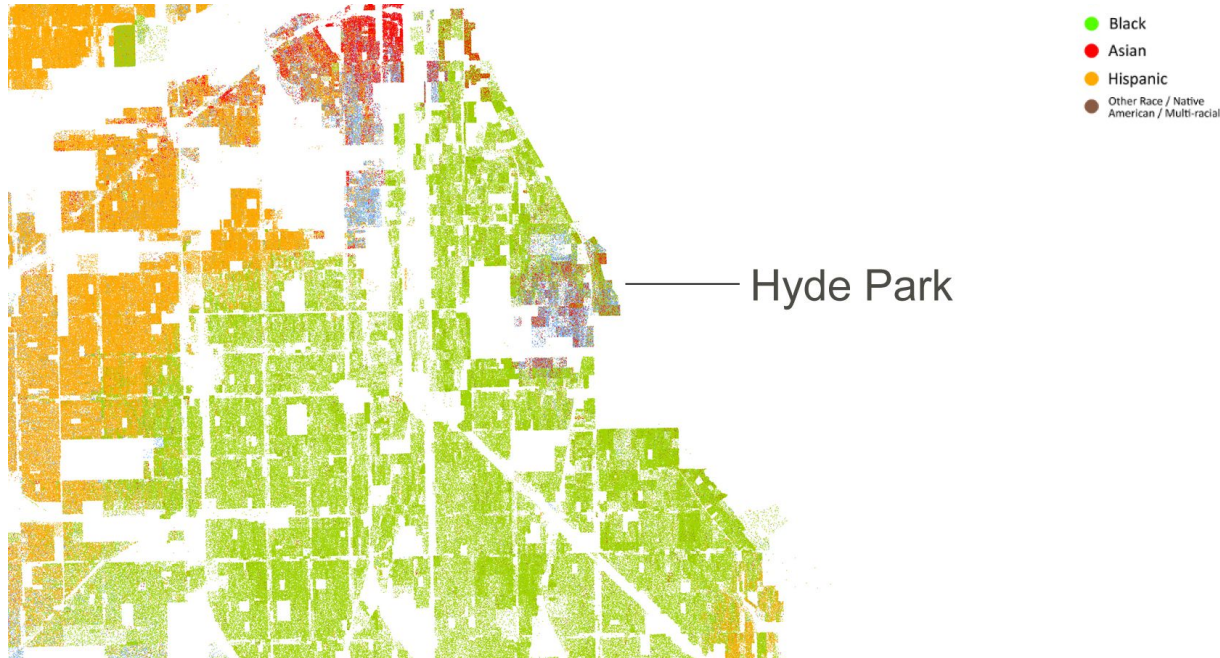
Fig: Racial residential segregation in Chicago according to the 2010 census [*Source: http://racialdotmap.demographics.coopercenter.org/*]

Why don't laws end segregation?

- Sociologists' Early Explanations:
    - Discrimination and prejudice by landlords, real estate agents
    - Economic inequality: wealth and income gaps limited housing options for Black families.
    - Institutional barriers: redlining, restrictive covenants, and zoning laws reinforced separation.

Fig: After a Federal court ordered the desegregation of schools in the South, U.S. Marshals escorted a young Black girl, Ruby Bridges, to school
[*Source: https://en.wikipedia.org/wiki/File:US Marshals with Young Ruby Bridges on School Steps.jpg*]

Schelling's Radical Idea

- What if segregation emerges even when people aren't strongly racist?
- Can large-scale segregation emerge from small, individual choices?
- Micro-motives leading to unintended macro-behaviors

- Build a simple model and let it evolve
- See what patterns naturally emerge

Using simulation to study social patterns systematically, anticipating modern agent-based modeling.

DYNAMIC MODELS OF SEGREGATION†

THOMAS C. SCHELLING

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Some segregation results from the practices of organizations, some from specialized communication systems, some from correlation with a variable that is non-random; and some results from the interplay of individual choices. This is an abstract study of the interactive dynamics of discriminatory individual choices. One model is a simulation in which individual members of two recognizable groups distribute themselves in neighborhoods defined by reference to their own locations. A second model is analytic and deals with compartmented space. A final section applies the analytics to 'neighborhood tipping.' The systemic effects are found to be overwhelming: there is no simple correspondence of individual incentive to collective results. Exaggerated separation and patterning result from the dynamics of movement. Inferences about individual motives can usually not be drawn from aggregate patterns. Some unexpected phenomena, like density and vacancy, are generated. A general theory of 'tipping' begins to emerge.

People get separated along many lines and in many ways. There is segregation by sex, age, income, language, religion, color, taste, comparative advantage and the accidents of historical location. Some segregation results from the practices of organizations; some is deliberately organized; and some results from the interplay of individual choices that discriminate. Some of it results from specialized communication systems, like different languages. And some segregation is a corollary of other modes of segregation: residence is correlated with job location and transport.

If blacks exclude whites from their church, or whites exclude blacks, the segregation is organized, and it may be reciprocal or one-sided. If blacks just happen to be Baptists and whites Methodists, the two colors will be segregated Sunday morning whether they intend to be or not. If blacks join a black church because they are more comfortable among their own color, and whites a white church for the same reason, undirected individual choice can lead to segregation. And if the church bulletin board is where people advertise rooms for rent, blacks will rent rooms from blacks and whites from whites because of a communication system that is correlated with churches that are correlated with color.

Some of the same mechanisms segregate college professors. The college may own some housing, from which all but college staff are excluded. Professors choose housing commensurate with their incomes, and houses are clustered by price while professors

Modeling society like atoms

- Sociophysics aims to explain collective social behavior by applying concepts and methods from physics.
- Its strength lies in uncovering **macro-level regularities** that arise from simple **micro-level rules**, even when individual behavior is diverse or unpredictable.

- **Early roots (19th–20th century):** Adolphe Quetelet (1820s–30s) applied statistics to social phenomena.
  "The greater the number of individuals observed, the more do individual peculiarities, whether physical or moral, become effaced, and allow the general facts to predominate, by which society exists and is preserved."

- **Mid-20th century:** Analogies between particles and people; studying collective behavior, opinion dynamics, and crowd behavior.
- **1950s–70s:** Models of social interactions using statistical mechanics.

SUR L'HOMME
ET LE
DÉVELOPPEMENT DE SES FACULTÉS,
OU
ESSAI DE PHYSIQUE SOCIALE;
PAR A. QUETELET,
Secrétaire perpétuel de l'Académie royale de Bruxelles, Correspondant de l'Institut de France, de la Société royale astronomique de Londres, des Académies royales de Berlin, de Turin, etc.

Appliquons aux sciences politiques et morales la méthode fondée sur l'observation et sur le calcul, méthode qui nous a si bien servi dans les sciences naturelles.
LAPLACE, *Essai ph. sur les probabilités.*

TOME PREMIER.

PARIS,
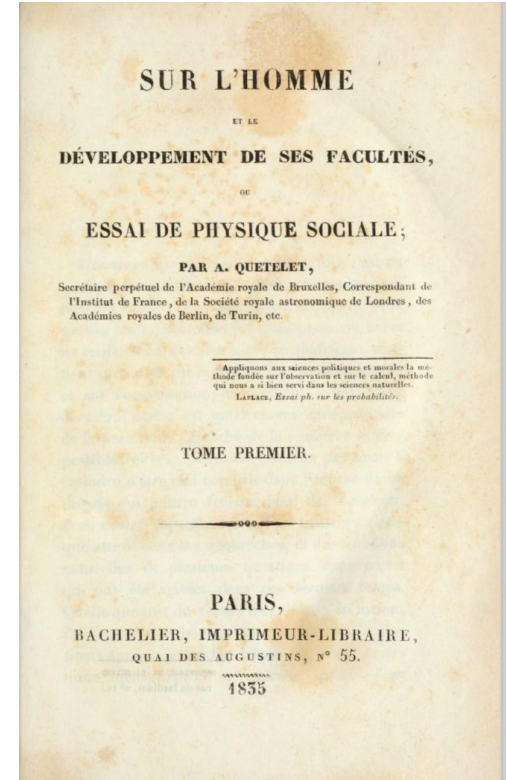BACHELIER, IMPRIMEUR-LIBRAIRE,
QUAI DES AUGUSTINS, N° 55.

1835

Fig: On Man and the Development of Faculties, or an Essay on Social Physics

Simulating society one agent at a time

- **NetLogo** – a tool for Agent–Based Modelling
- Introduced by **Uri Wilensky** in 1999 at Northwestern University.

NetLogo

Version 7

Uri Wilensky named 2025 Yidan Prize winner

This year's prize spotlights changemakers advancing complex systems literacy and multilingual education

September 29, 2025 | By **Shanice Harris**

Simple rules, surprising outcomes

- Rules for **Schelling's Segregation Model (1970)**:

  1. Agents are households of two types (e.g., black and white).

  2. Each agent prefers a certain percentage of neighbors to be similar.

  3. If unhappy, agent moves to a new location.

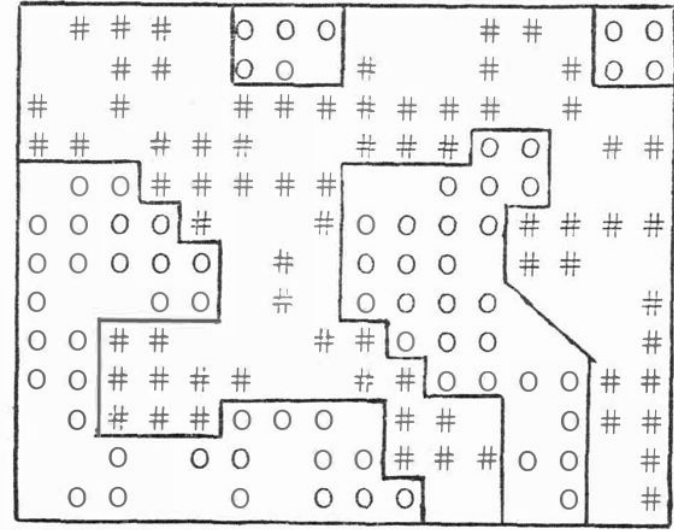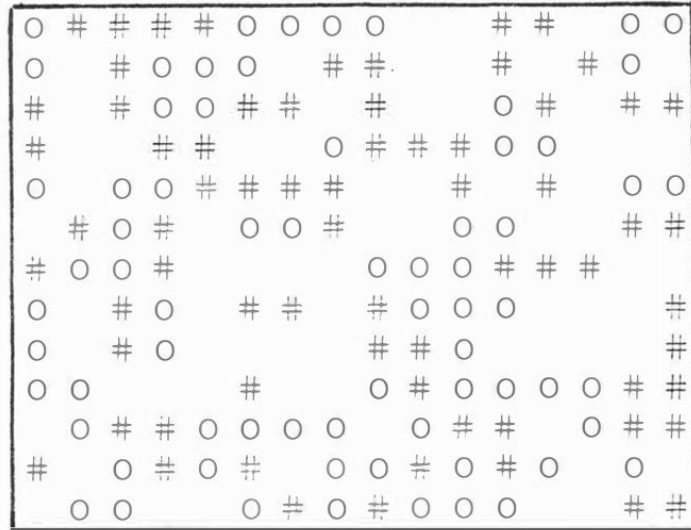 4. Repeat, till unhappiness is minimized (or eliminated).
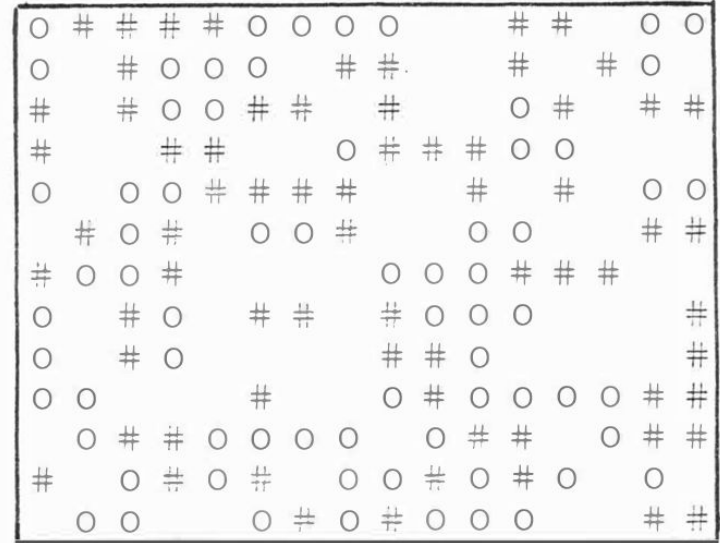
Source: Schelling, Thomas C. (1971). "Dynamic models of segregation". The Journal of Mathematical Sociology. 1 (2). Informa UK Limited: 143–186.

Emergence of Social Divides

–Simulation–

A Model That Changed Social Science

- Demonstrated that large-scale social patterns can emerge from simple individual behaviors.

- Pioneered the use of agent-based modeling (ABM) in sociology and social science.

- Influenced research in urban planning, segregation studies, economics, and sociophysics.

- Highlighted the concept of **emergence**, showing that unintended societal outcomes can arise naturally.

Fig: Thomas C. Schelling (1921-2016)

Shaping Neighborhoods

- Voluntary integration may fail without structural support

- Need for institutional changes:
  - Policies must actively shape the environment to counter emergent segregation.
  - **Structural interventions** are required to maintain diversity and prevent self-reinforcing clustering.

- Examples of interventions:
  - Mixed-income housing
  - Reintegrated schooling
  - Representation in power centers

Beyond the Original Model

- **Multiple agent types**: More than two groups, representing diverse populations.

- **Different tolerance thresholds:** Varying preferences for neighbor similarity to explore robustness.

- **Dynamic environments:** Agents can enter/exit the system, simulating migration or urban growth.

- Inclusion of **economic status** or income levels.

- Schools, workplaces, or social networks as interaction spaces.
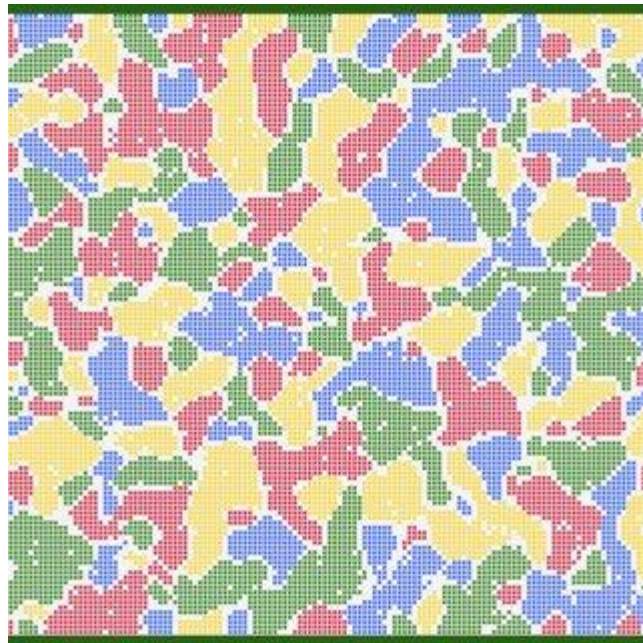
Source: On the Extension of Schelling's Segregation Model | ResearchGate

Parallels to Spin Models

- Schelling's segregation model is analogous to **spin models** in physics:

    ○ Agents = spins
    ○ Preferences = interaction energies
    ○ Clusters = Magnetic domains

- Concepts like emergence, phase transitions, and tipping points apply in both physics and social systems.

- Shows how small local rules can produce large–scale patterns without central coordination.

T = 3.00
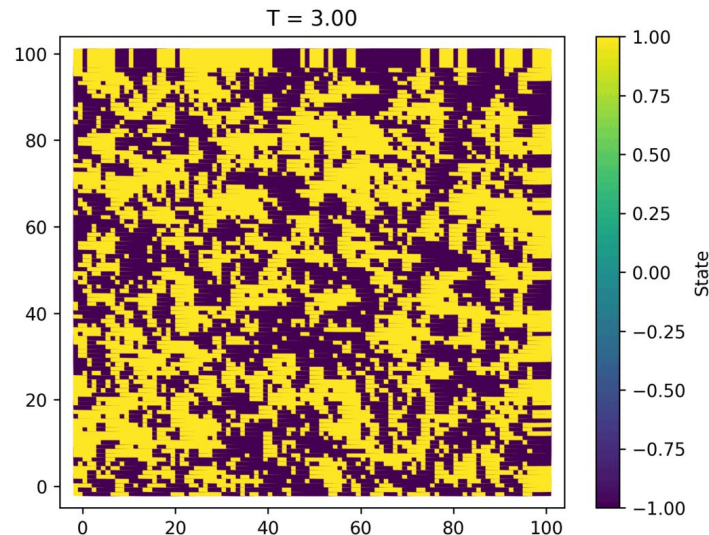
Conclusion

- Schelling's model shows that **macro-level segregation** can arise from simple **micro-level preferences.**

- Highlights the importance of **emergent phenomena** in social systems.

- Demonstrates the power of **agent-based modeling** for understanding society.

- Provides **insights for policy and planning**: voluntary integration may fail without structural support.

"Micromotives lead to macrobehavior."

– Thomas C. Schelling, Micromotives and Macrobehavior, 1978, p. 3

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